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Effect of Graded Levels of Concentrate Mixture on Skin and Leather Quality Traits of Afar and Bati Goat Breeds Fed on Panicum Grass Hay as Basal Diet

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Abstract

This study evaluated the effects of graded levels of concentrate supplementation and breed on skin and leather quality in yearling male goats. Thirty-six intact yearling males of Afar and Bati breeds (mean initial body weight 14.0 ± 0.61 kg) were obtained from local markets. The experiment used a randomized complete block design with a 2 × 3 factorial arrangement (two breeds × three concentrate levels); animals were blocked into six groups by initial body weight and, within blocks, randomly assigned to one of three concentrate-supplementation treatments: T1 = 200 g/day, T2 = 300 g/day, and T3 = 400 g/day (dry matter basis) for 90 days. The concentrate consisted of 51% wheat bran, 28% maize grain, 20% noug cake and 2% salt and mineral premix, and was offered in two equal meals at 08:00 and 16:00. At the end of the feeding trial, animals were randomly selected from each block, fasted overnight with ad libitum water, and slaughtered at the Haramaya University abattoir over three consecutive days. Skins were weighed and measured (length and width), preserved, and processed into leather for physicochemical analyses. Results showed that goats receiving the highest supplementation level (T3) produced heavier skins with larger surface area than those on T1 and T2. Breed influenced leather properties: Bati-derived leathers exhibited superior physical and chemical quality compared with Afar ($P < 0.05$). Specifically, leathers from Bati goats had higher tensile strength (21.91 vs. 18.13 N/mm2), greater elongation at break (49.52% vs. 44.16%), higher tear strength (28.6 vs. 26.11 N/mm), and larger distension at burst and at crack, while showing lower fat content (3.92% vs. 5.83%) than Afar leathers. In conclusion, both breeds and all supplementation levels produced quality leather characteristics comparable to industry quality standards.

Keywords: Chrome content; distension; leather; skin; tear and tensile strength

Introduction

Hides and skins are important byproducts of livestock and contribute significantly to Ethiopia's economy. Between 2004/2005 and 2021/22, Ethiopia produced an average of 9.8 million sheepskins and 10.7 million goatskins annually [1]. Goat skin and leather are valuable commodities that provide income to producers and generate foreign currency for the country. However, export revenues declined from USD 52.22 million to 33.2 million between 2002/03 and 2021/22. This decrease is attributed to a shortage of high-quality raw skins and the prevalence of defects that render many skins unsuitable for export markets [2], as well as the limited supply of raw skins delivered to tanneries.

In Ethiopia, goat skins are sourced through various systems including individual households, rural slaughter slabs, municipal slaughterhouses, and mechanized modern abattoirs. The majority of hides and skins are produced by individual households across kebeles, where animals are often slaughtered in backyard settings [3]. According to ILRI (2017), approximately 90% of shoats are slaughtered in backyards with minimal attention to hygiene and proper handling [1]

Ethiopian tanners face challenges related to the shortage and poor quality of skins, which are adversely affected by pre-slaughter and post-slaughter defects, impacting both production and supply quality [4]. These quality problems arise throughout the entire value chain, beginning with inadequate animal husbandry and weak veterinary care, continuing through traditional and suboptimal slaughtering methods, and extending to poor skin collection, handling, and preservation practices. Consequently, these issues result in failure to meet factory-quality standards and limit competitiveness in international markets [1].

Furthermore, research indicates that breed, age, nutrition, and environmental factors influence the chemical and physico-mechanical properties of hides and skins [5, 6]. Dereje *et al.* [7] found that goats supplemented with concentrate at 1.5% of their body weight produced leather with greater tear strength (51.6 N/mm) and fat content (6.2%) compared to those supplemented at 1% of body weight. However, there remains a lack of comprehensive empirical data on the physical and chemical quality of skins and leathers from different indigenous Ethiopian goat breeds [8].

To enhance competitiveness in international markets, it is essential to evaluate the chemical and physico-mechanical leather quality traits of Ethiopia's indigenous goat breeds and generate foundational data to inform future breeding and improvement programs. Therefore, the objective of this study was to assess the chemical and physico-mechanical characteristics of chromium-tanned leather derived from Afar and Bati goats supplemented with three varying levels of concentrate feed.

Materials and Methods

The Study Area

The research was carried out at the Dubti Pastoral and Agro-Pastoral Research Center (DPARC), situated 12 km from Samara, the capital city of the Afar National Regional State. The site lies at a latitude of 11°27′N and longitude of 41°20′E, approximately 630 km northeast of Addis Ababa, at an elevation of 382 meters above sea level. The area experiences an average annual rainfall of 400 mm, with temperatures ranging from a minimum of 28°C to a maximum of 34.1°C. Livestock production under pastoral and agro-pastoral systems is the predominant agricultural practice in this region [9].

Experimental Animals Management

A total of 36 yearling intact male goats, comprising 18 Afar and 18 Bati breeds with an average initial body weight of 14.0 ± 0.61 kg, were procured from local markets in the Afar region (Asayta) and Amhara region (Bati district), areas characterized by similar agro-ecologies where these breeds are typically found. The animals' ages were estimated based on dentition and owner

information. Following purchase, the goats were transported to the study site and subjected to a 21-day quarantine period for acclimatization to the new environment. During quarantine, all animals were ear-tagged and treated with anthelmintics to control internal and external parasites. Vaccinations against prevalent local diseases were also administered.

