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Effects of Promolux Platinum LED on Shelf-life of Ground Beef Patties

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Abstract

The objective of this study was to determine the effects of three light sources, Promolux platinum LED (PPLED), fluorescent (FLS) lighting, and no light (control), on shelf-life properties of ground beef patties. Treatments were evaluated for % drip loss, pH value, % moisture content, visual and instrumental color (L*, a* and b* values), lipid stability (TBARS), aerobic plate count, yeast/mold, *Escherichia coli*, *Salmonella* spp. and *Listeria* spp. every 3 days for 9 days. At day 9, drip loss was lowest ($P<0.05$) in patties under the control treatment. No difference was found in visual color appraisal between treatments based on evaluations by trained color panelists ($N=15$) from days 1 to 5. Patties under PPLED had the greatest ($P<0.05$) redness a* values at day 9 of the experiment. When patties were not exposed to light they had the lowest TBARs values at day 7 and 9. Aerobic plate counts were lowest in patties under the control treatment throughout the experimental patties. There was no yeast/mold, *E. coli*, *Salmonella* spp. and *Listeria* spp. found in this study from days 1 to 5 and minimal counts at day 7 and 9.

Keyword: light source, meat color, microorganism

1. Introduction

Color is an important factor in the marketing of meat because it influences consumers buying decisions (Banović, Aguiar, Barreira, & Grunert, 2012; Suman & Joseph, 2013). When the meat changes to discoloration or a brownish color in refrigerated display, consumers begin rejecting products (Mancini & Hunt, 2005), resulting in discounted or discarded meat and causing the retailers loss up to $1 billion dollar annually (Smith, Belk, Sofos, Tatum, & Williams, 2000).

Myoglobin is the primary pigment for meat color and it can exist as deoxymyoglobin, oxymyoglobin, or metmyoglobin. Deoxymyoglobin and metmyoglobin present a brown color to meat while oxymyoglobin shows a bright red color. These forms depend upon the pigment concentration, the state of iron molecule, and the occupation of the sixth ligand (Faustman & Cassens, 1990). In addition, they may be affected by several factors including absorbing properties (Kropf, 1998), temperature (Martin et al., 2013), the length of retail display (Jeremiah & Gibson, 2001; Martin et al., 2013), and lighting type (Steele et al., 2016). Lighting type and intensity have a major impact on the appearance and shelf-life of fresh beef in refrigerated retail display (Smith et al., 2000; Steele et al., 2016; Cooper, Suman, Wiegand, Schumacher, & Lorenzen, 2017). The previous studies reported that fluorescent lighting can increase the temperatures in the displayed cases and increase the rate of discoloration (Steele et al., 2016). Meat is displayed under refrigeration temperatures 3-5°C retards discoloration (MacDougall, 1982). Specifically, ground beef with an oxygen-permeable overwrapped film has a shelf-life of 2-3 days (Robert, 2009). The shelf-life of beef is important in the retail marketplace which determines the length of time that passes before meat becomes unpalatable or unpleasant for human consumption because of the discoloration or growth of spoilage microorganisms is important in the beef retail market place (Smith et al., 2000). Previous research (Marriott, Naumann, Stringer, & Hedrick, 1967) reported that beef short loin steaks stored in the dark at 27℉ for 10 days changed only slightly in visual color, while steak kept under 120 foot-candles of soft white fluorescent light discolored markedly after 5 days. Similarly, beef under lighting at 254 nm and 3230 lux of UV radiation accelerated discoloration (Hood, 1980).

Light emitting diode (LED) is commonly used in the meat industry which is more energy efficient and reduces heat generation throughout display (Steele et al., 2016). Previous studies demonstrated that LED light sources

promoted redness retention in ground beef patties during retail display (Cooper et al., 2016). In contrast, Steele et al (2016) showed that there was no difference in a* values between ground beef displayed under LED and fluorescent. Therefore, evaluating the impact of light sources during retail display on beef patties is still inconclusive.

Recently, newer technologies in lighting offer the ability to enhance meat color and to reduce energy costs for meat retail display. Promolux Platinum LED (PPLED) 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 PPLED on visual and instrumental meat color and shelf-life properties of ground beef patties.

