

# LED Lighting Extends Color Shelf Life for Three Beef Products Compared with Fluorescent Lighting

*K.S. Steele, M.J. Weber<sup>1</sup>, E.A.E. Boyle, M.C. Hunt, A.S. Lobaton-Sulabo, C. Cundith<sup>1</sup>, Y.H. Hiebert<sup>2</sup>, K.A. Abrolat<sup>2</sup>, J.M. Attey<sup>2</sup>, S.D. Clark<sup>2</sup>, D. Johnson, and T.L. Roenbaugh*

## Introduction

Consumers are not able to estimate tenderness, juiciness, or flavor when selecting beef cuts at retail stores. Instead, they rely on color as one of the major criteria to select beef cuts. During refrigerated display, fresh meat color changes and consumers discriminate against discolored meats. Meat items with discoloration must be discounted or discarded, leading to up to \$1 billion in revenue loss nationally for the meat industry.

Lighting type and intensity have a major impact on the appearance and shelf life of fresh beef in refrigerated retail display. Light emitting diode (LED) lighting offers advantages for display because it is more energy-efficient and generates less heat than fluorescent lights. These advantages may be beneficial for fresh meat color stability.

The objective of this study was to determine the effects of LED and fluorescent (FLS) lighting on visual and instrumental meat color and shelf-life properties of three fresh beef products displayed in two retail display cases that were set up to run at similar temperature profiles when case lighting was off prior to the initiation of the study.

## Experimental Procedures

Select/low choice beef *semimembranosus* subprimals, beef *longissimus dorsi* steaks enhanced at 8% pump (beef stock, lactate, phosphate, salt, and natural flavorings), and coarse ground beef (85% lean and 15% fat) were obtained from a commercial supplier (Cargill Meat Solutions, Wichita, KS). The beef was reprocessed by cutting into 1-inch-thick steaks or grinding and/or repackaging on foam trays with a moisture-absorbent pad, then overwrapped with PVC for display.

Two refrigerated retail display cases equipped with fluorescent or LED lighting were adjusted to operate at similar temperature profiles with the lights turned off so lighting would be the sole variable. Each display case had four adjustable shelves consisting of two sections and a fixed bottom shelf. Shelves were arranged identically in both cases and were similar in vertical spacing to cases in Manhattan, KS, supermarkets.

Within each product type, products were randomly selected for replication and display location on a specific shelf. For each case, one shelf held 6 replications of 6 beef *longissimus dorsi* steaks, another shelf held 4 replications of 6 ground beef packages, and the bottom shelf held 6 replications of 6 beef *semimembranosus* steaks. In total, 72 beef

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<sup>1</sup> Cargill, Wichita, KS.

<sup>2</sup> Hussmann Corporation, Bridgeton, MO.

*longissimus dorsi* steak packages, 48 ground beef packages, and 72 beef *semimembranosus* steak packages were evaluated for initial pH, visual and instrumental color, internal temperature, subjective odor, thiobarbituric acid reactive substances, and except for beef *semimembranosus* steaks, microbial populations during display. Packaged products were displayed immediately after final packaging (0 days) and displayed until the end of visual color life as determined by an average visual color panel score of 4.

The meat products in both cases were illuminated 24 hours per day. In the LED case, a canopy lighting fixture positioned above the top shelf had a correlated color temperature of 2,867 K and a color rendering index of 93. The bottom four shelves were illuminated with LED light bars with a correlated color temperature of 3,007 K and a color rendering index of 95.7. Lighting intensity in the LED case averaged 1,627 lm. The FLS lighting had a correlated color temperature of 3,500 K, a color rendering index of 82, and lighting intensity averaging 1,712 lm. Case temperatures were recorded every 10 minutes throughout display.

