Effects of Level and Length of Supplementation on Leather Characteristics of Yearling Boer and Spanish Wethers

by

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Abstract

Thirty Boer × Spanish and 29 Spanish wethers were used in a trial to determine the effects of goat breed, supplementation level, and age on the mechanical properties of chrome-tanned and glutaraldehyde-tanned goat skin. Six Boer and five Spanish wethers were harvested at the beginning of the trial with the remaining animals assigned to four groups, having equal breed numbers, receiving either a high or low supplement amount daily. Two groups were harvested after 110 days and the remaining groups after an additional 108 days. Skins were removed by hand, split down the dorsal midline, and salted. The left half of each skin was chrome-tanned and the right half was tanned using a glutaraldehyde based tannage. Tanning goat skins using chromium resulted in stronger leather than that produced using glutaraldehyde. Increasing age led to decreased % elongation and increased leather stiffness. The effects of supplementation level were of lesser importance than tannage or age upon the strength characteristics of leather produced. Boer goat leather was thicker than Spanish goat leather, although tensile strength was unaffected by breed. Goat skins were not shaved to an equal thickness during the tanning process, perhaps leading to some of the breed differences seen, notably in % elongation and fracture energy. Therefore, further research is needed to evaluate characteristics of shaved skins.

Introduction

Boer and Spanish are the predominant meat goat breeds in the U.S. In 2011, over 770,000 goats were slaughtered at U.S. federally inspected plants and other facilities, while goat slaughter numbers for 2010 were slightly higher.[1] Leather is a byproduct of the livestock industry and is a valued commodity around the world. The skins of goats have long been used for making leather and are renowned for use as glove, shoe, and garment leathers. Little is known about the characteristics of leather made from meat goats raised in the U.S. Breed or genotype, nutrition, and age are factors that have been shown to influence leather strength characteristics.[2,3,4]

In the leather industry goat skins, as are most hides and skins around the world, are tanned using chromium. Due to environmental concerns over the use of chromium and the disposal of chrome-tanned leather, there is increasing pressure on the leather industry to use alternative tanning methods (Wolf et al., 2001). One such alternative method is the use of glutaraldehyde in combination with other synthetic tanning chemicals. However, the mechanical properties of chrome-tanned and chrome-free leather may differ.[6,7] Thus, objectives of the experiment were to determine the effects of goat breed, supplementation level, and age on the mechanical properties of chrome-tanned and glutaraldehyde-tanned goat skin.

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MATERIALS AND METHODS

Animals and Treatments

The experimental protocol was approved by the Langston University Animal Care Committee. Thirty 7/8 Boer × 1/8 Spanish (B; 33 – 46 wk of age; 33.9 ± 6.99 kg) and 29 Spanish (S; 28 – 40 wk of age; 26.6 ± 4.43 kg) wethers were used. The trial began in January and had periods of 110 and 108 d (P1 and P2, respectively). At the beginning of the trial, 6 B and 5 S were harvested to provide baseline data on leather characteristics. The remaining animals were randomly assigned to 4 groups, each consisting of 6 B and 6 S, receiving either 0.5% or 1.5% BW (DM basis; L and H, respectively) daily of a pelleted diet (Table I). The supplement was fed at 0800 h and was totally consumed each day. All groups were raised in 1 ha grass/forb pastures consisting predominately of Bermuda grass, (*Cynodon dactylon*), fescue (*Festuca arundinacea*), and ragweed (*Ambrosia spp.*) and with unlimited access to hay, a trace mineralized salt block (Big 6® Mineral Salt, American Stockman, Overland Park, KS, USA; 2400 ppm Mn, 2400 ppm Fe, 260–380 ppm Cu, 320 ppm Zn, 70 ppm I, and 40 ppm Co) and water. Wethers were weighed and adjustments made to amount of supplement offered every 2 weeks. Animals were initially treated for internal parasites (Levasole, Merck Animal Health, Summit, NJ). Thereafter, at each weighing wethers were monitored using the FAMACHA© system and those recording a score of 4 or greater were treated with Levasole, Valbazen (SmithKline Beecham Animal Health, West Chester, PA), or Cydectin (Fort Dodge Animal Health, Fort Dodge, IA).

