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## The Use of Bioelectrical Impedance to Assess Shelf-Life of Beef *Longissimus Lumborum* Steaks

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### Abstract

The quality attributes of beef *longissimus lumborum* during 15 days of simulated retail display using bioelectrical impedance were assessed. Beef strip loins ( $n = 18$ ) were obtained from three commercial processors with 3 postmortem ages (27, 34, or 37 days). Loins were fabricated into 12 1-in thick steaks, subdivided into six consecutively cut pairs, and randomly assigned to one of six display days: 0, 3, 6, 9, 12, and 15. Microbiological and bioelectrical impedance analysis, pH, objective color assessment, proximate composition, and lipid oxidation were measured. There was a postmortem age  $\times$  display day interaction ( $P < 0.05$ ) for surface bioelectrical impedance. Overall, steaks aged 27 days had higher ( $P < 0.05$ ) surface bioelectrical impedance values than steaks aged 34 and 37 days. There was no postmortem age  $\times$  display day interaction ( $P > 0.05$ ) for internal bioelectrical impedance values; however, an effect on postmortem age and display day was found ( $P < 0.05$ ). Steaks aged 27 days had 17% higher internal bioelectrical impedance values ( $P < 0.05$ ) than steaks aged 37 days, but were similar ( $P > 0.05$ ) to steaks aged 34 days. For all postmortem age times, display day 0 had the lowest ( $P < 0.05$ ) internal bioelectrical impedance value. Furthermore, the covariance component was smaller in internal bioelectrical impedance than surface bioelectrical impedance. Internal bioelectrical impedance has potential for use to assess shelf-life of retail steaks and is more precise than surface bioelectrical impedance.

### Introduction

In the U.S., meat discounted or discarded due to discoloration accounts for 15% of meat loss, leading to revenue losses up to \$1 billion for the industry (Smith et al., 2000). As little as 20% discoloration is sufficient for consumers to reject meat (Djenane et al., 2001). A study by Buzby et al. (2014) estimated that 1.3 million tons of meat is not being utilized at the retail level. The need for quantitative, objective, fast, non-destructive, non-invasive methods to predict freshness has risen in the past decade. Bioelectrical impedance analysis has been studied as a potential technology to assess quality attributes of fresh meat. It is well documented that fresh meat has higher bioelectrical impedance values due to decreased extracellular fluid, allowing the flow of electric current. Conversely, increased extracellular fluid leads to lower bioelectrical impedance values due to membrane damage, resulting in poor water holding capacity. Meat scien-

tists have reported bioelectrical impedance as an effective technology to assess carcass composition, aging, and post-mortem changes in muscle cell membranes. At the carcass level, bioelectrical impedance has been shown to be highly correlated to fat and water content, salable yield, fat trim, and marbling scores. Slaughter plant location, types of breed, and sex had an impact on impedance measurements. The objective of this study was to evaluate the efficacy of using surface and internal bioelectrical impedance to assess beef *longissimus lumborum* shelf-life during 15 days of simulated retail display.

## Experimental Procedures

The experiment was designed as a split-plot with loin as the whole-plot and paired steaks as the sub-plot. Display day was treated as the sub-plot treatment. Postmortem age time and display day were treated as fixed effects. Beef strip loins ( $n = 18$ ; Institutional Meat Purchase Specifications #180) with a postmortem age of 27, 34, or 37 days were obtained from three commercial processors. Loins were fabricated into 12 1-inch thick steaks ( $n = 216$ ). Steaks were subdivided into 6 consecutively cut pairs and pairs were randomly assigned to one of six display days: 0, 3, 6, 9, 12, and 15.

For all pairs, one steak was allocated to microbiological analysis and pH and the paired steak for bioelectrical impedance analysis, objective color assessment, proximate composition, and lipid oxidation using the thiobarbituric acid reactive substances method. In addition, surface bioelectrical impedance and internal bioelectrical impedance assessment were compared. Steaks were packaged on Styrofoam trays with a moisture absorbent pad, overwrapped with polyvinyl chloride film, and displayed under fluorescent lighting at 32–40°F in coffin-style retail cases.

## Results and Discussion

There was a postmortem age  $\times$  display day interaction ( $P < 0.05$ ) for surface bioelectrical impedance (Figure 1). From day 0 to 12 of display, steaks aged 27 days had higher ( $P < 0.05$ ) surface bioelectrical impedance values than steaks aged 34 and 37 days. On day 15 of display, steaks aged 34 days had 22% higher ( $P < 0.05$ ) surface bioelectrical impedance values than steaks aged 37 days, but had similar ( $P > 0.05$ ) values compared to steaks aged 27 days. There was no postmortem age  $\times$  display day interaction ( $P < 0.05$ ) for internal bioelectrical impedance values; however, an effect on postmortem age and display day was found ( $P < 0.05$ ). Steaks aged 27 days had 17% higher internal bioelectrical impedance values ( $P < 0.05$ ) than at 37 days, but were similar ( $P > 0.05$ ) to steaks aged 34 days (Figure 2). For all postmortem aging times, day 0 had the lowest ( $P < 0.05$ ) internal bioelectrical impedance values among all display days (Figure 3). Day 3 had the next lowest internal bioelectrical impedance ( $P < 0.05$ ) and was 8% higher than day 0. Day 6 internal bioelectrical impedance was 16% higher ( $P < 0.05$ ) than day 3, but similar ( $P > 0.05$ ) to day 9 and day 12. Internal bioelectrical impedance was similar ( $P > 0.05$ ) for steaks displayed for 12 and 15 days.

