Vitamin D_3 Supplementation to Goats Does Not Improve Loin Chop Tenderness and Color Stability

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ABSTRACT

This study evaluated the effect of vitamin D_3 (VITD) supplementation on the tenderness and retail color stability of loin chops from older goats. Twenty purebred Boer goats, approximately 90 days of age, were fed a 10% crude protein concentrate and hay ad libitum for 365 days. During the final 7 days of feeding, goats were supplemented with two levels of VITD (0 and 750,000 IU/hd/d vitamin D_3). Following harvesting and a 10 day aging period, loin chops were evaluated for tenderness by Warner-Bratzler shear force (WBS) and sensory panel. Loin chops were also evaluated for retail color stability for 5 days by a Minolta CR-410 colorimeter and a visual sensory panel. Loin chops from VITD supplemented goats yielded higher ($P < 0.05$) WBS values compared to loin chops from controls. Sensory panel tenderness scores for VITD chops were lower ($P < 0.05$) than for the control chops, indicating decreased tenderness due to supplementation. Treatment did not affect ($P > 0.05$) Minolta CR-410 a* values. Minolta CR-410 b* values and L* values were higher ($P < 0.05$) for VITD chops throughout the 5-day retail display period. Visual panel scores for surface discoloration and overall appearance indicated VITD chops showed more ($P < 0.05$) surface discoloration and were less ($P < 0.05$) preferred by day 2 of display. Supplementing VITD to goats before harvesting negatively affected both tenderness and shelf-life.

KEY WORDS: goat, vitamin d_3, tenderness, shelf-life

INTRODUCTION

Consumption of goat meat, one of the most consumed meats in the world, continues to increase in the United States (Chenault, 1996). In 1977, the USDA began maintaining statistics on number of goats slaughtered annually, finding 35,000 goats harvested that year. By 1994, the industry harvested 350,000 goats (Gipson, 2004). In 2006, the USDA reported that slaughter plants harvested approximately 572,000 goats, and the numbers continue to increase. Sherman (2007) reported that goat meat production increased dramatically from 1.29 million metric tons in 1970 to 3.76 million metric tons in 2001. The growing population of immigrants and ethnic groups entering and living in the United States, whose dietary preferences favor the consumption of goat

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meat, contributes to the increase in demand (Gipson, 2004). Goat meat also provides favorable nutritional quality, which also increases demand (Webb et al., 2005).

Compared to lamb/mutton of similar age groups, consumers accept goat meat in a similar fashion. However, goat meat does not acquire high degrees of tenderness postmortem (Schonfeldt et al., 1993). Compared to beef and lamb/mutton, tenderness values are lower (Pike et al., 1973). Several factors contribute to less tenderness associated with goat meat. Lack of fat cover predisposes goat carcasses to cold shortening when chilled too quickly (Webb et al., 2005). Some breeds, such as Boer goats, contain higher collagen content, increased fibrous residues (Schonfeldt et al., 1993), and a coarser texture, which also contribute to decreases in tenderness (Gaili and Aili, 1985).

Several studies with beef cattle reported that supplementing vitamin D_3 (VITD) several days before slaughter increased tenderness (Swanek et al., 1997; Montgomery et al., 2000). According to Karges et al. (1999), VITD improves tenderness in various muscles, especially in breeds of cattle that produce less tender meat. The calcium-activated tenderization process (CAT) by the two calpain proteases, μ-calpain and m-calpain, contribute to increased tenderness (Swanek et al., 1999). The objective of this study was to determine if VITD supplemented prior to harvest improves goat longissimus dorsi chop tenderness without adversely affecting retail shelf-life.

