

A Novel Approach of Using Electrostatic Field to Reduce Thawing Time and Improve Frozen Beef Quality

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Abstract

The objective of this study was to evaluate the impact of applying an electrostatic field (EF) on thawing characteristics, such as thawing speed and purge loss, as well as its impact on quality attributes during subsequent aging and retail display of beef. Beef striploins from both sides of 12 USDA Choice carcasses were frozen and then thawed under 4 kV treatments: EF-0 (control), EF-2.5, EF-5, and EF-10. Within each treatment, half were thawed at 32°F (inside cooler) and half at 35.6°F (outside cooler). After reaching 30.2°F, striploins were weighed with the purge collected to assess purge loss and purge protein content, swabbed for microbial content, and then fabricated into steaks. After samples were collected for histological analysis, steaks were assigned to either 0 or 14 days of aging and then retail displayed for 0 or 7 days. During retail display, steaks were evaluated for discoloration and objective color measurements. Upon completion, steaks were analyzed for Warner-Bratzler shear force (WBSF), sarcomere length, myofibrillar protein degradation, lipid oxidation, and pH. It was found that all EF treatments increased purge loss in the outside cooler location and EF did not improve thawing speed, with the EF-10 samples taking longer to thaw ($P < 0.05$). There was also a trend that EF-10 samples in the outside cooler location had increased muscle fiber spacing ($P = 0.09$). All EF voltages reduced aerobic plate counts compared to the control. Samples aged for 0 days under EF-5 showed more discoloration than the other treatments ($P < 0.05$), and samples aged 14 days under EF-2.5 and EF-5 showed less discoloration than EF-0 and EF-10 ($P < 0.05$). The EF-10 samples showed a reduction in WBSF, but there was no impact of EF on sarcomere length and myofibrillar protein degradation ($P > 0.05$). The EF-10 treatment samples also showed an increase in pH in the outside cooler location ($P < 0.05$).

Introduction

Freezing is a common method of cold chain management to extend the shelf-life of beef. However, the thawing process of frozen beef usually results in increased purge loss due to cell membrane damage from the ice crystal formation and is thus viewed as an inferior product compared to fresh beef. Therefore, the beef industry is actively seeking new technologies with the goal of mitigating the negative impacts of freezing. Electro-

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static field (EF) assisted thawing is an emerging technology that relies upon applying an alternating current EF during thawing, which functions by oscillating the positive and negative ions in the ice crystals and thus potentially breaks apart the existing ice crystals into smaller and more uniform ice crystals. Based on this existing knowledge, we hypothesized that the EF thawing process reduces the physical damage of the cellular structure as the ice crystals gradually and uniformly reduce in size throughout the frozen meat.

Experimental Procedures

Striploins from both sides of USDA Choice carcasses ($n = 12$) were collected and portioned into four equal parts ($n = 48$). Portions were vacuum packaged and frozen at -40°F for 14 days and randomly assigned to one of four EF thawing treatments (Figure 1): 0 kV voltage (control), 2.5 kV voltage (EF-2.5), 5 kV voltage (EF-5), and 10 kV voltage (EF-10). Within each EF treatment, half of the striploin portions were thawed at 32°F (inside cooler) and half at 36°F (outside cooler), representing two areas within the cooler used in this study. Internal temperatures were recorded throughout the thawing process, and the thawing process was considered complete when all striploin portions reached 30.2°F . After thawing, striploin portions were weighed and purge was collected for microbial and protein analysis, and portions were fabricated into steaks. One steak was immediately cored parallel to muscle fiber direction for later histological analysis to assess muscle fiber damage. The remaining steaks were vacuum packaged and subjected to either 0 or 14 days of aging. After the designated aging, steaks were placed on Styrofoam trays, overwrapped with polyvinyl chloride, and placed in a coffin-style retail case for a designated 0 or 7 days of retail display. Steaks were evaluated daily for objective color as well as subjective evaluation of discoloration by trained panelists. After completion of each designated aging and display period, steaks were utilized for Warner-Bratzler shear force (WBSF), sarcomere length, lipid oxidation (TBARS), pH, and myofibrillar protein degradation analysis.