Covariance component was smaller in internal bioelectrical impedance than surface bioelectrical impedance. There was no postmortem age  $\times$  display day interaction ( $P > 0.05$ ) for  $a^*$  (redness) and  $b^*$  (blueness) values; however, there was an interaction for  $L^*$  (lightness) values. On display day 0, steaks aged 27 days were 6% lighter ( $P < 0.05$ ) than steaks aged 34 or 37 days, but on display day 15 all samples were similar

( $P > 0.05$ ) in lightness. Postmortem age had no effect ( $P > 0.05$ ) on  $L^*$ ; however, an effect on  $a^*$  and  $b^*$  was found ( $P < 0.05$ ). Steaks aged 27 days had higher ( $P < 0.05$ )  $a^*$  and  $b^*$  values by 12 and 7%, respectively, compared to other postmortem aging times. For aerobic plate count populations, there was a postmortem age  $\times$  display day interaction ( $P < 0.05$ ). Steaks aged 27 days had the lowest ( $P < 0.05$ ) aerobic plate count population on display day 0 with 2.3 log colony forming units/g in comparison to steaks aged 34 and 37 days, which had 4.3 and 4.5 log colony forming units/g, respectively. On display day 15, aerobic plate count populations were similar ( $P > 0.05$ ) among all postmortem days (6.3 to 7.2 log colony forming units/g). No postmortem age  $\times$  display day or postmortem age effects ( $P > 0.05$ ) were found for lipid oxidation; however, there was a display day effect ( $P < 0.05$ ). On display day 0, thiobarbituric acid reactive substances values were similar ( $P > 0.05$ ) on steaks, regardless of postmortem age with 0.15 mg malondialdehyde/kg. On display day 15, thiobarbituric acid reactive substances values on steaks aged 34 and 37 days were greater ( $P < 0.05$ ) with 0.9 mg malondialdehyde/kg than steaks aged 27 days with 0.55 mg malondialdehyde/kg. There was no postmortem age  $\times$  display day interaction ( $P > 0.05$ ) or postmortem age effect ( $P > 0.05$ ) for moisture content. Display day ( $P < 0.05$ ) had an effect on moisture content.

Moderate negative correlations occurred between surface bioelectrical impedance values and  $a^*$ ,  $b^*$ , and moisture content with -0.48, -0.46, and -0.46, respectively; and -0.51, -0.48, and -0.43, respectively, for internal bioelectrical impedance. Conversely, moderate positive correlations were found between surface bioelectrical impedance values and aerobic plate counts and lipid oxidation with 0.34 and 0.53, respectively; and 0.29 and 0.51, respectively, for internal bioelectrical impedance.

## Implications

Internal bioelectrical impedance has potential for use to assess shelf-life of retail steaks and was more precise than surface bioelectrical impedance; however, using the internal bioelectrical impedance method may translocate bacteria into the muscle. Protein degradation and water holding capacity should be evaluated to better understand bioelectrical impedance changes over time.

## References

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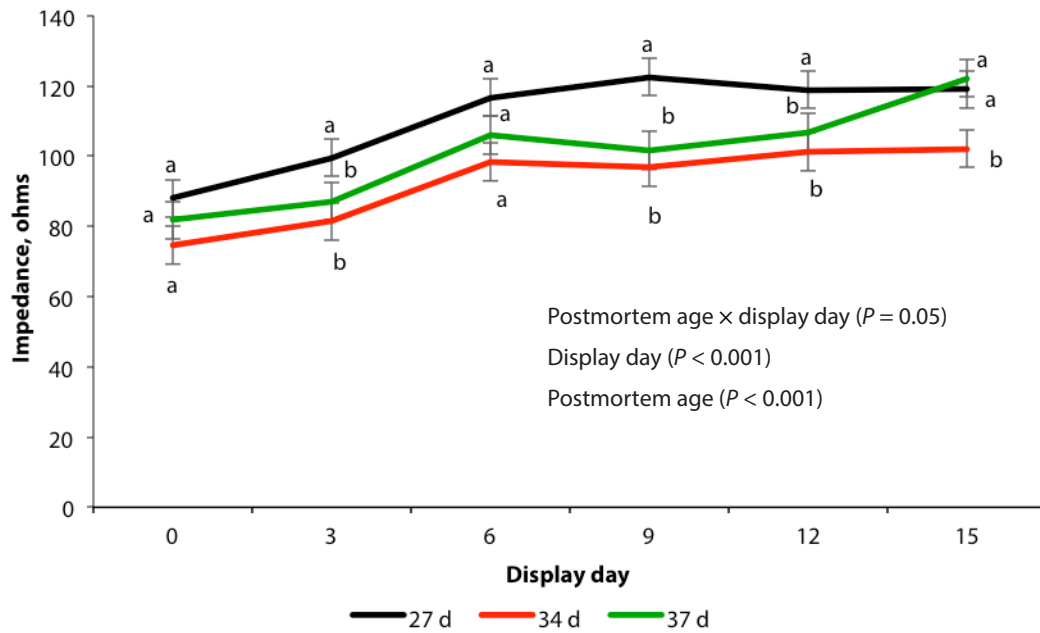