2. Method

2.1 Preparation of Beef Patties

Ground beef (80% lean and 20% fat) was obtained from the Center for Advancement of Meat Production and Processing (CAMPP) at McNeese State University in Lake Charles, Louisiana at 48 h postmortem. Beef patties (115 g) were made with a hamburger mold, placed on 20.96 x 14.61 x 1.59 cm foam tray with an absorbent pad, and wrapped with polyvinyl chloride (PVC) film. Patties (n = 81) were randomly assigned to three packaging treatments and stored in a 2.2 ℃ cooler under three types of lighting conditions: 1) Control (no light), 2) fluorescent (FLS) and 3) Promolux platinum LED (PPLED) for 9 days. Three replicates of each treatment (n = 243) were analyzed for % drip loss, pH value, % moisture content, visual and instrumental color (L*, a* and b* values), lipid oxidation (thiobarbituric acid-reactive substances (TBARS) protocol), aerobic plate count (APC), yeast/mold, *Escherichia coli* (*E. coli*), *Salmonella* spp. and *Listeria* spp. every 3 days for 9 days.

2.2 Sensory Analysis

Visual color was determined following the American Meat Science Association protocol (AMSA, 2012). Fifteen trained visual color panelists from McNeese State University evaluated beef patty color every 3 days for 9 days using hedonic 8-point scales unique to each product (1 = very bright red, 2 = bright red, 3 = dull red, 4 = slightly dark red, 5 = moderately dark red, 6 = dark red to tannish-red, 7 = dark reddish-tan, 8 = tan to brown).

2.3 pH Test

Each treatment was replicated three times (n = 243) and evaluated for pH with a probe electrode portable meter (Model 2000 VWR Scientific) and results are expressed as the mean and standard error of the mean (SEM). Calibration of the pH meter was accomplished using pH 7 and pH 4 standardization buffers before use.

2.4 Moisture Content

Moisture content was determined according to the design method of the Association of Official Analytical Chemists (AOAC, 2000). Crucibles were heated at 102 ℃ for 3 h and transferred to a desiccator to cool and record dry crucible weight. Each 3 g sample (n = 243) was weighed and dried in a hot air oven (Model 26 Precision Thelco) at 102 ℃ for 24 h. After drying, crucibles were moved to the desiccator to cool and obtain dry sample weight. The total moisture content was determined by dividing the difference between the initial weight (IW) and dry weight (DW) and dividing by initial weight.

$$[(IW-DW)/IW] \quad (1)$$

2.5 Drip Loss Analysis

For determination of exudation and weight retention during storage, all treatment samples (n = 243) were weighed separately at the time of initial sampling at days 1, 3, 5, 7, and 9. Weight loss was calculated as the difference of final sample weight and initial sample weight divided by the initial weight for ground beef patties.

2.6 Color Test

Instrumental color was determined following the American Meat Science Association protocol (AMSA, 2012). On each sampling day, each package was opened and exposed to the air for a maximum of 10 seconds. Color was measured at three different locations (n = 243) and was averaged to obtain single values for each sample using a Minolta spectrophotometer (Model CR-10 portable) with an 8 mm aperture, 10 ° observer angle, D65 illuminant source in terms of L* (100 = white, 0 = black), a* (+40 = red, -40 = green), b* (+40 = yellow, -40 = blue).

2.7 TBARS Test

The 2-thiobarbituric acid (TBARS) method was used to measure the lipid oxidation for each sample designated for TBARS analysis (Tarladgis, Watts, Younathan, & Jr. Dugan, 1964). A fifteen gram sample of each beef patty

(n = 243) was blended with 30 mL of trichloroacetic acid solution. The sample solution was filtered through Whatman No. 1 filter paper. Five ml aliquots of the filtrate were transferred to separate test tubes (in duplicate) and mixed with 5 mL of 0.02 M TBA. The mixture was vigorously agitated in a vortex and was heated in a boiling water bath (100°C) for 45 min to develop a pink color. After cooling the reaction mixture under running water the absorbance was determined at 530 nm using a Beckman Du-640 spectrophotometer against a blank containing 5 mL of distilled water and 5 mL of TBA reagent. The TBA value used to express the results were calculated from standard curves and known dilutions of tetraethoxypropane (TEP). The result was expressed by the mg malonaldehyde (MDA)/kg tissue.

