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SHORT COMMUNICATION

Nix Pro Color Sensor provides comparable color measurements to HunterLab colorimeter for fresh beef

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Abstract The HunterLab MiniScan (HunterLab) colorimeter is used in meat quality research worldwide for measuring meat color; however, the Nix Pro Color Sensor (Nix) could be a less expensive alternative that is easier to operate. Therefore, the objective of this study was to compare the two colorimeters to objectively evaluate fresh beef color. *Longissimus thoracis* muscle from one side of A maturity beef carcasses (n = 200) was evaluated using both the HunterLab (3 technical replicate scans) and Nix (3, 5, 7, and 9 technical replicate scans) colorimeters. The correlation between the HunterLab and Nix for L^* (lightness), a^* (redness), and b^* (yellowness) values ranged between r = 0.80 to 0.85 and the Bland Altman Limits of Agreement analysis indicated good agreement between the Nix and HunterLab colorimeters for all the color parameters. These results indicated that the Nix colorimeter could be a viable alternative for HunterLab colorimeters.

Keywords Beef color · HunterLab MiniScan colorimeter · Nix Pro Color Sensor

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Introduction

Meat color is the most important quality attribute that influences consumer purchasing decisions (Mancini and Hunt 2005). Monitoring color is routinely used in meat science research to evaluate shelf life and consumer acceptability. The HunterLab MiniScan (Hunter Associates Laboratory Inc., Reston, Virginia) colorimeter is used as a standard for objectively measuring meat color for both meat science research and industry. This device can collect tristimulus values (the measure of light intensity based on three primary color values) of CIE L^* (lightness), a^* (redness), and b^* (yellowness) for color measurements based on the light reflectance from the meat surface. The HunterLab provides accurate color values similar to the human perception of color. In order to maintain accuracy, at a minimum, three color readings (technical replications) per sample are recommended while using the HunterLab, which are then averaged to obtain the L^*, a^*, and b^* values (AMSA 2012).

While the HunterLab colorimeter serves as an accurate measure of meat color, there are greater upfront and maintenance costs associated with the equipment. Additionally, the larger size of the Hunterlab (compared to Nix) could make it more difficult to maneuver in a meat processing plant setting. In comparison, the Nix Pro Color Sensor (Nix Sensor Ltd., Ontario, Canada; Nix) colorimeter has lower initial cost and is a smaller handheld device that can capture the CIE L^*, a^*, b^* values which can be downloaded to a smartphone app (Nix Sensor Ltd, Nix Pro: https://www.nixsensor.com/nix-pro/). The differences between the HunterLab and Nix includes price (HunterLab: 9,000–12,000 USD; Nix: 99–349 USD), dimensions (HunterLab: 13.9 × 10.9 × 26.7 cm; Nix: 6.0 × 4.2 cm), weight (HunterLab: 1 kg; Nix: 43 g), and aperture size

(HunterLab: 6 mm; Nix: 14 mm; HunterLab, 2020; Nix Sensor Ltd., 2019). Furthermore, the HunterLab can be standardized before use, whereas the Nix Pro cannot be standardized (Nix QC can be calibrated).

Limited research has explored using the Nix Color Sensor for the color measurement of fresh meat. Corlett et al. (2017) compared the Nix a^* values with consumer meat color scores, whereas Holman et al. (2018) assessed the accuracy of the Nix Color Sensor for the measuring fresh meat color. Further studies by Holman and Hopkins (2019) compared Nix to HunterLab and concluded the two instruments were not exactly comparable, as the Nix was not able to determine beef color variations with the same precision. Therefore, the objective of this study was to investigate the potential of the Nix colorimeter as an alternative tool for objectively measuring fresh beef color for both research and industrial purposes, as well as, the effect of technical replicate scans on the accuracy of Nix color readings.