Figure 1. Surface bioelectrical impedance values of beef *longissimus lumborum* (strip loin) steaks aged 27, 34, or 37 days and displayed for 15 days under fluorescent lighting at 32–40°F. <sup>ab</sup>Means with different superscripts differ ( $P < 0.05$ ).

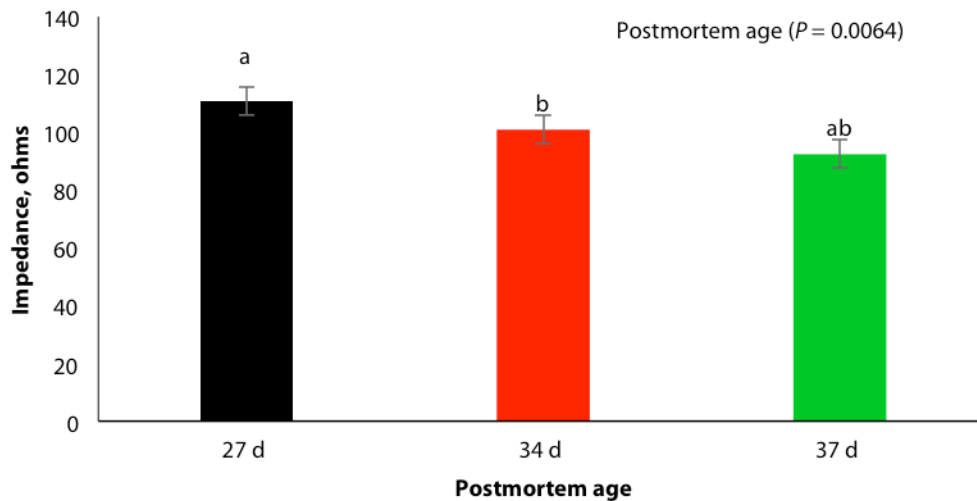


Figure 2. Internal bioelectrical impedance values of beef *longissimus lumborum* (strip loin) steaks aged for 27, 34, or 37 days. <sup>ab</sup>Means with different superscripts differ ( $P < 0.05$ ).

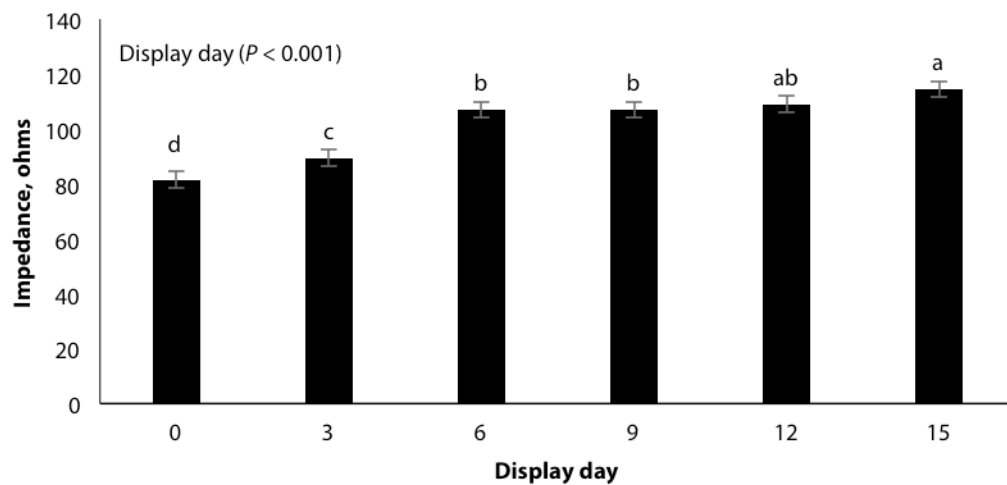


Figure 3. Internal bioelectrical impedance values of beef *longissimus lumborum* (strip loin) steaks displayed for 15 days under fluorescent lighting at 32–40°F.

<sup>ab</sup>Means with different superscripts differ ( $P < 0.05$ ).