Samples of hay, pasture forage, and pelleted supplement were taken monthly. Available pasture forage was measured at three random sampling areas per pasture by clipping all herbage in a 0.25 m^2 quadrat to a height of 2.54 cm and placing it in a labeled paper bag. Samples were dried at 60°C in a forced-air oven and ground in a mill (Thomas-Wiley Laboratory Mill, Model 4, Thomas Scientific, Swedesboro, NJ) to pass a 1-mm screen and analyzed for DM, ash, CP[8], and NDF (filter bag technique; ANKOM Technology Corp., Macedon, NY).

Harvest and Tannage Measures

One H and 1 L group were harvested after P1, with the remaining groups harvested after P2. On the morning prior to harvest, wethers were weighed full or unshrunk. Wethers were held without feed for a 24-h period prior to harvest via stunning with a captive bolt pistol and exsanguination. Skins were removed by hand, weighed, split down the dorsal midline, labeled, and salted with fine grain salt for subsequent tanning into leather. The left half of each salted skin was chrome-tanned (CT; Capital Leather, Gloversville, NY). The right half of each skin was tanned at Langston University using a glutaraldehyde based pre-tan and synthetic chemical re-tan protocol (GT; BASF, Florham Park, NJ).

Leather Testing

Goat leather was sent to the USDA-ARS Eastern Regional Research Center, Biobased and Other Animal Coproducts Research Unit (ERRC), Wyndmoor, PA for mechanical testing and other measurements. To prepare leather for testing, dumbbell-shaped samples were cut from each skin in the standard test area as described in American Society for Testing and Materials (ASTM) D2813-91 and stored in a conditioned room at 23°C and 50% relative humidity before testing according to ASTM D1610-96. The moisture content of samples was determined by a JL 2000 Delmhorst leather moisture meter (Delmhorst Instrument Co., Towaco, NJ). Thickness was measured using a Randall and Stickney Dial Indicator (Waltham, MA) according to ASTM D 1813-00.

The mechanical tests conducted at USDA ARS ERRC included tensile strength, elongation, Young's modulus, and fracture energy. Tensile strength is defined as the maximum stress a sample can sustain without fracture, whereas elongation is the strain (%) at fracture (break). Young's modulus is a physical quantity representing the stiffness of a material. It is determined by measuring the slope of a line tangent to the initial stress-strain curve from the origin to 10 percent strain. Fracture energy is determined by measuring the energy to fracture the sample, which is the area under the stress-strain curve. An upgraded Instron (Norwood, MA) mechanical property tester, Model 1122, and Testworks 4 data acquisition software (MTS Systems Corp., Minneapolis, MN) was used throughout the tests. Each test was conducted on five samples to obtain an average value.[9,10,11]

Statistical Analyses

Data were analyzed as 2^4 factorial arrangement of tannage, breed, level of supplementation, and period using the GLM procedure of SAS (SAS Inst. Inc., Cary, NC; SAS version 7). Initial testing of the model included all main effects and interactions. The 4-way interaction among tannage, breed, supplementation level, and period was found to be non-significant for all variables. Thus, in the final analysis, this interaction was included in the error term. Animal was the experimental unit. Means were separated by least significant difference.

RESULTS

Feedstuffs

There was no pasture forage growth for the first two months of the trial and goats had unlimited access to hay along with their daily pellet supplement (Table I). Wheat hay (59.8±9.42% NDF, 1.9±0.82% N) was fed during the first month of the trial. The goal of the trial was not to have the supplemental feed compensate for deficiencies of the basal diet but rather to provide additional nutrients to an adequate basal diet. The level of N in the wheat hay was a concern in this regard and, thus, thereafter alfalfa hay (40.8±6.77% NDF, 3.2±0.27% N) was fed free choice rather than wheat hay. From the third month through the end of the trial, pasture forage availability averaged 3,060±1022 kg/ha (55.8±9.09% NDF, 1.3±0.52% N).

TABLE I
Ingredient and chemical composition of pellets fed at either 0.5% or 1.5% BW to Boer and Spanish wethers.

Item	Concentration	SE
Ingredient, % as-fed basis		
Cotton seed hulls	15.0	
Alfalfa meal	20.0	
Wheat middlings	13.4	
Ground corn	25.0	
Soybean meal	18.85	
Dicalcium phosphate	0.4	
Calcium carbonate	1.1	
White salt	0.5	
Trace mineralized salt[1]	0.25	
Ammonium chloride	0.5	
Pellet binder	5.0	
Chemical Constituent		
Ash, %	7.9	0.96
N, %	3.0	0.18
NDF, %	28.2	3.08

[1] 95–98.5% NaCl and at least 0.24% Mn, 0.24% Fe, 0.05% Mg, 0.032% Cu, 0.011% Co, 0.007% I and 0.005% Zn.