MATERIALS AND METHODS

Animal Management. The Sul Ross State University Institutional Animal Care and Use Committee approved the protocol for this study. Twenty purebred Boer goats (7 wether males and 13 females) were separated into two dietary treatment groups (n = 10/group). Treatments consisted of 0 (CON) and 750,000 IU/hd/d of Vitamin D_3 (VITD) for 7 days prior to harvesting. The level of VITD was chosen based on the results of Wiegand et al. (2001). We chose a level lower than these published results to prevent the possibility of VITD toxicity in the goats. Ten goats were born at the Sul Ross State University Animal Science Complex, and weaned at 3 months of age. The other ten goats were purchased from a purebred Boer goat producer (Woodward Trading Company, Bakersfield, TX) at approximately 3 months of age. Goats from each source were evenly stratified between treatment groups. To prevent mixing of treatment groups, each goat recieved a colored ear tag corresponding to the appropriate treatment group (Allflex USA Inc., Dallas, TX).

Both treatment groups were housed at the Sul Ross State University feed lot in pens containing dirt flooring, a shelter area, and a source of drinking water. During the pre-harvest period, goats in each study pen were fed alfalfa hay twice a day, and a 10% crude protein concentrate (Baeza Feeds, Marfa, TX) fed *ad libitum*. To ensure each group received the proper dosage of VITD, the vitamin was given via two 1 g boluses containing one-half gram of Rovamix D_3 500 (DSM Nutritional Products Inc., Fort Worth, TX) and one- half gram of ground corn.

Harvesting and Sample Collection. After the feeding and supplementation period, the goats were weighed and transported to a commercial slaughter facility, and harvested in accordance with the Humane Methods of Slaughter Act of 1978 (Clark's & Winford's Fine Quality Meat Company, Midland, TX). The age of these animals were approximately 455 days of age. Following an initial chill period at 35°F for 24 hours,

carcasses were fabricated Hotel Style, based on Institutional Meat Purchase Specifications for fresh goat. The right loin was removed from each carcass, vacuum packaged, aged for 10 days, and frozen for use in the Warner-Bratzler shear force (WBS) evaluation and the trained sensory panel analysis. The left loin from each carcass also was vacuum packaged, aged and frozen for use in the instrumental color and visual panel analysis.

Shear Force Evaluation. Loins were thawed at 39°F for 24 hours. The longissimus dorsi from each loin was removed and cut into 1 inch chops. Chops were weighed to obtain a pre-cooked weight. A meat thermometer (Koch, Kansas City, MO) was placed in the geometric center of each chop to record internal temperatures during cooking. Using a Blodgett convection oven (The G. S. Blodgett Co., Burlington, VT) set at 325°F, chops were cooked to an internal temperature of 160°F, then allowed to cool to room temperature (AMSA, 1995). Post-cooked weight was recorded for each chop. Three half-inch cores from each chop were removed parallel to the muscle fiber orientation, and sheared perpendicular to the orientation of the muscle fiber using a Warner-Bratzler shear machine (The G-R Electric Mfg. Co., Manhattan, KS). The three shear force values for each chop were averaged to obtain a mean chop value for statistical analysis.

Sensory Panel. Chops used for the sensory panel evaluation were thawed and cooked according to the same procedures as WBS chops. After cooking, the longissimus dorsi of each chop was cut into 1cm x 1cm x 1cm cubes, kept warm in a water bath, and fed to a panel of thirty individuals. Sensory panelists included Sul Ross State University students and staff with little to no experience consuming goat meat. In two independent training sessions panelists were trained to evaluate samples for juiciness, tenderness, connective tissue amount, and goat flavor intensity. Panel members independently evaluated four randomly assigned cubes for juiciness (8 = extremely juicy; 1 = extremely dry), tenderness (8 = extremely tender; 1 = extremely tough), amount of connective tissue (8 = none; 1 = abundant), and goat flavor intensity (8 = extremely intense; 1 = extremely bland). Panelists cleansed their palettes with crackers and water between consuming each cube.