2.8 Microbial Counts

The microorganisms were determined following the standards of the Association of Official Analytical Chemists (AOAC, 2000). Buffered peptone water (BPW) was added as a diluent option for serial dilutions. All samples were plated on 3MTM Petrifilm to determine the enumeration (log CFU/g) of APC, yeast/mold, and *E. coli*. *Salmonella* was isolated with xylose lysine deoxycholate (XLD) agar and ACTERO™ *Listeria* enrichment media agar was used for *Listeria* spp. Plates were incubated in a horizontal position, clear side up in stacks of no more than 20 plates at 37 ℃ for 24-48 h. Results were obtained by selecting a countable plate (30-300 colonies) and the colonies were counted and reported as CFU/g.

2.9 Statistical Analysis

The Proc GLM procedures of SAS windows (SAS, 2003) were used to evaluate the significance of differences of the obtained data. The PDIFF option of LSMEANS was employed to determine significance among treatments. All data are presented as means with standard error (SD) and a significance level of $P<0.05$ was used in ANOVA technique for statistical analysis of means from treatments.

3. Results and Discussion

3.1 Sensory Analysis

Using the hedonic scale, fifteen trained visual color panelists from McNeese State University evaluated beef patty color every 3 days for 9 days (Figure 1). No difference was found in visual color appraisal between treatments based on evaluations by trained color panelists from days 1 to 5. The trained panelists scored all treatments 1.8 (bright red) at d 1. On d 5, the average color scores ranged from 3.27 to 3.87 (dull red). Over 9 d storage, all treatments increased in discoloration ($P<0.05$). As expected, control patties had the lowest ($P<0.05$) scores 4.83 (moderate dark red) and 5.83 (dark red) at days 7 and 9, respectively. There were significant differences between FLS and PPLED treatments throughout the 9 d storage period. These results are consistent with those reported by Lentz (1971) and Barbut (2002) who reported that the panelists found dark red or brown color of ground beef under FLS lighting. In addition, Bertelson and Skibsted (1987) indicated that the beef retains an acceptable color under LED light for 3 days.

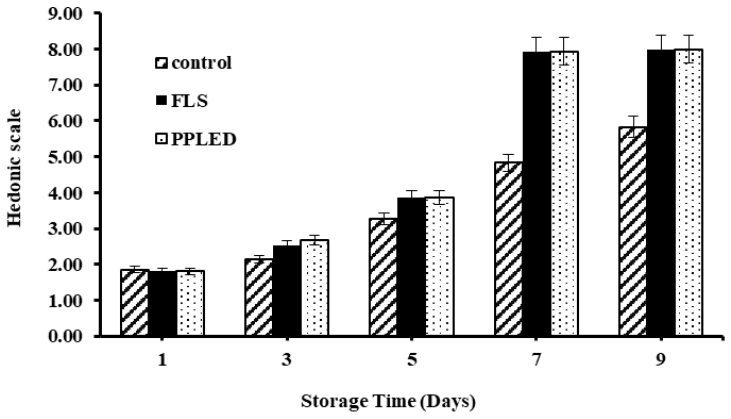


Figure 1. Least squares means for hedonic scales from trained panelists of beef patties at 2.2°C for 9 days

3.2 pH

Initial pH values of each treatment ranged from 7.60 to 7.64 which are similar to previous studies (Tangkham,

Rushing, & LeMieux, 2016). Over the 9-day experimental period, the pH values of beef patties were similar as all treatments decreased (Figure 2). The pH values of control patties declined from 7.60 to 7.46, from 7.63 to 7.38 in the FLS treatment, and from 7.64 to 7.46 in the PPLED treatment. Decreasing pH may lead to unacceptable discoloration of beef patties. Cornforth (1994) indicated that pH value affects the rate of formation of MMb pigment in brownish color. Specifically, our results showed that the pH values were lower in the beef patties under FLS lighting (7.38) than PPLED (7.46) over 9-day storage. Therefore, the pH values of beef patties at 2.2°C for 9 days are impacted by light source.