Materials and methods

Experimental design

The *Longissimus thoracis* muscle from one side of A maturity (less than 30 months of age) beef carcasses ($n = 200$) was evaluated for instrumental color measurements using the HunterLab MiniScan EZ Model 4500L, aperture size 6 mm; Hunter Associates Laboratory Inc., Reston, Virginia) and Nix (Nix Pro Color Sensor, aperture size 14 mm; Nix Sensor Ltd., Ontario, Canada) colorimeters. Color measurements were obtained at a large-scale commercial beef harvest facility in Colorado over a 3-day period. About 24–36 h *post-mortem*, carcasses were separated between the 12th and 13th rib. They were allowed approximately one hour to bloom prior to color measurements. The 1 h bloom time enabled oxygenation of the muscle myoglobin, replicating the myoglobin state observed in retail meat. Three (technical replicate) scans as recommended by the American Meat Science Association meat color guidelines (AMSA 2012) were obtained using the HunterLab colorimeter (illuminant A and 10° standard observer), and the mean readings were recorded. A series of independent technical replicate (3, 5, 7, and 9) scans were obtained using the Nix colorimeter with illuminant A and 10° standard observer as well. The means from each of the technical replicate scans were recorded and used for statistical analysis.

Statistical analysis

The PROC CORR procedure of SAS (version 9.4; SAS Institute Inc., Cary NC) with α set at 0.05 was utilized to compare the two instruments. While correlation is an effective way to determine the association relationship between the two colorimeters, it does not assess the agreement differences. Therefore, the Bland Altman Limits of Agreement (Bland and Altman 1986; Giavarina, 2015) analysis in SAS was utilized to compare the instruments. This analysis is used to compare two methods/equipment and to determine if the new methods/equipment can sufficiently replace old one by evaluating the mean differences and estimating where 95% of the differences between methods fall. Thus, if there is "good agreement" according to the Bland Altman Limits of Agreement, the methods could be used interchangeably.

Results and discussion

Beef muscle color contributes to beef quality grade determination as well as consumer purchasing decisions. Therefore, instrumental color measurements are important for the meat industry as well as meat science research (Mancini and Hunt 2005). Instrumental color is typically measured using CIE Lab values (L^*, a^*, b^*). The L^* value represents the lightness, the a^* value represents the amount of redness, and the b^* value represents yellowness. Together, L^*, a^*, and b^* values can provide an objective measurement of meat color. As there are different instruments available to measure color, careful consideration should be given when choosing an instrument to conduct research (Brewer et al. 2001). The most commonly used instruments to measure fresh meat color are Minolta and HunterLab colorimeters (Tapp et al. 2011), both of which are relatively expensive and less compact, whereas Nix could be a less costly alternative.

In the current study, Pearson's correlation (Table 1) between the HunterLab and Nix was highest for a^* value with 3 scans ($r = 0.85$; $P < 0.01$), followed by 7, 5, and 9 scans ($r = 0.84$, 0.82, 0.82 respectively; $P < 0.01$). Additionally, L^* values were highly correlated for all the scanning series ($r = 0.79$–0.81; $P < 0.01$). Similar to a^* values, 3 scans with the Nix for b^* values demonstrated the best correlation with the HunterLab ($r = 0.83$; $P < 0.01$), while the 5, 7, and 9 scans were still highly correlated ($r = 0.79$–0.82; $P < 0.01$). In contrast, previous research by Holman et al. (2018) using Nix to measure the color of beef *longissimus thoracis* muscle during display (0, 1, 2, and 3 days) after aging (6, 8, 10, or 12 days) at three holding temperatures indicated that a greater number of

Table 1 Pearson's correlation coefficient between CIE *L** (lightness), *a** (redness), and *b** (yellowness) values obtained from beef *longissimus thoracis* muscle (n = 200) using the HunterLab Miniscan (HunterLab; three scans) and Nix Color Sensor (Nix) colorimeters scanning series (3, 5, 7, or 9 technical replicates)

	HunterLab (3 scans)					
	*L**[a]	*P*-value	*a**[b]	*P*-value	*b**[c]	*P*-value
Nix 3	0.80	< 0.0001	0.85	< 0.0001	0.83	< 0.0001
Nix 5	0.81	< 0.0001	0.82	< 0.0001	0.79	< 0.0001
Nix 7	0.79	< 0.0001	0.84	< 0.0001	0.82	< 0.0001
Nix 9	0.79	< 0.0001	0.82	< 0.0001	0.80	< 0.0001

[a]*L** (lightness; 0 = black and 100 = white)

[b]*a** (redness; – 60 = green and 60 = red)

[c]*b** (yellowness; – 60 blue and 60 = yellow)

technical replicates (7 or more) would be necessary to adequately measure color using Nix.