Instrumental Color Analysis. Loins used for instrumental color analysis were thawed for 24 hours and then boned to obtain the longissimus dorsi. Chops measuring 1 inch in thickness from the longissimus dorsi were placed on white Styrofoam trays (Instawares Inc., Kennesaw, GA), and over-wrapped with polyvinyl chloride film (oxygen transmission rate of 6,500 cc/m^2 for 24 hours at 0% relative humidity; Glad Products Company, Oakland, CA). To simulate actual retail conditions, packaged products were displayed in a retail coffin-case at 35ºF (Tyler Refrigeration, Niles, MI) and illuminated by fluorescent lamps emitting 4,100K (General Electric Company, Cleveland, OH). To avoid variability in light exposure, packages were rotated randomly in the display case daily. Using a Minolta CR-410 colorimeter (Minolta USA, Ramsey, NJ), objective color measurements were taken for L* (lightness), b* (yellowness), and a* (redness) once daily (at 4 p.m.) for a five days.

Consumer Visual Panel. During the five-day display period, panelists (n = 30; separate from sensory panelists) visually evaluated each chop for characterization of oxygenated pigment lean color (8 = extremely bright red; 1 = extremely dark red), fat color (5 =

yellow; 1 = white), surface discoloration (7 = total discoloration [100%]; 1 = no discoloration [0%]), and color of the chop (7 = like very much; 1 = dislike very much). No scale exists to evaluate goat lean color, therefore scales for evaluating lamb and beef were used in this process (AMSA, 1991).

Statistical Analysis. This study was designed as a 2 x 2 randomized complete block design, with individual carcasses as the experimental unit. Warner-Bratzler shear force and Minolta colorimeter data were analyzed using the PROC MIXED procedure of SAS (SAS Inst. Inc., Cary, NC, 2002). Fixed factors included sex, treatment, and their interaction. In addition, display day and the appropriate interactions were also fixed factors in analyzing Minolta color data. Random factors included animal within treatment and goat birth place. Pair-wise comparisons between least square means of factor levels were computed using the PDIFF option of the LSMEANS statement. For ordinal scale data from the trained sensory panel and trained visual panel, the Wilcoxon rank-sum test for discrete data was used to detect differences between panel treatment preferences for tenderness and color stability.

RESULTS

Data from antemortem weight and WBS values indicated that treatment produced a significant ($P < 0.05$) effect (Table 1). Sex and the sex/treatment interaction did not ($P > 0.05$) produce a significant effect in antemortem weight and WBS values. Least square mean antemortem weight of VITD treated goats was significantly larger ($P = 0.04$) than the least square mean antemortem weight of CON goats. Data from postmortem weight showed that treatment tended ($P < 0.10$) to yield an effect, while sex and the sex/treatment interaction did not ($P > 0.05$) yield an effect. Goats from the VITD treatment tended ($P = 0.08$) to have heavier average postmortem weights when compared to CON treatment goats. Least square means for the two treatments showed VITD chops as significantly tougher ($P = 0.02$) than CON chops.

Juciness, tenderness, and connective tissue scores were significantly ($P < 0.05$) affected by VITD treatment, whereas sex and the sex/treatment interaction did not ($P > 0.05$) produce a significant effect (Table 1). Neither sex, treatment, nor their interaction affected flavor intensity ($P > 0.05$). Sensory panel scores demonstrated that panelists rated chops from CON goats as significantly ($P < 0.05$) more tender and juicy, and containing less connective tissue, than VITD chops. Panelists detected no difference ($P = 0.36$) in goat flavor intensity between the two treatments.

Minolta CR-410 colorimeter L*, a*, and b* scores were recorded over a 5-day display period (Table 2). Day of display significantly affected ($P < 0.0001$) Minolta a* values, while treatment or the display day/treatment interaction did not significantly affect ($P > 0.05$) a* values. Minolta a* values for both treatments declined ($P < 0.05$) as display day increased, indicating that chops became less red, but these values did not differ from one another on each day of display. Minolta b* values demonstrated a significant ($P = 0.01$) display day/treatment interaction.

