Differences in Minolta Color Score and Beef Tenderness Associated with Feedlot Stress and Slaughter Method

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Abstract— **The objective was to investigate the effect of beef cattle temperament and slaughter method on Minolta color scores and tenderness. Measurements of temperament including exit velocity (EV), chute score (CS), and capture score (CAPS) were obtained prior to slaughter on Angus x Peidmontese crossbred heifers (n = 126). Heifers were slaughtered on two consecutive Mondays (64 and 62 head, respectively) using either Kosher or captive bolt slaughter methods. Climatic conditions and transportation method and duration were similar between slaughter dates. At approximately 24 h post-mortem, carcass measurements and marbling scores were obtained. *Longissimus thoracis* (LT) samples were collected and aged 14 d prior to Minolta color score and Warner-Bratzler shear force (WBSF) measurements. CS, CAPS, and vocalization scores (VOCAL) significantly correlated ($P < 0.03$) with blood lactate (LAC). The LT from kosher slaughtered heifers had significantly higher ($P < 0.01$) L*, a*, b* and WBSF values than that of captive bolt stunned heifers. LT from captive bolt stunned heifers had significantly higher ($P = 0.04$) marbling, and a tendency (P = 0.08) for increased cook loss compared with that from Kosher slaughtered heifers. These data indicate that chute behavior is significantly correlated to measurements of LAC and suggests that the Kosher slaughter method may affect Minolta color score values, as well as decrease tenderness, marbling score, and cook loss in LT when compared with the captive bolt stunning method, and warrants further research.**

Keywords— **Beef, Tenderness, Kosher**

I. INTRODUCTION

Beef tenderness is the most studied and most variable palatability attribute of cooked beef [1, 2]. The continued research focus on this topic is due to the vast number of factors influencing tenderness and the consumer's demand for a tender product. Research has shown that increased stress in the feedlot, during transportation and at the slaughterhouse can lead to increased bruising, decreased tenderness, and increased risk of dark cutters [3]. These negative quality traits can influence the producer's bottom line and the consumer's willingness to purchase beef. This study was conducted to evaluate the influence of feedlot and preslaughter temperament, as well as slaughter method, on meat color and tenderness.

II. EXPERIMENTAL PROCEDURES

All methods and procedures were reviewed and approved by the North Dakota State University Animal Care and Use Committee.

A. Feedlot Data Collection

Feedlot temperament data was collected on September 9, 2010 on 126 Angus x Peidmontese heifers located at the Carrington Research Extension Center (CREC). Exit velocity (EV) was measured by infrared motion sensors (FarmTek, Inc., Wylie, TX). The "start" sensor was placed approximately one half meters from the end of the working chute (head gate) and the "finish" sensor was placed 1.82 meters away. Exit velocity was recorded as the time it took each heifer to run 1.82 meters from the exit of the working chute, after being restrained in the head gate. Faster times are thought to be indicative of more excitable cattle. Chute score was visually observed and scored while animals were on the weigh scale (SenseTek, Saskatoon, SK, Canada) with both entry and exit gates closed. The same technician evaluated the behavior throughout the study. The temperament scoring system was 1 = calm, no movement; 2 = slightly restless; 3 = squirming, occasionally shaking the

chute; 4 = continuous, very vigorous movement and shaking of the chute; 5 = rearing, twisting of the body and struggling violently [4]. Animals on the weigh scale were not under restraint at any time. Capture score was recorded utilizing the same numeric score (1 to 5) as chute score; however, this evaluation was recorded based on activity while the heifer was captured in the head gate.

B. Carcass Data

At approximately 14 to 16 months of age (580 ± 43 kg of body weight), heifers were transported to the North Dakota Natural Beef facility in New Rockford, ND where they were slaughtered on 2 consecutive Mondays (September 13 and 20; 64 and 62 heifers, respectively) with 53 of the 64 on d 1 harvested kosher, and the remaining 73 stunned using a captive bolt. Climatic conditions, transportation method, and transportation time were similar between harvest dates. Vocalization scores (0 = no vocalization, 1 = little vocalization, 2 = extensive vocalization) and blood lactate measurements were also obtained at time of harvest.