The results of the Bland Altman Limits of Agreement analysis (Table 2) demonstrated the mean difference between HunterLab and Nix for each of the color parameter (*L**, *a**, *b**) measured and it's variation with increasing the number of Nix technical replicates (Nix 3, 5, 7, or 9). In addition, the standard deviation (SD) and ± 95% SD results are also presented in Table 2 to provide clear indication of the variation between the treatments. The results indicated that the mean difference in *a** values using 3 scans of both colorimeters was -1.68, whereas it was -0.91 for *L** values and 0.25 for *b** values (Fig. 1). Additional scans (5, 7, or 9) for all the parameters (*L**, *a**, or *b**) also had similar mean differences as the 3 scans, indicating that increasing the number of scans does not necessarily result in a better agreement in readings from the two instruments. The 95% limits of agreement provided in Table 2 indicates the range within which 95% of the measurements fall. For example, the *a** values (redness) of the three scan series from Nix (Nix 3) fell within + 0.39 or -3.75 with the HunterLab readings 95% of the time (Fig. 1). Overall, the analysis indicated good agreement between the Nix and Hunterlab colorimeters for all the color parameters. These results are in contrast to studies by Holman and Hopkins (2019) in which Nix and Hunterlab colorimeters were compared using beef *longissimus thoracis* samples aged (0, 3, and 5 weeks) and then displayed (0, 1, 2, and 3 d). Holman and Hopkins (2019) reported that these colorimeters are not comparable for measuring beef color variation. However, the difference between the results could be due to the vastly different sample sizes employed in the studies as the current study evaluated 200 experimental units, whereas Holman and Hopkins (2019) utilized 8 beef *longissimus lumborum* samples. Recently, Tomasevic et al. (2019) compared a Minolta colorimeter vs. a computer vision system (CVS) for measuring color of meat products with various physical properties. These researchers indicated that there were significant differences between *L**, *a**, *b** color values of the meat products measured with CVS and traditional colorimeter, but suggested that CVS system could be considered a desirable alternative to the traditional methods for measuring meat color.

Table 2 Bland Altman Limits of Agreement analysis of CIE *L** (lightness), *a** (redness), and *b** (yellowness)* values obtained from beef *longissimus thoracis* muscle (n = 200) using the HunterLab Miniscan (3 scans) and Nix Color Sensor (Nix) colorimeters scanning series (3, 5, 7, or 9 technical replicates)

		Mean Diff[a]	Diff SD[b]	95% (+ SD)[c]	95% (−SD)[c]
*L**	Nix 3	−0.91	2.06	3.14	−4.95
	Nix 5	−0.96	1.97	2.90	−4.82
	Nix 7	−0.92	1.97	2.95	−4.78
	Nix 9	−0.92	1.91	2.83	−4.67
*a**	Nix 3	−1.68	1.06	0.39	−3.75
	Nix 5	−1.72	1.17	0.57	−4.01
	Nix 7	−1.75	1.10	0.40	−3.89
	Nix 9	−1.77	1.15	0.49	−4.03
*b**	Nix 3	0.25	0.91	2.03	−1.53
	Nix 5	0.22	1.02	2.22	−1.77
	Nix 7	0.23	0.93	2.05	−1.59
	Nix 9	0.20	1.00	2.16	−1.75

[a]Mean Difference (HunterLab color value – Nix color value)

[b]Standard Deviation Difference (HunterLab – Nix)

[c]Limit of Agreement ("95% LoA" = Mean Diff ± 1.96*Diff SD)

Previous research by Brewer et al. (2006) evaluated pork chops before and after blooming with both HunterLab and Minolta colorimeters and reported that the Minolta *a** values did not increase with blooming unlike the HunterLab *a** values. Therefore, they concluded that the HunterLab *a** value agreed more with the perception of bloom in a visual sense when compared to the Minolta. In another study, Khliji et al. (2010) assessed the relationship between consumer ranking of lamb color and the instrumental color measurements, and determined that *a** values explained the most variation in the consumer scores. Both of these studies indicated that *a** is a good representative of human perception of meat color. The high correlation and good agreement of Nix *a** values with HunterLab measurements could indicate that the Nix is also agreeable with human perception of color.