Table 1. Mean Warner-Bratzler shear force and sensory panel scores of loin chops from goats fed a control or vitamin D_3 supplemented diet for 7 days prior to harvesting

	Control[a]	Vitamin D_3[b]	SEM	*P* > *F*
Antemortem Weight, lb	107.6	126.7	8.5	0.04
Postmortem Weight, lb	54.9	64.1	4.5	0.08
Cook loss, %	19.7	25.6	1.9	0.11
Warner-Bratzler Shear Force, lb	9.8	11.8	0.6	0.02
Juiciness[c]	5.10	4.43	0.14	0.03
Tenderness[d]	5.70	4.50	0.18	<0.01
Connective Tissue[e]	5.80	5.13	0.20	0.05
Flavor Intensity[f]	4.20	4.33	0.10	0.36

[a] Three females and 7 males fed 10% CP concentrate and hay ad libitum

[b] Four females and 6 males fed 10% CP concentrate and hay ad libitum and supplemented 750,000 IU/d vitamin D_3

[c] 8=Extremely Juicy; 7=Very Juicy; 6=Moderately Juicy; 5=Slightly Juicy; 4=Slightly Dry; 3=Moderately Dry; 2=Very Dry; 1=Extremely Dry

[d] 8=Extremely Tender; 7=Very Tender; 6=Moderately Tender; 5=Slightly Tender; 4=Slightly Tough; 3=Moderately Tough; 2=Very Tough; 1=Extremely Tough

[e] 8=None; 7=Practically None; 6=Traces; 5=Slight; 4=Moderate; 3=Slightly Abundant; 2=Moderately Abundant; 1=Abundant

[f] 8=Extremely Intense; 7=Very Intense; 6=Moderately Intense; 5=Slightly Intense; 4=Slightly Bland; 3=Moderately Bland; 2=Very Bland; 1=Extremely Bland

Throughout the display period, VITD chops recorded greater least square mean b* values than did CON chops. Minolta L* values were significantly affected ($P = 0.01$) by treatment, tended to be affected ($P = 0.06$) by display day, and were not affected ($P > 0.05$) by the display day/treatment interaction. Throughout the display period, VITD chops L* values were greater than for CON chops, indicating VITD chops were lighter. While not significant, the L* values for both CON and VITD chops decreased on day two but increased each day afterward.

A panel visually evaluated lean color, fat color, surface discoloration, and overall color of chops each day during the display period. Lean color visual panel scores (Table 3) for VITD and CON chops declined from slightly bright red scores to moderately dark red scores over the 5-day display period. Mean lean color scores for VITD and CON chops did not differ ($P > 0.05$) on each day of the display period. Least squares means fat color scores (Table 3) for both treatment groups were white on day one, then changed to creamy white by day five. On each day of the display period, fat color scores for VITD and CON chops were similar ($P > 0.05$).

Surface discoloration scores (Table 4) for the two treatment groups did not differ ($P > 0.05$) on day one. Beginning on day two, panelists assigned higher ($P < 0.05$) discoloration scores to VITD chops. On day five, VITD chops received greater discoloration scores, and CON chops received slight discoloration scores. Overall preference scores (Table 4) did not differ ($P > 0.05$) between VITD and CON chops on days one or two, but thereafter consumers scored ($P < 0.05$) CON chops higher than VITD chops.

Table 2. Mean Minolta CR-410 a*, b*, and L* values from goats fed a control[1] or vitamin D_3[2] supplemented diet for 7 days prior to harvesting

Day	1	2	3	4	5
a*[3]					
Control	15.13[a]	14.49[b]	13.98[c]	13.44[d]	13.18[e]
Vitamin D	16.10[a]	15.21[b]	14.74[c]	14.17[d]	13.73[e]
SEM	0.47	0.40	0.41	0.40	0.40
Trt×Day *P* > *F*	0.13	0.29	0.19	0.29	0.19
b*[4]					
Control	5.49[a]	5.46[a]	5.46[a]	5.36[a,b]	5.21[a]
Vitamin D	6.81[a]	6.49[b]	6.42[b]	6.26[b,c]	6.15[c]
SEM	0.25	0.23	0.23	0.24	0.23
Trt×Day *P* > *F*	<0.01	0.01	0.01	0.02	0.01
L*[5]					
Control	42.95[a]	42.73[a]	42.82[a]	42.98[a]	42.92[a]
Vitamin D	45.43[a]	45.41[a]	45.53[a]	45.74[a]	45.92[a]
SEM	0.73	0.77	0.78	0.72	0.78
Trt×Day *P* > *F*	0.03	0.03	0.02	0.01	0.02

