HIGH-INTENSITY ULTRASOUND INFLUENCES THE COLOR STABILITY OF *Longissimus lumborum* STEAKS FROM GRAIN-FINISHED NELLORE CATTLE

ABSTRACT

Brazil is the greater beef producer worldwide, and 80% of the production is consumed domestically. The consumption profile is associated with meat color and texture, in which the color of fresh meat is the main attribute influencing purchase decisions. The use of emerging non-thermal technology, such as high-intensity ultrasound (HIU), is a promising way to increase meat tenderness, however, promotes negative effects on color. Therefore, we aimed to evaluate the influence of different HIU levels (control: 0; low: 276.36; moderate: 422.67; and high: 747.79 W/cm^2) on instrumental color (CIE $L^*a^*b^*$ and ΔE) and color stability (metmyoglobin reducing activity – MRA) of *Longissimus lumborum* steaks from Nellore cattle stored at 4 ± 1°C for 7 days. All treatments exhibited similar ($P > 0.05$) L^*, a^* and b^* values on days 0 and 7, indicating that ultrasound intensities could maintain the color stability, which was reinforced by MRA ($P > 0.05$) on days 0 and 7 and during storage ($P > 0.05$). The decrease ($P < 0.05$) in a^* and b^* values during storage may be attributed to the myoglobin oxidation, although HIU at low level exhibited lowest color change (ΔE = 9,65). Therefore, use of HIU is a promise technology to promote the increase of beef color stability.

INTRODUCTION

Brazil is on the top position of beef production and exportation, with 80% of production is consumed internally in the country (1). The Brazilian beef consumption profile is associated with the concern with quality parameters, such as color and texture (2).

The color of fresh meat is the main attribute influencing purchase decisions. The color desired by the consumer market is bright cherry-red (determined by oxymyoglobin), and any deviation to brown (caused by metmyoglobin) leads to product rejection and significant economic losses (3,4).

The color of fresh meat is influenced by endogenous and exogenous factors, such as species (*Bos indicus* and *Bos taurus*) and feeding system, respectively (5). In Brazil, mostly beef herd is the Nellore cattle (*Bos indicus*) raised in different production systems. Diet plays a key role in the susceptibility of meat to oxidative deterioration. In this sense, Salim et al. (6) evaluated the effect of different feeding systems on color of *longissimus muscle* from *Bos* cattle and documented that the beef from grain-fed cattle exhibited lower redness than their pasture-fed counterparts.

In this regard, although the use of high-intensity ultrasound (HIU) is a promising way to increase meat tenderness, it may lead to adverse physicochemical changes (e.g., discoloration, oxidation) according to frequency, power, or exposure time (7).

Therefore, the aim of this study was to evaluate the influence of different HIU intensities on instrumental color and color stability of *Longissimus lumborum* steaks from *Bos indicus* (Nellore) cattle stored under refrigeration for 7 days.

OBJECTIVE

The aim of this study was to evaluate the influence of different high-intensity ultrasound (HIU) levels: no intensity level (control), low level (276.36 W/cm^2), moderate level (422.67 W/cm^2), and high level (747.79 W/cm^2) on instrumental color (CIE $L^*a^*b^*$ and ΔE) and color stability (metmyoglobin reducing activity - MRA) of *longissimus lumborum* steaks stored at 4 ± 1°C for 7 days.

RESULTS AND DISCUSSION

All treatments (Table 1) exhibited similar ($P > 0.05$) L^* values on day 0 and day 7. The observed similarity in lightness could be attributed to the natural protein denaturation during refrigerated storage, favoring the release of bound water (8) and, thus, the superficial light reflectance (9).

In agreement with our results, Carrillo-Lopez et al. (10) evaluated the effect of HIU (14 W/cm^2; 37 kHz) and storage (days 0 and 7) on the color of *Longissimus dorsi* beef from Hereford (*Bos taurus*) animals and reported similar lightness values in both treated and control samples.

Control and HIU levels exhibited a decrease ($P < 0.05$; Table 1) in a^* and b^* values during storage. Meanwhile, these parameters were not influenced ($P > 0.05$) by any HIU level on days 0 and 7. The decrease in redness and yellowness over refrigerated storage reveals beef discoloration and may be attributed to the simultaneous increase in lipid and protein oxidation. The secondary products of lipid oxidation (e.g., malonaldehyde; MDA) can bind to myoglobin, exposing it to a prone oxidizing environment (11).

The myoglobin autooxidation is the conversion of ferrous iron (Fe^{2+}) in the oxymyoglobin (OxyMb), in ferric iron (Fe^{3+}), resulting in metmyoglobin (MetMb) accumulation decreasing a^* and b^* values (4, 12). Furthermore, the release of iron during protein oxidation contributes to increased oxidative reactions (13, 12). The HIU levels used in this study, associated with muscle type and animal factors, including breed, could act into NADH, reducing MetMb into OxyMb through non-enzymatic MRA (14), contributing to the maintenance of redness.

Supporting our results, Carrillo-Lopez et al. (15) reported similar a^* values applying HIU (37 kHz, 90 W/cm^2) on bovine *Longissimus lumborum* muscle from a crossbred *Bos taurus* x *Bos indicus* cattle after 7 days of storage (4°C).

From the literature, while some HIU intensities (16, 28, and 90 W/cm^2; 37 kHz) are reported in the literature as not affecting b^* values of *Longissimus dorsi* beef (16), other ones (14 W/cm^2; 37 kHz) are reported increasing b^* values of Hereford (*Bos taurus*) *Longissimus dorsi* during 7 days of refrigerated storage (10), emphasizing that meat changes depend on HIU conditions (frequency, power, exposure time).