Carcass measurements were obtained approximately 24 h postmortem at the North Dakota Natural Beef facility in Fargo, ND, and included carcass weight, 12^{th} rib fat depth, ribeye area, kidney, pelvic, and heart fat percentage, marbling, and yield grade. Also at 24 h postmortem, a 1 inch-thick strip steak was obtained at the 13^{th} rib, placed in a labeled Ziploc bag, packed in a cooler, and transported to the NDSU meats laboratory.

Color was measured using a Minolta Chroma-meter (Konica Minolta, Grand Rapids, MI, USA) to record L* (white to black), a* (red to green), and b* (yellow to blue) from each strip steak after approximately 15 min. After aging 14 days, each steak was then measured for tenderness by WBSF [5].

III. STATISTICAL ANALYSIS

Data was analyzed using Proc CORR and Proc GLM procedures of SAS (SAS Institute Inc., Cary, NC) with slaughter method x slaughter date and pen within slaughter date in the model. These procedures accounted for variation as a result of 2 different slaughter days, 2 slaughter methods, and the cattle being group housed in 16 total pens.

IV. RESULTS AND DISCUSSION

The relationship between feedlot temperament and preslaughter measurements are reported in Table 1. Temperament scores including chute score, capture score, and vocalization correlated ($P < 0.03$) with lactate concentration ($r = 0.267$, $r = 0.249$, and $r = 0.369$, respectively). The strongest correlation is between vocalization and lactate concentration. Animals that are more stressed just prior to slaughter, measured by vocalization, probably undergo a faster rate of anaerobic metabolism, where lactate is produced. Exit velocity and capture score were negatively correlated ($P < 0.001$; $r = -0.385$), suggesting that heifers who were more stressed in the working facility, were more anxious to leave, and exited at a faster rate. These data show a relationship between feedlot behavior and stress in the plant prior to slaughter, with measurements of temperament correlating with lactate concentration. Gruber et al. [6] also found that cattle exhibiting restless or agitated behavior at the slaughterhouse following transportation, had higher blood lactate concentrations, and produced less tender meat.

Wulf et al. [7] reported that meat color could serve as an indicator of beef tenderness and reported lighter, redder, and yellower meat color were associated with more tender beef. Our data is contrary to those reports as we found meat toughness to be positively correlated ($P \leq 0.01$) to lighter, redder, and yellower meat color ($r = 0.278$, $r = 0.332$, and $r = 0.359$, respectively). One possible explanation could be the interaction of slaughter method, particularly the kosher method, possibly resulting in changes in state of muscle contraction and pre-rigor metabolism. Cattle slaughtered by the kosher method typically remain conscious for 17 to 85 seconds after a proper throat cut [8], compared to immediate unconsciousness with captive bolt stunning. We hypothesize that the muscles are in tense contraction prior to unconsciousness, shortening the muscle fiber length at rigor, thus resulting in more muscle fiber overlap, leading to a less tender steak [9].

Strip steaks from kosher slaughtered heifers were darker, greener, bluer, and tougher ($P < 0.01$) than that of captive bolt stunned heifers (Table 2). Strip steaks from captive bolt stunned heifers had increased marbling ($P = 0.04$) and a tendency (P = 0.08) for increased cook loss compared with that from kosher slaughtered heifers. Cook loss represents the percentage of weight lost as a result of the cooking or heating process.

Table 1. Partial correlation coefficients (*P*-value*)* for Warner-Bratzler shear force (WBSF), chute score (CS), capture score (CAPS), exit velocity (EV), vocalization prior to slaughter, blood lactate concentration (mmol/L) at time of slaughter, and L*, a*, and b* Minolta color scores.