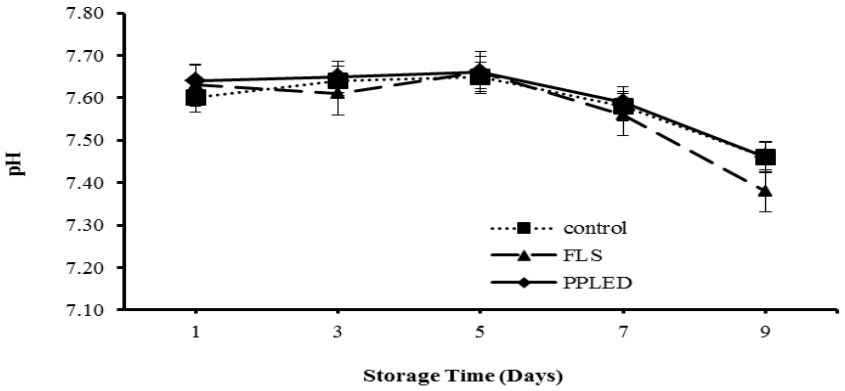


Figure 2. Least squares means for pH value of beef patties at 2.2°C for 9 days

3.3 Moisture Content

Moisture content of the three beef patty treatments are shown in Figure 3. The average initial moisture content of the three treatments ranged between 51.60%-54.82%. This value was similar to the study of USDA (2011). Moisture content declined from days 1 through 9 regardless of treatment. Beef patties under FLS treatment decreased from 54.82 to 48.49 and from 51.60 to 48.65 in the PPLED treatment. The control treatment had the lowest moisture content at 48.07% on day 9. These results are consistent with those reported by Zamudio-Flores et al. (2015). These results suggest that the lighting type affects moisture loss from the meat surface during the 9 d storage period.

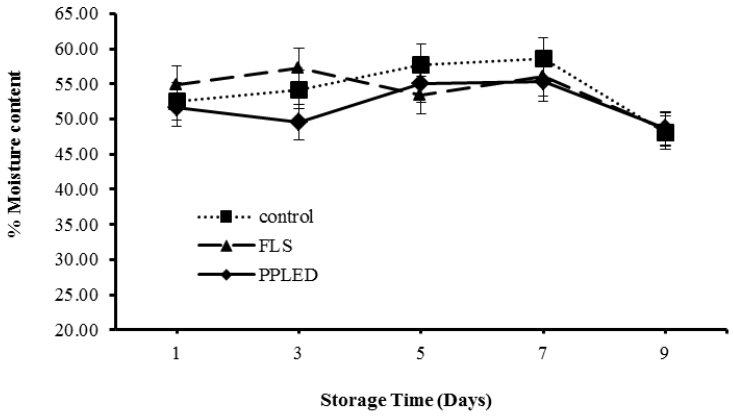


Figure 3. Least squares means for moisture content (%) of beef patties at 2.2°C for 9 days

3.4 Drip Loss

Percent drip loss was affected ($P<0.05$) by lighting treatments and storage time (Figure 2). All treatments increased in % drip loss ($P<0.05$) over 9 d storage. Beef patties under FLS treatment increased from 5.36% to 10.31% and from 5.26% to 11.17% in the PPLED treatment. On d 9, beef patties under control treatment had the lowest ($P<0.05$) percent drip loss at 6.72%. Our results suggest that the percent drip loss of beef patties at 2.2°C

for 9 days are influenced by lighting type.

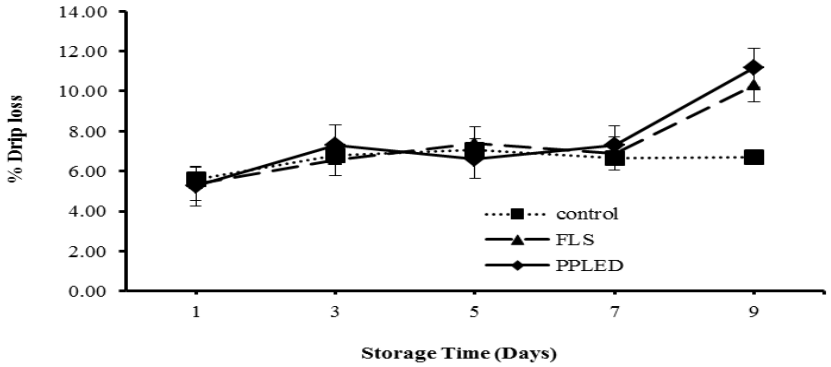


Figure 4. Least squares means for drip loss (%) of beef patties at 2.2°C for 9 days

3.5 Color Test

Meat color is major factor when consumers select meat at a retail outlet. Lighting type and intensity become important on meat appearance in the retail display. These may be beneficial to enhance meat color and reduce heat generation throughout the display. Over a 9 d experimental period, lighting type had an effect ($P<0.05$) on the instrumental color in terms of redness a* and yellowness b* values (Table 1). No difference was found in the lightness L* values. These results are consistent with those reported by Jade et al. (2017) who found that fresh steaks from beef triceps brachii under LED had no effect in lightness (L*) values over 7 day of retail display. However, our results disagreed with the findings by King, Shackelford, and Wheeler (2011) who reported that triceps brachii steaks consistently decreased in L* values from d 0 through d 6 of retail display.