[a-e]Means within a row with a different superscript are significantly different (P < 0.05)
[1]Three females and 7 males fed 10% CP concentrate and hay ad libitum
[2] Four females and 6 males fed 10% CP concentrate and hay ad libitum and supplemented 750,000 IU/d vitamin D_3
[3]Redness: 60 = Red; -60 = Green
[4] Blueness: 60 = Yellow; -60 = Blue
[5]Lightness: 100 = White; 0 = Black

Table 3. Consumer panel mean scores of lean and fat color from goats fed a control or vitamin D_3 supplemented diet for 7 days prior to harvesting

	Time	Control[1]	Vitamin D_3[2]	*P* > *F*
Lean Color[3]				
	Day 1	5.34[a]	5.49[a]	0.39
	Day 2	4.97[b]	4.79[b]	0.23
	Day 3	4.44[c]	4.35[c]	0.35
	Day 4	3.81[d]	3.74[d]	0.32
	Day 5	3.77[d]	3.81[d]	0.39
Fat Color[4]				
	Day 1	1.24[a]	1.36[a]	0.40
	Day 2	1.60[b]	1.61[b]	0.22
	Day 3	1.79[c]	1.90[c]	0.15
	Day 4	2.03[d]	2.10[d]	0.21
	Day 5	2.17[e]	2.23[e]	0.38

[a-e] Means within an attribute and treatment with different superscripts significantly different (P < 0.05)
[1]Three females and 7 males fed 10% CP concentrate and hay ad libitum
[2] Four females and 6 males fed 10% CP concentrate and hay ad libitum and supplemented 750,000 IU/d vitamin D_3
[3]8=Extremely Bright Red; 7=Bright Red; 6=Moderately Bright Red; 5=Slightly Bright Red; 4=Slightly Dark Red; 3=Moderately Dark Red; 2=Dark Red; 1=Extremely Dark Red
[4] 5=Yellow; 4=Moderately Yellow; 3=Slightly Yellow; 2=Creamy White; 1=White

Table 4. Consumer panel mean scores of surface discoloration and overall color from goats fed a control or vitamin D_3 supplemented diet for 7 days prior to harvesting

	Time	Control[1]	Vitamin D_3[2]	*P > F*
Surface Discoloration[3]				
	Day 1	1.27[a]	1.28[a]	0.28
	Day 2	1.50[b]	1.68[b]	0.03
	Day 3	1.69[c]	2.07[c]	0.01
	Day 4	1.99[d]	2.66[d]	< 0.01
	Day 5	2.36[e]	3.19[e]	< 0.01
Overall Color[4]				
	Day 1	5.96[a]	5.88[a]	0.36
	Day 2	5.40[b]	5.20[b]	0.15
	Day 3	5.40[b]	4.81[c]	< 0.01
	Day 4	5.00[c]	4.24[d]	< 0.01
	Day 5	4.57[d]	3.69[e]	< 0.01

[a-e] Means within an attribute and treatment with different superscripts significantly different (P < 0.05)
[1] Three females and 7 males fed 10% CP concentrate and hay ad libitum
[2] Four females and 6 males fed 10% CP concentrate and hay ad libitum and supplemented 750,000 IU/d vitamin D_3
[3] 7=Total Discoloration (100%); 6=Extensive Discoloration (80-99%); 5=Moderate Discoloration (60-79%); 4=Modest Discoloration (40-59%); 3=Small Discoloration (20-39%); 2=Slight Discoloration (1-19%); 1=No Discoloration (0%)
[4] 7=Like Very Much; 6=Like Moderately; 5=Like Slightly; 4=Neither Like Nor Dislike; 3=Dislike Slightly; 2=Dislike Moderately; 1=Dislike Very Much