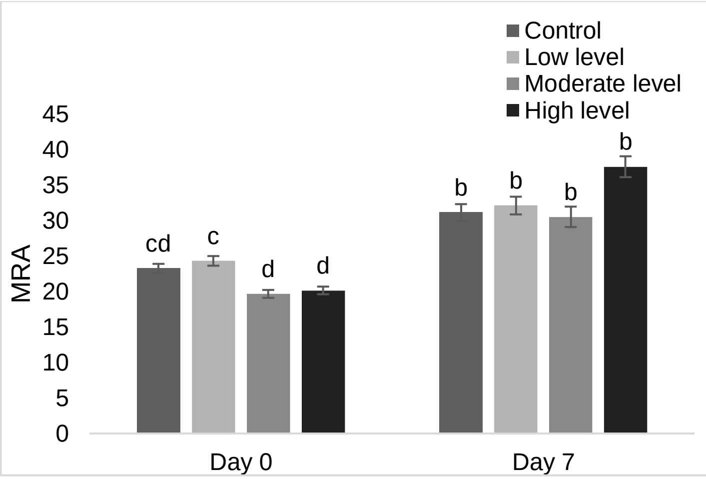

Figure 1. Metmyoglobin Reducing Activity (MRA) of *Longissimus lumborum* from Nellore cattle treated with different high-intensity ultrasound (HIU) levels and at 4ºC for 7 days. Standard error bars are indicated.
[a–d] Means without common superscripts indicate significant differences ($P < 0.05$) among treatments or days of storage.
Control: no HIU level; HIU at low level (276.36 W/cm^2); HIU at moderate level (422.67 W/cm^2); HIU at high level (747.79 W/cm^2).

MRA is the ability to reduce metmyoglobin by adding an electron to oxidized ferric myoglobin, increasing muscle color stability (17, 18). MRA increased over the storage in all treatments ($P < 0.05$; Figure 1), which could be explained by reactions that naturally occur over storage, releasing electrons and hydrogen ions, which are responsible for activating the MRA via non-enzymatic (14). On day 0, HIU treatments exhibited similar ($P > 0.05$) MRA to control, whereas, on day 7, HIU at high level exhibited greater ($P < 0.05$) MRA than control, low level, and moderate level.

Due to the ability to improve the mass transfer, through cavitation, HIU could translocate NADH from the inner (higher concentration) to the outer (lower concentration) meat portion, increasing the electron donation into the NADH-cytochrome b_5 reductase system and, consequently, reducing MetMb into myoglobin (19). It is worth highlighting that no study has investigated the effect of HIU on MRA in any meat matrix.

Delta E (ΔE) expresses the total color change over a period and was calculated from day 0 to day 7 of storage. Greater Delta E values reflect greater changes in overall color. Steaks treated with HIU at low level exhibited lowest (ΔE = 9.65) Delta E than control (ΔE = 11.73) and their moderate and high HIU levels counterparts (ΔE = 11.42 and 12.40, respectively). This result may can be attributed to the improved color stability even with natural increasing discoloration during refrigerated storage (19, 11).

Table 1. Lightness (*L** value), redness (*a** value) and yellowness (*b** value) of *Longissimus lumborum* from Nellore cattle treated with different high-intensity ultrasound levels and stored at 4 ± 1°C for 7 days.

Parameters	High-intensity ultrasound levels[¥]	Days of storage	
		0	7
Lightness (*L** value)[Ω]	Control	40.54 ± 0.78^{ax}	38.66 ± 0.76^{ax}
	Low	39.32 ± 0.54^{ax}	39.24 ± 0.53^{ax}
	Moderate	39.91 ± 0.69^{ax}	39.01 ± 0.56^{ax}
	High	38.65 ± 0.70^{ax}	39.31 ± 0.55^{ax}

Redness (a^* value)$^{\Delta}$	Control	24.01 ± 0.42^{a}	13.13 ± 0.53^{b}
	Low	23.49 ± 0.21^{a}	14.33 ± 0.77^{b}
	Moderate	24.14 ± 0.39^{a}	13.25 ± 0.24^{b}
	High	24.67 ± 0.34^{a}	12.77 ± 0.46^{b}
Yellowness (b^* value)$^{\Omega}$	Control	16.52 ± 0.40^{ax}	12.57 ± 0.42^{by}
	Low	16.17 ± 0.36^{ax}	13.14 ± 0.35^{by}
	Moderate	16.48 ± 0.40^{ax}	13.18 ± 0.41^{by}
	High	16.78 ± 0.41^{ax}	13.39 ± 0.42^{by}

Results are expressed as average ± standard error (n = 6).
$^{¥}$Control: no intensity level; low level (276.36 W/cm^2); moderate level (422.67 W/cm^2); high level (747.79 W/cm^2).
$^{\Delta}$Parameters with storage x treatment interaction. $^{a–b}$ Means without common superscripts indicate significant differences ($P < 0.05$) among treatments or days of storage.
$^{\Omega}$Parameters without storage x treatment interaction. $^{a–b}$ Means without common superscripts in a column indicate significant differences ($P < 0.05$) among treatments;
$^{x–y}$ Means without common superscripts in a row indicate significant differences ($P < 0.05$) among days of storage.

CONCLUSION

Our findings indicated that high-intensity ultrasound levels did not influence color, whereas HIU, at high level, improved the metmyoglobin reducing activity (MRA) contributing to beef color stability. Additionally, there was an influence of storage on redness, yellowness and MRA. Therefore, HIU application is a promising alternative to improve the color stability of *Longissimus lumborum* beef from Nellore (*Bos indicus*) cattle.

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