We found that the redness a* and yellowness b* values declined during the experiment regardless of lighting technique which was similar to the study of Jade et al. (2017) which could be attributed to the formation of brown MMb on the beef patty surface. Data on surface redness agrees with previous studies (Hamling, Jenschke, & Calkins, 2008; Steele et al., 2016; Canto et al., 2016), which showed a decrease in a* values and a decline in red color retention with increasing retail display time. At day 9, the redness a* value was greater in beef patties under PPLED (18.16) lighting than FLS (17.11). According to Holman, et al. (2017), a threshold for consumer acceptance of redness is 14.5. In our experiment, all treatments had a* redness values above this threshold which is acceptable for consumers. This is similar to Cooper et al. (2016) who found that LED light sources promoted redness retention in ground beef patties during retail display. Our results indicate that beef patties under PPLED increased the redness value. These results are consistent with those reported by Steele et al. (2016) for beef patties. At day 7, control patties had the highest yellowness b* value at 15.20. Samples under FLS treatment had the yellowness b* value at 12.64 in the FLS treatment and 13.07 in PPLED treatment. Therefore, PPLED light source and retail display length impact a* and b* values of beef patties which help to minimize surface discoloration in low color stability beef muscles.

Table 1. Least squares means for HunterLab L*, a*, and b* values (n = 243) of beef patties at 2.2°C for 9 days

Parameter	Treatment	Storage time (d)				
		1	3	5	7	9
L*	Control	47.29^{a}	47.43^{a}	49.24^{a}	49.57^{a}	44.78^{a}
	FLS	49.33^{a}	48.01^{a}	49.44^{a}	51.70^{a}	42.56^{a}
	PPLED	45.77^{a}	47.83^{a}	48.60^{a}	51.69^{a}	41.71^{a}
a*	Control	26.78^{a}	26.53^{a}	21.92^{a}	19.57^{a}	16.39^{a}
	FLS	25.47^{a}	24.56^{a}	20.48^{a}	19.14^{a}	17.11^{b}
	PPLED	27.64^{a}	23.88^{a}	20.64^{a}	19.32^{a}	18.16^{c}
b*	Control	17.56^{a}	17.38^{a}	15.39^{a}	15.20^{a}	12.92^{a}
	FLS	17.72^{a}	16.71^{a}	15.06^{a}	12.82^{b}	12.64^{a}
	PPLED	17.81^{a}	16.09^{a}	14.87^{a}	12.62^{bc}	13.07^{a}

^{a,b,c}LSMeans with different superscripts within a same column is significantly different ($P<0.05$). Data are means from three replications. SEM for L* value = 0.972, SEM for a* value = 0.712, SEM for b* value = 0.346

3.6 Lipid Stability (TBARS)

Lipid oxidation is determined by the malonaldehyde concentration as a secondary bi-product of the propagation step. This measurement is used to detect oxidative deterioration of beef patties which correlate between the accumulation of malonaldehyde and MMb buildup (Hutchins, Lui, & Watts, 1967). The degree of lipid oxidation is dependent on several factors: the composition of the phospholipids, the amount of polyunsaturated fatty acids, and the concentration of pro-oxidants (Calkins & Hodgen, 2007). Lipid oxidation can be related to many different meat quality factors including loss of color, development of off-flavor, odors and loss of nutritional value.

The initial TBARS values of beef patties in this experiment ranged from 1.31 to 1.42 mg MDA/kg. As expected, TBARS values increased ($P<0.05$) throughout the storage time which is similar to the study of Jade, Surendranat, Bryon, Leon, and Carol (2017). In addition, other studies (Esmer, Irkin, Degirmencioglu, & Degirmencioglu, 2011; Martin et al., 2013; Steele et al., 2016) were similar in their findings. This is expected as the autoxidation of lipids and pigment oxidation lead to increase the amount of lipid oxidation. However, PPLED treatment exhibited higher TBARS values ($P<0.05$) at 2.90 mg MDA/kg than the remaining treatments at day 9. This is supported by a previous study (Steele et al., 2016).