Results and Discussion

There was an increase in purge loss for all EF samples regardless of voltages compared to the control samples in the outside cooler location ($P < 0.05$; Table 1). Furthermore, application of EF did not reduce thawing times ($P > 0.05$; Figure 1), with EF-10 samples taking longer to reach the targeted 30°F than the rest of the treatments ($P < 0.05$). All EF treatments in the outside cooler location reduced the purge aerobic plate count ($P < 0.01$; Table 1). The EF-10 had lower WBSF ($P < 0.05$; Figure 2) compared to the control. The EF-10 samples from the outside cooler location tended to have greater muscle fiber spacing compared to the other EF treatments ($P = 0.09$; Table 1). There were no differences found for troponin-T degradation, sarcomere length and purge protein concentrations ($P > 0.05$; data not shown). For the 0-day aged samples, EF-5 on day 7 resulted in more discoloration than the rest of the treatments ($P < 0.05$; Table 2). Interestingly, when looking at the 14-day aged samples, EF-5 as well as EF-2.5 had less discoloration than the control and EF-10 ($P < 0.05$; Table 2). When looking at the impact of EF on a^* (redness), EF-5 had higher a^* values (more redness) than control samples and EF-2.5 on days 4 and 5 of retail display ($P < 0.05$; Figure 3). Lipid oxidation increased over display time as expected ($P < 0.05$; data not shown); however, none of the EF applications or aging periods altered the lipid oxidation of the samples ($P > 0.10$). The EF-10 treatment samples showed an increase in pH in the outside cooler location compared to the control samples ($P < 0.05$).

Implications

Overall, the application of EF during thawing did not reduce purge loss and thawing times, but the EF-10 treatment yielded a more tender product, which could likely be explained by the oscillating ions from the voltage elevating the muscle structural damage. Application of a moderate EF intensity showed potential to be used as a color stabilizer during retail display without affecting other characteristics such as lipid oxidation, particularly for EF-5. Along with the impacts on meat color preservation, future research should investigate the impact of EF thawing as an antimicrobial intervention as well as a color stabilizer.

Acknowledgments

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Table 1. Interaction of electrostatic field treatments on thawing traits × location¹

| | Treatment | Location | | SEM ³ | P-value |
|----------------------------------------|-----------|---------------------|---------------------|------------------|---------|
| | | Inside | Outside | | |
| Purge loss (%) | 0 kV | 1.27 ^{ab} | 1.45 ^{bB} | 0.31 | < 0.05 |
| | 2.5 kV | 0.94 ^{ab} | 2.51 ^{aA} | | |
| | 5 kV | 1.38 ^{ab} | 2.50 ^{aA} | | |
| | 10 kV | 1.14 ^{ab} | 3.26 ^{aA} | | |
| APC log CFU purge | 0 kV | 2.00 ^{bB} | 2.38 ^{aA} | 0.12 | < 0.05 |
| | 2.5 kV | 2.44 ^{aA} | 1.78 ^{bcB} | | |
| | 5 kV | 2.27 ^{abA} | 1.66 ^{cB} | | |
| | 10 kV | 2.25 ^{abA} | 1.98 ^{bcA} | | |
| Muscle fiber spacing ² (μm) | 0 kV | 11.75 ^{aA} | 10.76 ^{aA} | 0.84 | 0.09 |
| | 2.5 kV | 9.66 ^{aA} | 9.40 ^{aA} | | |
| | 5 kV | 10.39 ^{aA} | 9.96 ^{aA} | | |
| | 10 kV | 9.92 ^{ab} | 13.03 ^{aA} | | |
| pH | 0 kV | 5.68 ^{aA} | 5.62 ^{bA} | 0.03 | < 0.05 |
| | 2.5 kV | 5.64 ^{aA} | 5.64 ^{abA} | | |
| | 5 kV | 5.67 ^{aA} | 5.64 ^{abA} | | |
| | 10 kV | 5.65 ^{aA} | 5.65 ^{aA} | | |

^{a-c} Least square means within columns without common superscript differ ($P < 0.05$).

^{A-B} Least square means within respective rows within a measurement without common superscript differ ($P < 0.05$).

¹ Location regarding cooler placement: inside (32°F), outside (36°F).

² Average of 60 spaces were measured between muscle fibers.

³ Standard error of mean of the least square means.