Live and Fresh Skin Weight
Boer goats were heavier than S goats at the start of the trial (33.3 vs 29.7 kg for B and S, respectively; SE = 2.91; P < 0.05) and at harvest following P1 and P2 (P < 0.001; Table II). No differences were seen in fresh skin weight between B and S wethers slaughtered for baseline data (2.48 vs. 2.19 kg for B and S, respectively; SE = 0.188; P = 0.19) but B skins were heavier than S skins during the trial (P < 001; Table II). Wethers supplemented at 1.5% BW weighed more and had heavier fresh skin weights than those supplemented at 0.5% BW (P < 0.05). Skins from P2 were numerically heavier than P1 skins; however, the difference was not significant (P = 0.08).

TABLE II
Effects level of supplementation, goat breed and experimental period upon body and skin weights of Boer and Spanish wethers.

Item	Supplementation[1]		Breed[2]		Period[3]		SE
	H	L	B	S	P1	P2	
Body weight, kg	48.2^{a}	43.1^{b}	53.1^{a}	38.2^{b}	41.8^{b}	49.5^{a}	1.26
Fresh skin weight, kg	3.45^{a}	3.07^{b}	3.86^{a}	2.66^{b}	3.12	3.40	0.112

^{a,b}Means within supplementation, breed, or period grouping without a common superscript letter differ (P < 0.05).

[1]Daily supplementation with either 1.5 (H) or 0.5% BW (L) of a pelleted concentrate.

[2]B = Boer; S = Spanish.

[3]P1 = 108 days; P2 = 110 days.

Leather Thickness
Boer goat leather was thicker than S goat leather at the initial harvest (P < 0.05; Table III) and throughout the experiment (P < 0.001, Table IV). Goats supplemented at the higher level recorded thicker skins than those fed the low level of supplement (P < 0.01). Type of tannage affected thickness of skins harvested during the experimental period, as synthetically tanned skins (GT) were thicker than skins tanned using chromium (P < 0.001).

% Elongation
Boer goat leather had greater % elongation than S leather both initially (P < 0.01; Table III) and throughout the experimental period (P < 0.001; Table IV). Leather from goats harvested in P1 and P2 exhibited a significant tannage by period by supplementation interaction (P < 0.001). Whereas the % elongation was lower in P2 than P1 for both CT and GT leather, the highest value for % elongation was recorded for CT leather from goats fed the low level of supplementation in P1 (58.6%) and the lowest for CT leather from goats fed the low level of supplementation in P2 (40.5%). It is unclear why this dichotomy occurred. Harvested skins were shipped for chrome tannage within 2 wk of harvest; thus, P1 and P2 skins were tanned roughly 4 months apart at the same tannery.

TABLE III
Effects of chrome or glutaraldehyde tannage and goat breed upon leather characteristics from Boer and Spanish goats harvested at the beginning of the trial.

Item	Tannage[1]		Breed[2]		SE
	CT	GT	B	S	
Thickness, mm	1.66	1.71	1.84[a]	1.53[b]	0.084
Elongation, %	60.8[a]	50.8[b]	59.9[a]	51.7[b]	1.76
Fracture, J/cm^3	4.73[a]	3.26[b]	4.21	3.78	0.261
Tensile strength, MPa	25.5[a]	19.0[b]	22.1	22.4	1.13
Young's Modulus, MPa	5.94[b]	8.27[a]	6.29[b]	7.91[a]	0.531

[a,b]Means within supplementation, breed, or period grouping without a common superscript letter differ (P < 0.05).
[1]CT = chrome-tanned; GT = glutaraldehyde-tanned.
[2]B = Boer; S = Spanish.

Differences in the exact chrome tannage formula used or during the tanning procedure, e.g., milling procedure, may have contributed to some of the differences noted in CT skins.

Fracture Energy
Leather made from B and S goats initially slaughtered was unaffected by breed, but CT leather recorded greater fracture energy than GT leather (P < 0.001, Table III). CT leather continued to record greater fracture energy throughout the trial as noted by both tannage by breed (CT B > CT S > GT B = GT S; P < 0.05) and tannage by period interactions (CT P1 > CT P2 > GT P1 = GT P2; P < 0.05). A period by supplementation by breed interaction was also noted (P < 0.05), with the fracture energy value for leather from S goats fed the high level of supplementation in P1 lower than might have been expected.