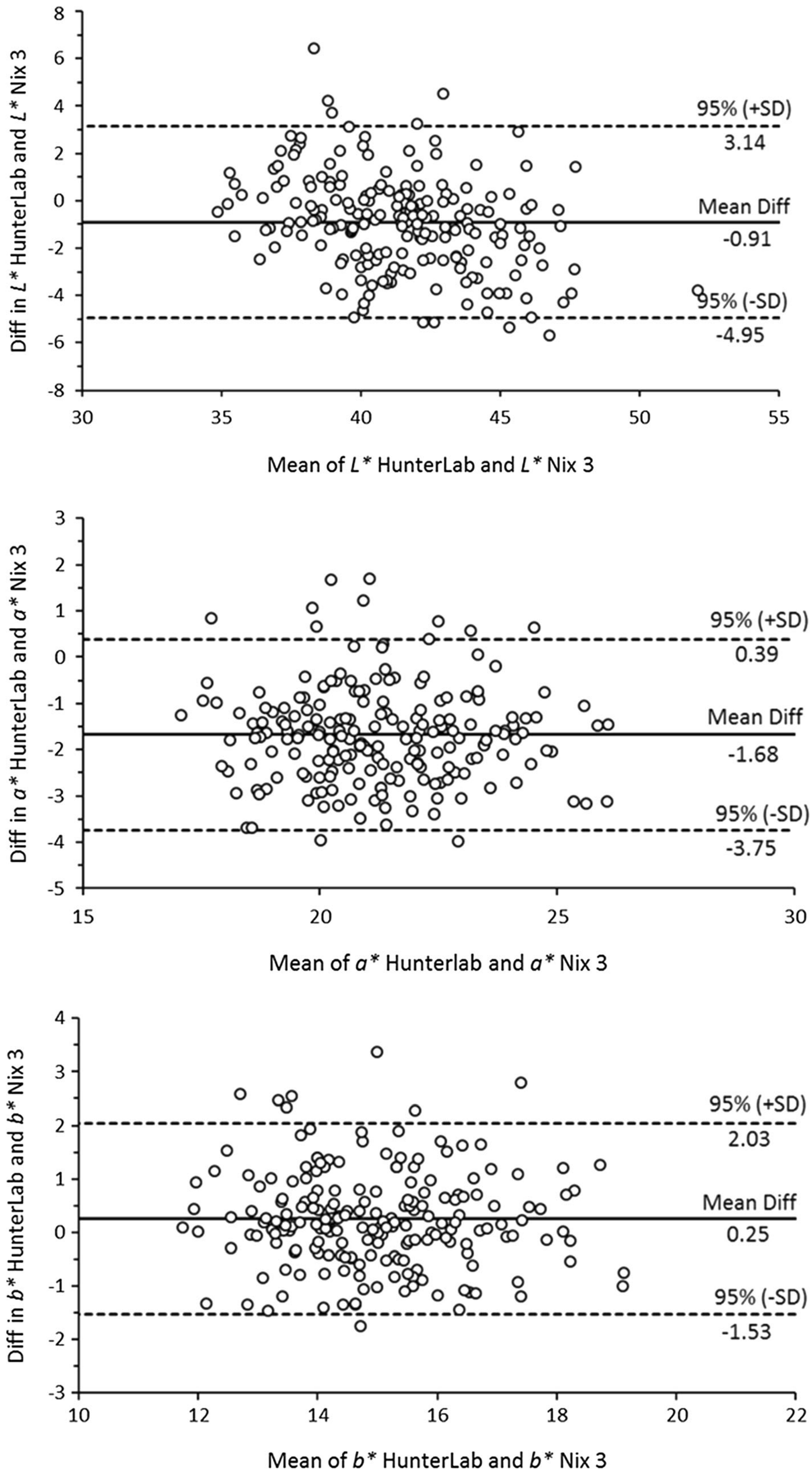

Fig. 1 Bland–Altman Plots indicating the mean difference between HunterLab and three replicate scans using Nix (Nix 3) for *L** (lightness), *a** (redness) and *b** (yellowness) from beef l*ongissimus thoracis* muscle (n = 200)

Conclusion

Three replicate scans using the Nix for CIE L^*, a^*, and b^* values were highly correlated with the values obtained with the HunterLab MiniScan. Moreover, the limits of agreement analysis indicated that the measurements using the two instruments fell within an acceptable range. Although these two equipment are not equivalent, these results indicated that three replicate scans using Nix can serve as an acceptable additional resource for objectively measuring fresh beef color and is comparable to the HunterLab. Thus, Nix provides an opportunity for a less expensive, more mobile, and multipurpose device for measuring beef color.

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Declaration

Conflict of interest Authors declare that there is no conflict of interest.

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