Table 2. Interaction of electrostatic field treatments × aging × display on discoloration¹

| Treatment ² | kV | | | | | | | | | SEM ⁴ | P-value |
|---------------------------------|-----------|--------------------|--------------------|---------------------|----------------------|----------------------|----------------------|---------------------|----------------------|------------------|---------|
| | Treatment | Day 0 | Day 1 | Day 2 | Day 3 | Day 4 | Day 5 | Day 6 | Day 7 | | |
| Discoloration: 0 days aging | 0 kV | 0.08 ^{ba} | 0.03 ^{ba} | 0.04 ^{ba} | 0.13 ^{ba} | 0.75 ^{ba} | 1.40 ^{ba} | 1.86 ^{abB} | 3.36 ^{abcB} | 1.51 | < 0.05 |
| | 2.5 kV | 0 ^{ba} | 0 ^{ba} | 0.17 ^{ba} | 0.36 ^{ba} | 0.57 ^{ba} | 1.35 ^{ba} | 1.89 ^{abB} | 6.00 ^{ab} | | |
| | 5 kV | 0.25 ^{ca} | 0.24 ^{ca} | 0.15 ^{ca} | 0.56 ^{ca} | 0.43 ^{ca} | 1.43 ^{ca} | 6.35 ^{ba} | 15.26 ^{aa} | | |
| | 10 kV | 0.08 ^{ba} | 0.08 ^{ba} | 0.06 ^{ba} | 0.40 ^{ba} | 0.50 ^{ba} | 1.00 ^{ba} | 2.05 ^{abB} | 3.35 ^{abB} | | |
| Discoloration: 14 days aging | 0 kV | 0.03 ^{ga} | 0.93 ^{ga} | 4.61 ^{fgA} | 19.97 ^{caB} | 43.47 ^{da} | 63.10 ^{bcA} | 80.03 ^{ba} | 89.69 ^{aa} | 6.89 | < 0.05 |
| | 2.5 kV | 0 ^{ea} | 1.10 ^{ca} | 9.41 ^{deA} | 31.67 ^{ca} | 42.86 ^{bcA} | 49.40 ^{abA} | 53.22 ^{ab} | 56.35 ^{ab} | | |
| | 5 kV | 0 ^{ca} | 0.61 ^{ca} | 0.78 ^{ca} | 1.97 ^{ceB} | 4.78 ^{ceB} | 12.42 ^{cdB} | 32.90 ^{bc} | 53.74 ^{ab} | | |
| | 10 kV | 0.02 ^{da} | 0.44 ^{da} | 0.46 ^{da} | 1.29 ^{deB} | 4.46 ^{deB} | 25.64 ^{cb} | 56.33 ^{bB} | 80.65 ^{aa} | | |

¹Trained panelists score from 0–100 line scale; 0 = no discoloration and 100 = complete discoloration.

^{2a-b}Least square means within rows without common superscript differ ($P < 0.05$).

^{3A-C}Least square means within columns of aging treatment without common superscript differ ($P < 0.05$).

⁴Standard error of the mean (largest) of the least square means.