DISCUSSION

While numerous studies documented effects of VITD supplementation on beef, the authors could not find studies in the published literature involving VITD supplementation with goats to improve tenderness. Koohmaraie (1992) proposed three possible calcium-mediated mechanisms by which pre-harvest supplementation of VITD increases postmortem tenderization: non-enzymatic weakening of structural proteins involved in stability of the Z-disk, protein solubilization due to salting-in action by calcium, and activation of calcium activated calpain proteases. Supplementing VITD in the diet prior to harvesting raises the calcium level in the intestine, circulating plasma, and ultimately the muscle. Elevated levels of calcium in the muscle subsequently activate postmortem tenderization by the calpain proteases. Several studies report an increase in plasma calcium concentration by supplementing VITD (Karges et al., 1999; Montgomery et al., 2002), and followed by a subsequent increase in calpain activity (Montgomery et al., 2002).

Swanek et al. (1997) found a 21 percent reduction in occurrence of tough steaks and a reduction in shear force values by 18 percent with VITD supplementation. In a separate study, Swanek et al. (1999) reported that VITD reduced shear values by .58 kg. Montgomery et al. (2000) determined that supplementing 5 x 10^6 IU/d of VITD for 10 days prior to slaughter, followed by 14 days of postmortem aging, effectively reduced WBS values of steaks from the strip loin and top round. Montgomery et al. (2002)

reported similar findings when supplementing 0.5 x 10^6 IU/d for 10 days prior to harvesting.

Data from the present study does not agree with the aforementioned studies. However, conflicting findings from several studies found VITD as being detrimental to tenderness or having no effect on tenderness in beef. Berry et al. (2000) found VITD steaks were less tender than non-supplemented steaks when aged 7 or 21 days. Scanga et al. (2001) reported that feeding VITD 2 to 8 days before harvesting did not improve longissimus steak tenderness. Wiegand et al. (2002) concluded that supplementation of swine with VITD for 3 days prior to harvest did not improve loin chop tenderness. The researchers suggested that tenderization did not improve because the extent of supplementation was insufficient to raise intracellular calcium concentrations to activate postmortem proteolysis. In the present study, VITD levels may have not raised calcium levels in the muscle enough to activate postmortem calpain proteolysis in all goats. Therefore, the specific level of VITD supplementation required to activate postmortem proteolysis in goats requires further investigation.

Calpastatin, an inhibitor of the calpain proteolytic system, also could have affected degree of tenderness in the present study. Doumit and Koohmaraie (1999) found a negative correlation between level of calpastatin activity and tenderness. Species differences in rate of postmortem proteolysis result from the level of calpastatin activity (Ouali and Talmant, 1990; Koohmaraie et al., 1991). Pringle et al. (1997) demonstrated that Bos Indicus cattle exhibit a low level of postmortem tenderization because calpastatin activity blocks tenderization. Therefore, as with the Bos Indicus cattle, high calpastatin activity in Boer goats may decrease tenderness by blocking μ-calpain activity.

Increased levels of calcium ions activate the calpain proteolytic system postmortem. Calcium levels, influenced by calcitonin, may affect the system, thereby limiting positive effects of VITD supplementation. Boleman et al. (2004) concluded that VITD supplemented by Rovamix 500 did not improve the tenderness of various lamb muscles. They suggested that hormones such as calcitonin can limit deposition of calcium in muscles, thus limiting the amount of calcium available to activate the calpains. The role of calcitonin in this process requires further examination.