A minimum of 8 trained visual color panelists from Kansas State University evaluated beef color daily to the nearest 0.5 increment using 8-point scales unique to each product. The beef loin steak, ground beef, and beef inside round superficial portion color scale was: 1 = very bright red, 4 = slightly dark red, 8 = tan to brown. The beef inside round deep portion steak visual color scale was: 1 = very bright pinkish red, 4 = slightly dark pinkish red, 8 = tan to brown. An average visual panel score of 4 represented the end of product color shelf life (estimated as the point of objectionable color in retail displays). The color of beef loin steaks and beef inside round steaks was evaluated by panelists once per day at a standardized time. The superficial and deep portions of the inside round steaks were evaluated separately for color. Ground beef color was visually scored every 12 hours through day 2 of display, then every 24 hours for the remaining display time.

Instrumental color of the meat products was recorded using a HunterLab MiniScan EZ (Model 4500; Reston, VA) for values of L\* (lightness), a\* (redness), and b\* (yellowness). Saturation index (degree of redness) was calculated using the a\* and b\* measurements. Internal product temperature was measured daily at the geometric center of samples using a thermocouple (Omegaette HH300 Series Thermometer, Stamford, CT). Odor was scored immediately after opening a package on day 0 and at the end of display. Three trained odor panelists subjectively evaluated off-odors using a 5-point scale: 1 = no off-odor, 2 = slight, 3 = small, 4 = moderate, and 5 = extreme off-odor. Product oxidation was analyzed using the thiobarbituric acid reactive substances procedure on samples collected from the upper ¼ in. of the displayed surface on day 0 and at the end of display.

Two packages of each product under fluorescent and LED lighting were evaluated for microbial populations at the beginning, middle, and end of color shelf life. Initial microbial testing was performed on day 0 for all products. The middle and end sampling day was determined by an average visual color panel score of 2 and 4, respectively. As a result, each product had a unique middle and end microbial sampling day. Aerobic Plate Count and *Enterobacteriaceae* populations were determined using Petrifilm (3M Microbiology Products; St. Paul, MN). Plates for Aerobic Plate Count and *Enterobac-*

*teriaceae* populations were incubated at 89.6°F for 48 hours and 24 hours, respectively, prior to enumeration.

## Results and Discussion

Throughout display, the LED case temperature was 1.2°F lower ( $P < 0.05$ ) than the fluorescent case (Figure 1). Temperatures at the front of the shelves were from 3.5 to 4.2°F higher ( $P < 0.05$ ) than temperatures at the back of the shelves. No differences ( $P > 0.05$ ) were observed for temperatures among the 5 shelves. The average case condenser cycle during display for LED and fluorescent cases was 10.7 cycles/hour and 18.0 cycles/hour, respectively. Although numerous factors affect case operation efficiency, lower temperatures indicate shelf life advantages for products held under LED lighting. An LED case not only operates with greater energy efficiency, but also sustains lower temperatures than a fluorescent lighted case.

Ground beef and beef inside round steaks in the LED case had lower ( $P < 0.05$ ) internal temperatures than under FLS (Figure 2). The internal temperature of beef loin steaks was similar ( $P > 0.05$ ) regardless of lighting type.

All three beef products on display had better ( $P < 0.05$ ) color stability under LED lighting based on evaluations by trained color panelists except the deep portion of the beef inside round steak (Figure 3), resulting in an extended color shelf life and economic benefits for retailers. As expected, the discoloration of products increased over the duration of the study. End product color shelf life, as determined by the panelists' scores, were 2, 4, and 4 days for beef loin steaks, ground beef, and beef inside round steaks, respectively.

Visual color results shown in Figure 3 demonstrate that the superficial portion of beef inside round steaks should be displayed under LED lighting for extended shelf life. Using instrumental color parameters to support the subjective comparison of visual scores can give an indication of shelf life extension. The deep portion beef inside round steaks had greater ( $P < 0.05$ )  $a^*$  redness values under LED lighting compared with fluorescent lighting. Redness or  $a^*$  values decreased ( $P < 0.05$ ) over time for beef loin steaks, ground beef, and the deep and superficial portions of beef inside round steaks. The superficial and deep portions of beef inside round steaks had 1.1 and 1.4 more ( $P > 0.05$ ) red saturation units under LED lighting compared with fluorescent lighting, but no difference existed for the other two beef products. The visual differences observed for the superficial portion of beef inside round steaks under LED or fluorescent lighting were confirmed by instrumental data, where redness saturation values were higher for LED lighting.