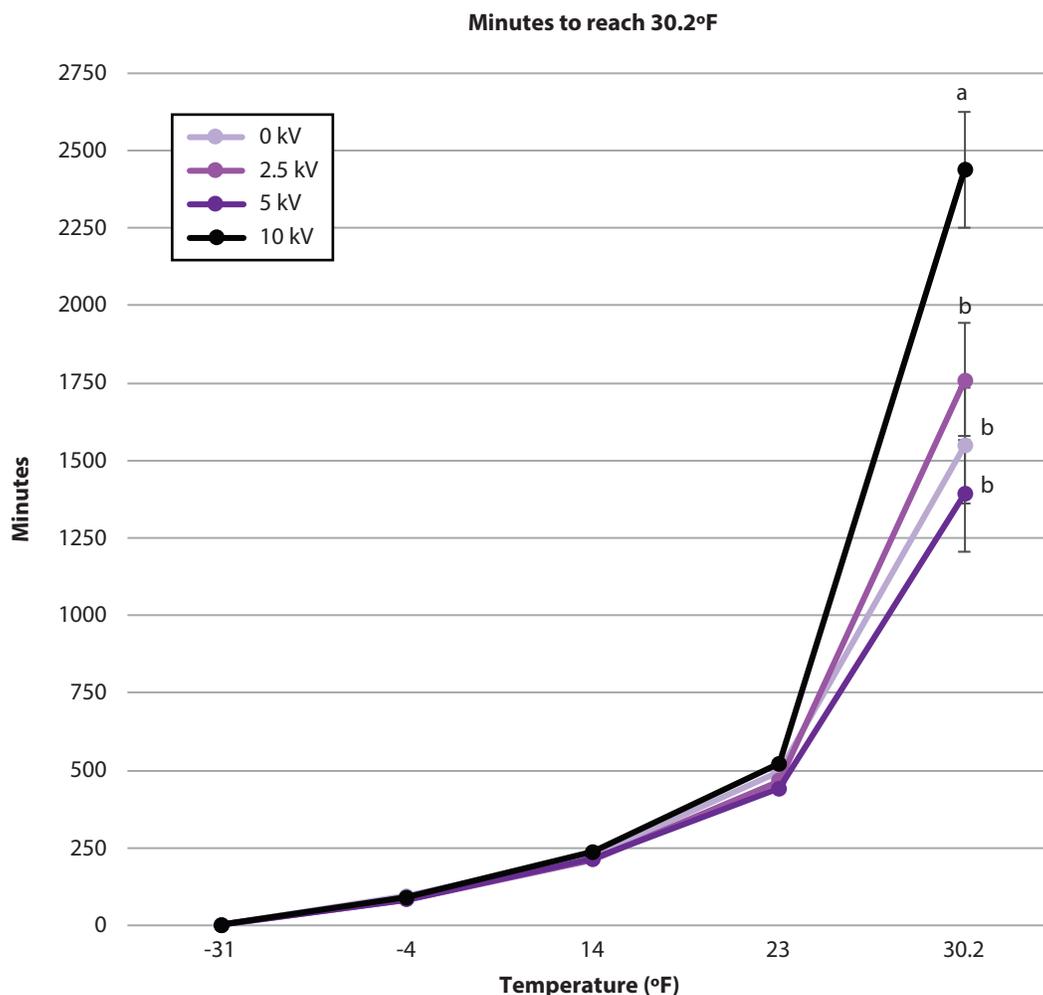


Figure 1. Thawing speed (minutes) of electrostatic field treatments until thawed temperature (30.2°F).