Analysis of sensory panel data in the present study may indicate why VITD chops proved less tender than CON chops. Panelists rated chops from VITD goats as less juicy, which may have affected perceived tenderness. Lower juiciness scores may indicate that VITD chops experienced greater cooking loss. In the present study, VITD goats tended (P = 0.11) to show more cooking loss than CON goats (Table 1). Wheeler et al. (1999) reported that steaks a with higher cook loss percentage produced steaks with higher WBS values. Rhee et al. (2004) reported similar findings from evaluating tenderness differences among muscles. When consumers evaluate meat subjectively, Aberle et al. (2001) identified the components of juiciness contribute to an improvement in ratings of apparent tenderness. Laakkonen et al. (1970); as well as Obuz et al. (2003); all reported that greater cooking losses resulted in a tighter meat structure, which could produce less tender meat.

In addition to assigning low juciness ratings, panelists in the present study indicated VITD chops contained more connective tissue, which contributed to lower tenderness scores. However, Montgomery et al. (2004) found VITD had no effect on perceived amount of connective tissue when evaluated by a sensory panel. Differences in ratings of perceived tenderness can be explained by amount of connective tissue in combination with sarcomere length and postmortem proteolysis (Koohmaraie et al,

2002). Rhee et al. (2004) supported this premise by demonstrating a correlation between lower tenderness ratings by trained panelists and higher WBS values in muscles with more connective tissue. While the treatment most likely did not have an affect of connective tissue deposition or cross-linking, the greater amount of connective tissue detected by the panelists may be the source of lower tenderness scores for the VITD chops. Therefore, lack of moisture and the increased levels of connective tissue detected by panelists for VITD chops, explain the lower tenderness ratings and increased WBS scores.

During the 5-day retail display period in the present study, VITD did not affect Minolta color a* values, indicating a similarity in redness of chops between the two treatments. The b* and L* values of VITD chops were greater than values for the CON chops during the entire retail display period, confirming the VITD chops was lighter and more blue in appearance. The visual panel determined that VITD and CON chops did not differ in lean appearance or fat discoloration. Beginning on day two of the display period, VITD chops showed a higher discoloration score, prompting a panelist preference for CON chops over VITD chops for the remainder of the study.

Only a few studies have observed the effect of VITD on meat color stability. Two swine studies determined that VITD improved loin eye color. The first study reported that VITD supplementation lightened chops based on both subjective and objective measures (Enright et al., 1998). The second study found that VITD supplementation produced chops with lower L* values (darker) and higher a*values (redder) when aged 14 days (Wiegand et al., 2002).

As meat ages, oxymyoglobin becomes oxidized, forming metmyoglobin. Lipid oxidation occurs in the intramuscular fat, membrane phospholipids, and intermuscular fat (Sherbeck et al., 1995). Increased levels of metmyoglobin in meat correlates with the amount of discoloration observed. Depending on the amount of discoloration present, the overall color of a product primarily influences meat purchasing decisions (Faustman and Cassens, 1990). Kannan et al. (2001) reported that various cuts of goat meat remained moderately stable in color until day four, when discoloration accelerated dramatically. On day four of the present study, panelists assigned discoloration and preference scores to CON chops indicating that discoloration began to negatively affect their preferences. However, negative scores were assigned to VITD chops earlier than CON chops. The mechanism leading to acceleration of discoloration and subsequent decline in panelist preference for VITD chops warrant further research.

CONCLUSION

Contrary to results observed from research with beef cattle, providing supplementation of 750,000 IU/hd/d VITD to goats seven days prior to slaughter produced decreased tenderness, as measured by Warner-Bratzler shear force and sensory panel analysis. Sensory panelists reported increased levels of connective tissue and decreased levels of juiciness in VITD chops, which may have contributed to panelists giving lower tenderness scores. During the 5-day retail display period, VITD supplementation did not affect lean color or fat color. Panelists assigned VITD chops higher discoloration scores beginning on day two. By day three, panelists preferred CON steaks over VITD steaks for color. While the results of the present study were contrary to

published beef cattle results, they require further study to corroborate these findings and identify mechanisms that may explain these differences.

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