Tensile Strength
Tensile strength was consistently affected by tannage, with CT leather recording greater tensile strength than GT leather both at the initial harvest (P < 0.001; Table III) and during the experimental periods (P <0.001; Table IV). No effects of breed, period, or supplement treatment were noted.

Young's Modulus
Leather from S goats harvested initially had greater Young's modulus than B goat leather (P < 0.05; Table III); however, no breed difference was seen in leather after P1 or P2 (P = 0.78). Interestingly, GT leather from the initial harvest had greater Young's modulus than CT leather (P < 0.01), whereas the effect was reversed in leather from goats harvested in the experimental period. A tannage by period by supplementation effect was noted, with the highest Young's modulus recorded by CT leather from goats fed the low level of supplementation in P2 while the lowest Young's modulus was for CT leather from goats fed the low level of supplement in P1. This is similar to the effect seen in % elongation, as both measures relate to the stiffness of a material, and a lower % elongation prior to fracture would indicate a stiffer material.

DISCUSSION

Boer goats are a meat type breed originating in South Africa. Boer goats, or their crossbred offspring with local or indigenous breed goats such as S in the current trial, are typically larger and heavier than local breed goats at comparable ages,[12,13] factors that led to heavier skin weights for B goats as compared with local breeds as noted in this trial and those of Ngwa et al.[12] and Mohammed et al.[13]. High and low nutritional planes have corresponding effects on live and skin weights of goats.[12,13,14]

Breed and supplement level differences in leather thickness were noted, with both B and S leather increasing approximately 0.4 mm in average thickness from the initial slaughter to after P1 and P2. Similar effects of nutritional plane on leather thickness were seen by Passman and Sumner[3], where an increase in the forage allotment led to thicker leather in three breeds of sheep; however, no effect of breed was found. Conversely, Mohammed et al.[13] found no differences in leather thickness due to level of nutrition or breed between B x Arsi-Bale and Arsi-Bale goats in Ethiopia. However, only three

TABLE IV
Effects of chrome or glutaraldehyde tannage, level of supplementation, goat breed and experimental period upon leather characteristics from Boer and Spanish wethers.

Item	Interaction	Tannage[1]		Supplementation[2]		Breed[3]		Period[4]		SE
		CT	GT	H	L	B	S	1	2	
Thickness, mm		1.81[b]	2.22[a]	2.09[a]	1.95[b]	2.12[a]	1.91[b]	2.05	1.98	0.036
Elongation, %						50.4[a]	47.2[b]			0.64
	P1 H	52.0[b]	50.9[b]							1.28
	P1 L	58.6[a]	49.9[bc]							
	P2 H	45.1[d]	46.6[cd]							
	P2 L	40.5[e]	46.9[cd]							
Fracture, J/cm[3]	B	5.39[a]	3.49[c]							0.163
	S	4.62[b]	3.63[c]							
	P1	5.49[a]	3.53[c]							0.163
	P2	4.53[b]	3.33[c]							
	H B							4.54[ab]	4.18[bc]	0.231
	H S							3.79[cd]	3.82[cd]	
	L B							4.80[ab]	4.25[c]	
	L S							4.90[a]	3.46[d]	
Tensile strength, MPa		29.6[a]	21.3[b]	24.6	26.1	26.0	24.8	25.6	25.2	0.58
Young's Modulus, MPa						12.9	12.7			0.50
	P1 H	9.5[cd]	8.3[de]							0.99
	P1 L	6.9[e]	9.8[cd]							
	P2 H	19.4[b]	11.15[cd]							
	P2 L	25.6[a]	11.5[c]							

[a-e]Means within supplementation, breed, or period grouping without a common superscript letter differ ($P < 0.05$).
[1]CT = chrome-tanned; GT = glutaraldehyde-tanned
[2]Daily supplementation with either 1.5 (H) or 0.5% BW (L) of a pelleted concentrate
[3]B = Boer; S = Spanish.
[4]P1 = 108 days; P2 = 110 days.

skins from breed type and supplementation level were processed into leather in that trial. Those Ethiopian goats were slaughtered at 10 mo of age, similar to the initial slaughter in the present trial where a breed difference was recorded.