All products had no off-odor on day 0 except for the beef loin steaks, which had a very slight off-odor, possibly because they were 9 days post-case-ready packaging at the initiation of the study. Over the duration of the study, beef loin steaks and ground beef had odor scores of 3, equating to small amounts of detectable odor at the end of their color life.

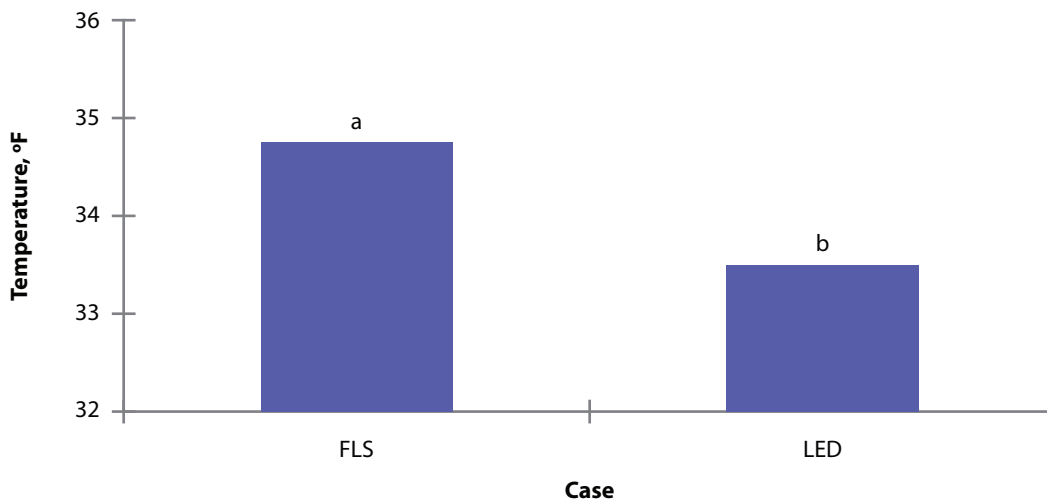
Beef inside round steaks had higher ( $P < 0.05$ ) oxidation values when displayed under LED lighting than fluorescent lighting, and there was a day effect, with higher ( $P < 0.05$ ) oxidation values on the last day of display compared with the first day. Consumers can

begin to detect rancid flavors when oxidation or thiobarbituric acid reactive substances values reach 2 mg malonaldehyde/kg. Beef inside round steaks had 1.98 mg malonaldehyde/kg by the final day of display.

No differences were measured ( $P > 0.05$ ) in Aerobic Plate Count or *Enterobacteriaceae* growth for any of the beef products due to lighting type.