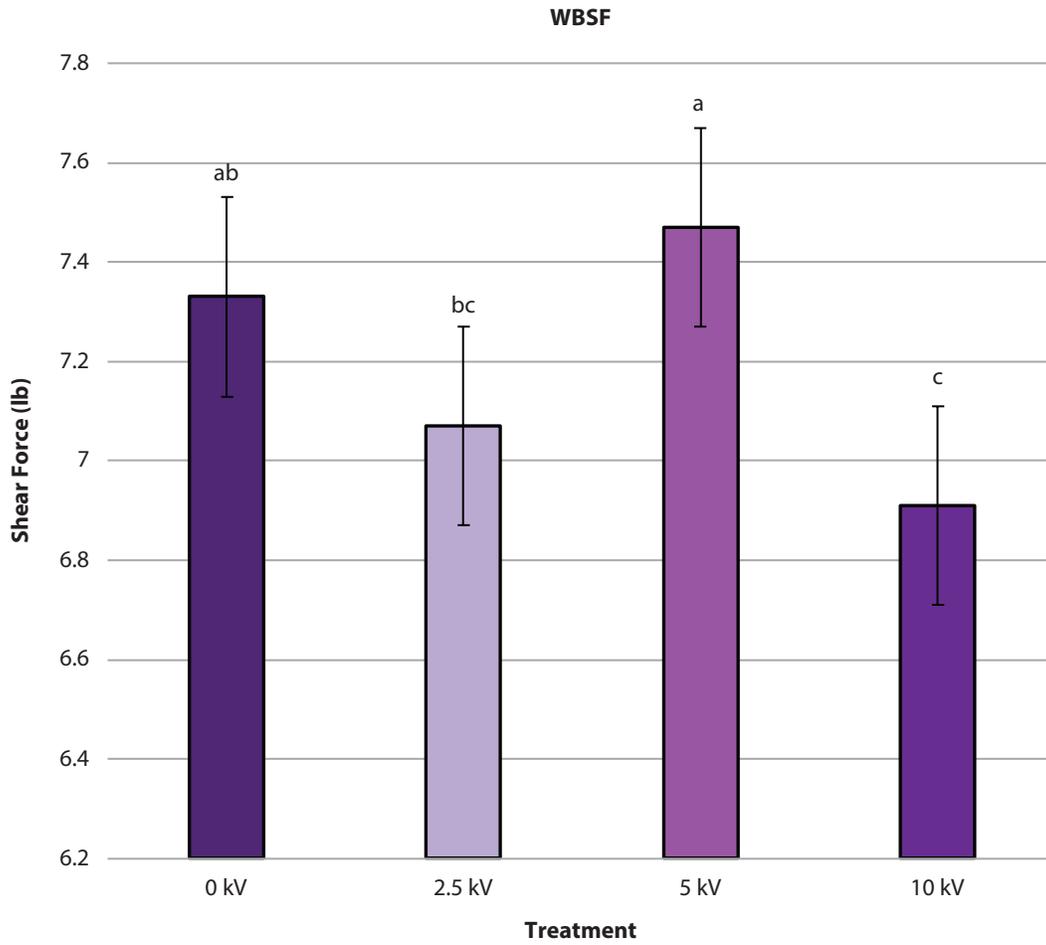


Figure 2. Warner-Bratzler shear force (WBSF) values of samples from electrostatic field thawing treatments.

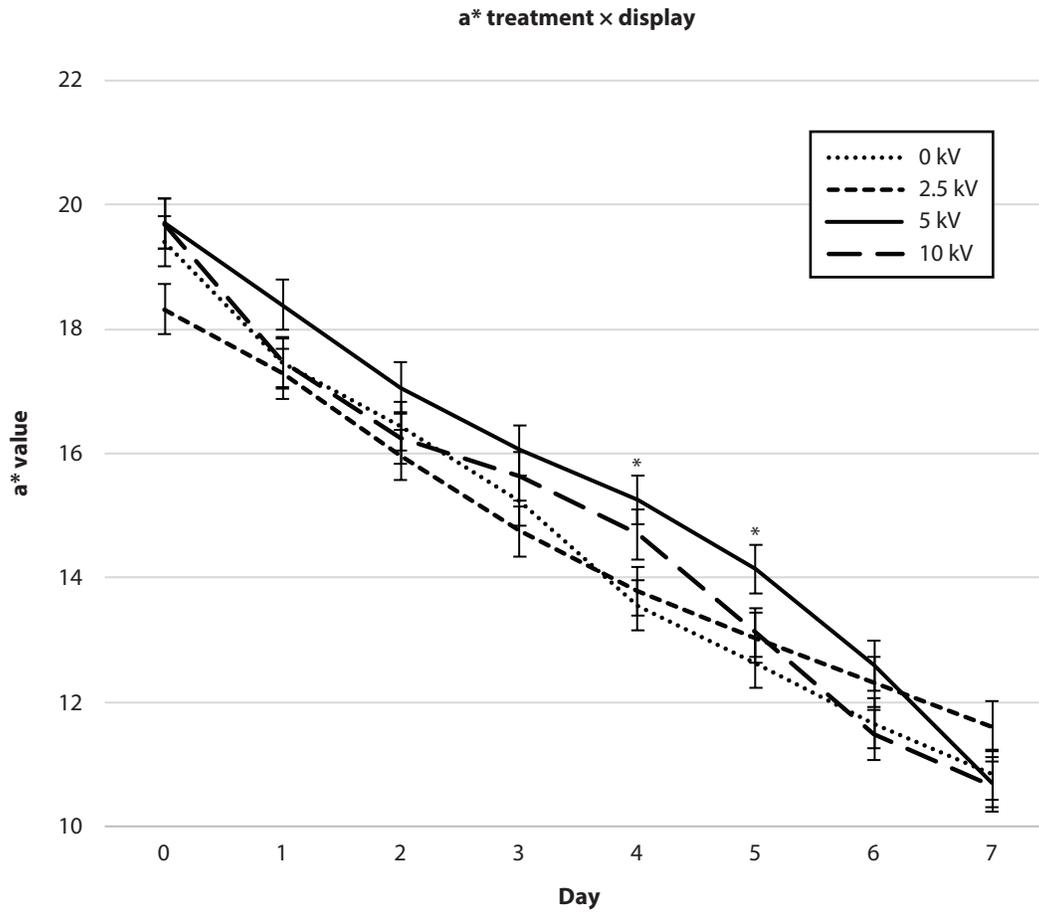


Figure 3. a* values (redness) of samples from the electrostatic field thawing treatments during 7 days of retail display.