Item[a]	Chute Score	Capture Score	Exit Velocity	Vocalization	L*[b]	a*	b*
WBSF	0.211	-0.010	0.073	0.006	0.278	0.332	0.359
	(0.06)	(0.40)	(0.52)	(0.96)	(0.01)	(<0.01)	(<0.01)
Lactate	0.267	0.249	-0.209	0.369	0.042	0.165	0.155
	(0.02)	(0.03)	(0.06)	(<0.01)	(0.71)	(0.15)	(0.17)
Chute Score		0.179	-0.183	-0.006	-0.192	-0.048	-0.090
		(0.11)	(0.11)	(0.96)	(0.09)	(0.67)	(0.43)
Capture Score			-0.385	-0.005	0.029	0.079	0.091
			(<0.01)	(0.96)	(0.80)	(0.49)	(0.42)
Exit Velocity				0.136	0.012	-0.036	-0.020
				(0.23)	(0.91)	(0.75)	(0.86)

[a]CS, CAPS, EV, vocalization, and lactate (n = 126). WBSF, L*, a*, and b* (n = 107).
[b]L* = electronic color measurement indicating lightness/darkness whereby 100 is pure white and 0 is black, a* = electronic color measurement whereby a positive value is in the red color spectrum and a negative value is in the green color spectrum, and b* = electronic color measurement whereby a positive value is in the yellow color spectrum and a negative value is in the blue spectrum.

Table 2. Means and standard errors (SE) between slaughter method, slaughter day, and pen for L*, a*, b* Minolta color scores, Warner-Bratzler shear force (WBSF), cook loss, and marbling.

	Day 1		Day 2	Method	Pen (Day)	Overall
Item	Kosher	Captive Bolt	Captive Bolt	x Day	*P*-value	*P*-value
n evaluated	40	6	61			
Color[a]						
L*	42.77 (0.54)	39.99 (1.70)	41.23 (0.45)	0.135	0.129	0.001
a*	27.72 (0.44)	26.18 (1.36)	26.25 (0.36)	0.299	0.389	0.001
b*	8.55 (0.34)	7.33 (1.06)	7.29 (0.28)	0.291	0.176	< 0.001
WBSF (kg)	3.64 (0.15)	3.94 (0.48)	3.19 (0.13)	0.566	0.047	< 0.001
Cook loss (%)[b]	23.0 (1.0)	27.0 (3.0)	26.0 (1.0)	0.268	0.376	0.076
Marbling[c]	387.0 (10.0)	418.0 (32.0)	417.0 (8.0)	0.378	0.232	0.040

[a] L* = electronic color measurement indicating lightness/darkness whereby 100 is pure white and 0 is black, a* = electronic color measurement whereby a positive value is in the red color spectrum and a negative value is in the green color spectrum, and b* = electronic color measurement whereby a positive value is in the yellow color spectrum and a negative value is in the blue spectrum.
[b] Cook loss is the % change in steak weight as the result of cooking to 71°C (160°F).
[c] Marbling score designation: 100 = traces (standard), 200 = slight (select), 300 = small (low choice), 400 = modest (average choice), and 500 = moderate (high choice).

V. CONCLUSIONS

Our data suggests a positive relationship between feedlot temperament measurements and blood lactate concentration at time of slaughter, suggesting that an animal's stress response in the feedlot is similar to their response at the slaughterhouse. Slaughter method can also have an impact on meat quality, as strip steaks from kosher slaughter heifers had less desirable color, decreased tenderness, reduced marbling, and reduced cook loss. We plan to continue exploring the differences between kosher and captive-bolt slaughter methods, to understand the impacts each of them have on the end product. Lastly, producers should continue to implement strategies to reduce livestock stress in the feedlot phase, as there are not only production benefits, but also consumer benefits that could result in a more enjoyable eating experience.

ACKNOWLEDGMENT

Financial support for this project was provided by the North Dakota Department of Agriculture Specialty Crop Block Grant 12-25-B-0942.

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