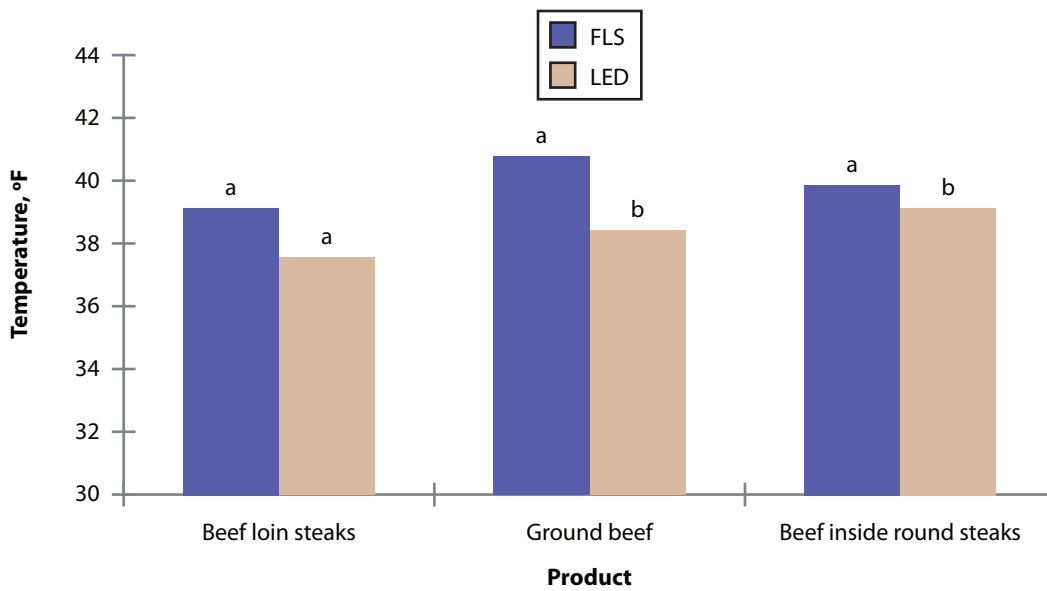
## Implications

Using LED lighting in retail meat display cases will save money by reducing overhead operational costs while extending the color life of beef loin steaks, ground beef, and beef inside rounds.



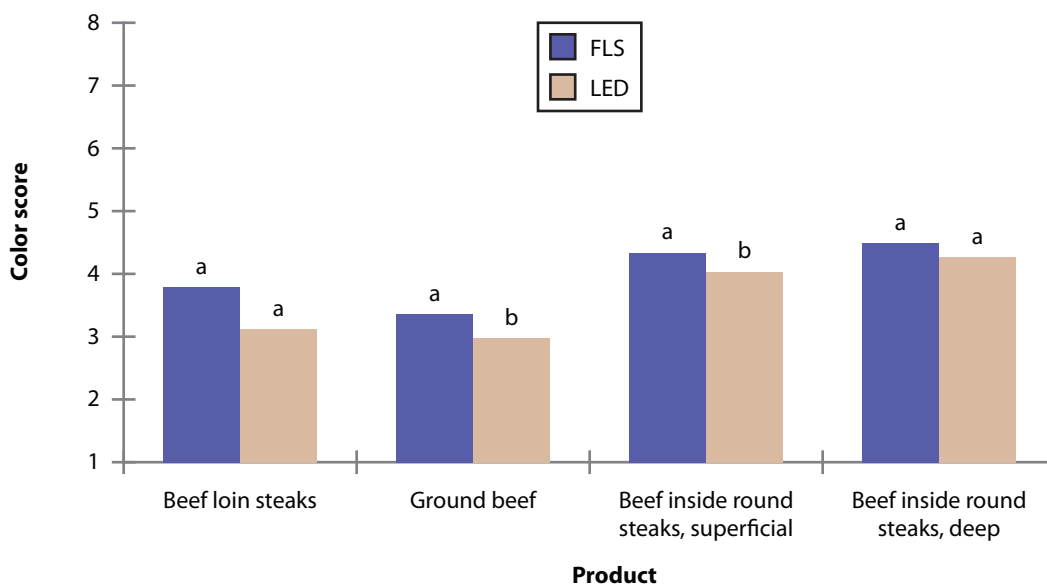
<sup>ab</sup> Means without a common superscript differ ( $P < 0.05$ ).

**Figure 1. Case temperature for cases equipped with fluorescent (FLS) or light emitting diode (LED) lighting.**



<sup>ab</sup> Columns with different letters differ at  $P < 0.05$ .

**Figure 2. Internal product temperature.**



<sup>ab</sup> Columns with different letters differ at  $P < 0.05$ .

**Figure 3. Visual color of five products displayed in two meat retail display cases equipped with fluorescent (FLS) or light emitting diode (LED) lighting.**

Beef loin steak color scale: 1 = very bright red, 4 = slightly dark red, 8 = tan to brown. Ground beef visual color scale: 1 = very bright red, 4 = slightly dark red, 8 = tan to brown. Beef inside round superficial portion steak visual color scale: 1 = very bright red, 4 = slightly dark red, 8 = tan to brown. Beef inside round deep portion steak visual color scale: 1 = very bright pinkish red, 4 = slightly dark pinkish red, 8 = tan to brown.