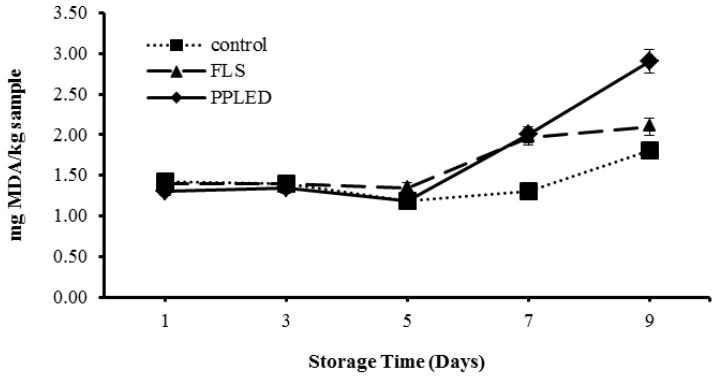


Figure 5. Least squares means for TBARS values of beef patties at 2.2°C for 9 days

3.7 Microbial Counts

Microorganism populations increased as display time increased for beef patties (Table 2) which similar to findings of Steele (2016) who reported that APC populations increased as display time increased for ground beef. Specifically, APC in the beef patties under PPLED lighting (5.60 log CFU/g) were lower than FLS (5.77 log CFU/g). These results are consistent with those reported by Steel, 2016 who reported that pork chops under LED lighting had lower ($P<0.05$) APC populations than FLS by the end of display.

Previous studies indicated that FLS influences the discoloration of meat which related to bacteria growth as the logarithmic growth phase of aerobic bacteria (Renerre & Labadie, 1993; Seideman, Cross, Smith, & Durland, 1984). Using proper packaging and storage temperatures can control bacteria growth in meat. Higher temperatures and oxygen permeable film will lead to an increase in bacterial growth on meat products (Seideman et al., 1984). At the end of display, the beef patties under FLS lighting had lower number of *Salmonella*, *Listeria* and yeast/mold as compared to PPLED. No *E. coli*, *Salmonella*, *Listeria* and yeast/mold were found in this study from days 1 to 5.

Table 2. Least squares means for microorganisms (n = 243) of beef patties at 2.2°C for 9 days

Microorganisms	Treatment	Storage time (d)				
		1	3	5	7	9
APC	Control	3.30[a]	3.39[a]	3.00[a]	4.29[a]	4.87[a]
	FLS	3.20[a]	3.50[a]	4.76[b]	4.83[ab]	5.77[b]
	PPLED	3.00[a]	4.24[b]	4.78[b]	4.99[b]	5.60[b]
E. coli	Control	ND	ND	ND	ND	ND
	FLS	ND	ND	ND	1.67[a]	3.82[a]
	PPLED	ND	ND	ND	2.13[b]	3.59[b]
Salmonella spp.	Control	ND	ND	ND	4.25[a]	5.18[a]
	FLS	ND	ND	ND	5.59[b]	6.59[b]
	PPLED	ND	ND	ND	5.53[b]	7.18[c]
Listeria spp.	Control	ND	ND	ND	3.90[a]	3.99[a]
	FLS	ND	ND	ND	5.30[b]	5.79[b]
	PPLED	ND	ND	ND	5.30[b]	5.99[c]
Yeast/mold	Control	ND	ND	ND	3.31[a]	4.18[a]
	FLS	ND	ND	ND	4.60[b]	5.60[b]
	PPLED	ND	ND	ND	4.49[c]	6.00[c]

a,b,cLSMeans with different superscripts within a same column is significantly different (P<0.05). ND = nondetectable. Data are means from three replications. SEM for APC = 0.208, SEM for *E. coli* = 0.050, SEM for *Salmonella* = 0.013, SEM for *Listeria* = 0.004, SEM for yeast/mold = 0.013.

4. Conclusions

Light source influenced surface discoloration (a* and b* values), pH, drip loss, lipid oxidation and microorganisms.

Our findings suggest that PPLED lighting is an effective light source for maintaining color stability in the redness a* and yellowness b* values. Control patties had lower drip loss, TBARS values, and the counts of APC compared to experimental treatments. Beef patties under FLS lighting had the lowest pH value.

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