That GT leather was thicker than CT leather could be due to the more open structure and swollen fibrils found in glutaraldehyde-tanned leather than seen in chrome-tanned leather.[11] This difference in structure was reported to be responsible for lower resiliency values of glutaraldehyde- vs. chrome-tanned leather[11] and could be responsible for GT leather's lower fracture energy and tensile strength in the current trial. Wang and Attenburrow[15] associated leather strength with increasing apparent density or compactness of the fiber bundle weave in the skin. The open spaces found in chrome-free leather should act to decrease its apparent density, leading to lower values for strength characteristics.

Differences in % elongation and tensile strength among ten Brazilian crossbred sheep and goat genotypes were noted by Oliveira et al.[4] In that experiment, % elongation ranged from 60 to 77.6%, higher than in the current trial. The chrome tanned Brazilian sheep and goat skins were thinner and came from younger animals (approximately 5.5 months of age) than the B and S goats harvested in P1 and P2 (10 to 14 and 14 to 18 months of age, respectively). Increasing animal age results in decreased skin elasticity. This was illustrated by Wang and Attenburrow[15] who found that relaxation of isometric tension on leather decreased drastically in goats from 3 to 10 months of age with a continual slow decline thereafter. The authors attributed this decrease to an increasing degree of crosslinking within collagen fibers that naturally occurs with ageing.

Fracture energy is proportional to % elongation and tensile strength and effects of breed and age on fracture energy in the current trial largely follow differences in % elongation. Interactions among tannage, period, and supplementation in % elongation, and period, supplementation, and breed in fracture energy appear largely driven by values in P1, particularly the high % elongation for CT L leather and the low fracture energy for H S leather. It is not clear what caused these inconsistencies in the data. Great variation within individuals of the same breed in leather thickness and strength characteristics have been recorded in cattle hides.[2] In the current trial, S leather showed much greater variation than B leather regardless of tannage, period, or supplementation level. The maximum individual animal values for tensile strength and fracture energy for CT P2 S leather were over 200% greater than the minimum values for both H and L supplementation (data not shown). Similar magnitudes of difference were seen for the same tannage, breed, and supplement combinations and variables in P1 and in GT leather. All CT skins were tanned together by period, obviating any possibility of differences due to individual tanning runs within period.

That tensile strength was unaffected by age, breed, and supplement level was somewhat surprising, particularly in light of the differences noted in % elongation and fracture energy and due to the fact that tests were done on full, not shaved, skins. Mohammed et al.[13] found no breed or supplement level effect upon elongation, tensile, or tear resistance of B x Arsi-Bale or Arsi-Bale goat leather, whereas Passman and Sumner[3] found that leather from better-fed sheep wethers had greater resistance to tearing. Tensile strength of Brazilian goat leather recorded a 50% increase between 3 and 24 months of age, with little further change above 24 months of age.[15] Offer of fatliquor has affected tensile strength of goat leathers with increasing percent offer leading to increased tensile strength and % elongation.[16,17] In the current trial, offer of fatliquor to both CT and GT skins was similar at 15 to 18%.

Young's modulus is an indicator of leather stiffness or its inverse leather softness. Low values for Young's modulus at the initial harvest indicate the softness of leather from these younger B and S goats, perhaps due in part to thinner skins at that age and to a lower amount of crosslinking of collagen fibers that could lead to stiffness[15]. Breed differences seen at the initial harvest disappeared during the experimental period. Values recorded for CT P2 H and CT P2 L leather were significantly higher than all other values and were the main factor in the tannage by period by supplementation effect noted. Young's modulus can be affected by fatliquor offer[9], but percent fatliquor offered was similar between CT and GT processes. CT skins were tanned, milled, and machine staked following each animal harvest. Milling, done to improve softness and tactile feel of skins, can lead to a decrease in Young's modulus.[7] Differences in the tanning or milling process of CT skins from P2 may have influenced values for Young's modulus.

CONCLUSION

Tanning goat skins using chromium resulted in stronger leather than leather produced using glutaraldehyde as the base tanning agent, perhaps due to the inner structural differences of the tannage. Age effects of decreasing % elongation and increasing stiffness are similar to results seen in the literature. Supplementation effects were of lesser importance than tannage or age. Boer goat leather was thicker than S leather although tensile strength was unaffected by breed. Goat skins were not shaved to an equal thickness during the tanning process, perhaps leading to some of the breed differences seen, notably in % elongation and fracture energy. Further research is needed to evaluate characteristics of shaved skins.

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