After quarantine, the animals were further acclimated to the experimental diets and individual pen management for two weeks. During this time, each goat was housed individually in pens equipped with feed and water troughs, cleaned daily prior to feeding. The animals were randomly assigned to their respective dietary treatment groups and provided with unrestricted access to water and mineral licks. Throughout the adaptation and feeding periods, the goats were closely monitored for health issues, and detailed records were maintained. The acclimatization phase was followed by a 10-day digestibility trial and a 90-day feeding trial.

Feed Preparation and Feeding Management

The experimental diet consisted of Panicium grass hay provided ad libitum as the basal feed, complemented by a concentrate mixture formulated from wheat bran (50%), maize grain (28%), noug seed cake (20%), and salt with ruminant premixes (2%) as detailed in Table 1. The concentrate formulation followed the guidelines of the National Research Council [10], adjusting the energy and protein content by varying ingredient proportions to achieve the desired nutritional levels. Prior to the start of the feeding trial, the concentrate mixture was gradually introduced on a dry matter basis to acclimate the animals to the dietary treatments and experimental conditions. After a two-week pen adaptation period, graded levels of concentrate were offered.

The concentrate was divided into two equal portions and fed twice daily at 08:00 and 16:00 hours, using a conventional feeding approach whereby roughage was provided before the concentrate to help prevent nutritional disorders. Panicium grass hay was offered freely throughout the entire experimental period. Feed refusals were collected and weighed daily for each animal to facilitate chemical composition analysis. Body weights of the experimental animals were recorded at the start and subsequently every 10 days during the trial. Clean and fresh water was available to all animals at all times.

Table 1: Chemical composition of experimental feeds

Experimental feeds (%)	DM (%)	OM (%)	Ash (%)	CP (%)	NDF (%)	ADF (%)	ADL (%)
PG	88.3	89.6	11.9	10.0	69.8	42.7	5.9
NSC	92.1	90.9	8.3	33.9	31.1	23.2	7.4
WB	90.4	93.1	6.1	16.8	48.2	15.3	4.8
Maize	89.2	88.4	1.7	7.1	24.2	8.2	4.5
Conc.Mix	90.1	91.1	7.1	21.9	38.5	17.1	5.3

DM=dry matter; OM=organic matter; CP=crude Protein; NDF=neutral detergent fiber; ADF=acid detergent fiber; ADL=acid detergent liginin; PG=panicum grass; NSC=nuge seed cake; WB=wheat bran; Conc. Mix= concentrate mixture

Experimental Design and Treatments

The study employed a randomized complete block design (RCBD) with a 2 × 3 factorial arrangement, involving two goat breeds and three concentrate supplementation levels (T1 = 200 g/day, T2 = 300 g/day, and T3 = 400 g/day). The goats were blocked into six groups based on their initial body weight and then randomly assigned to the dietary treatments [11]. Each block contained six goats three from each breed with goats within each block randomly allocated to one of the three concentrate levels. Consequently, there were three replications per breed within each block, with two goats assigned to each treatment. Breed and diet served as the main factors analyzed.

Sample Skin Preparation and Processing

At the end of the growth trial, all goats were slaughtered at the Haramaya University abattoir. Skins were carefully flayed while the carcasses were suspended and placed on wooden slanted tables to facilitate the removal of excess fat, blood, and other impurities. Fresh skin weight was measured using a precision scale with a sensitivity of 0.01 kg and expressed as a percentage of the shrunk body weight (SBW) at slaughter. Skin length and width were measured using a tape measure, and skin area was calculated by multiplying length (cm) by width (cm).

The skins were then cured by applying salt to the flesh side at approximately 50% of the fresh skin's weight. Over the subsequent days, the skins were turned and re-salted to ensure thorough curing. After one week, the salt was removed by shaking the skins, which were then weighed again to determine the dry-salted skin weight.

The cured skins were transported to the Ethiopian Manufacturing Industry Development Institute (EMIDI), Leather and Leather Products Industry Research and Development Center, for further processing and quality assessment. At EMIDI (formerly ELDI), skins underwent processing to the chrome crust stage, which included key steps such as dehairing; fleshing, involving mechanical removal of residual flesh, connective tissue, and fat using hand knives or fleshing machines; washing; pickling a process that acidifies the scudded pelts in drums containing salt solution and diluted acid to prepare the pelts for tanning; and finally, tanning, where the skins are chemically converted into leather by the addition of tanning agents.

Leather Physico-Mechanical Quality Testing

The chrome crusted leathers were conditioned at a temperature of 20 ± 2°C and 65 ± 5% relative humidity for 48 hours prior to physical testing, following the standard procedures outlined in ISO 2419 [12]. After processing into the undyed crust stage, leather thickness was measured in millimeters according to ISO 2589 [13]. Samples were taken from the butt region, recognized as the official site for leather quality assessment [14]. Duplicate samples of standard size were prepared from this region in accordance with ISO 2418 (2005b) standards for leather quality testing.

Tensile strength, percentage elongation, and tear strength determinations were assessed using a dynamometer while distension and strength of grain were determined by the ball burst test using a lasto meter. Tensile strength was expressed in relation to the diameter at the narrowest part of the dumbbell-shaped piece of leather and the thickness of the sample [15]. It is defined as the force required for the breaking of a dumbbell-shaped leather sample on the test machine.

$$Tensile\ strength/resistance\ (N/mm^2) = \frac{\text{Breaking load (N)}}{\text{Thickness (mm)} \times \text{Width (mm)}}$$

Elongation at grain break was determined during the test for tensile strength. It is defined as the percentage stretch of the dumbbell shaped leather sample before it broke.

$$\%Elongation = \frac{(\text{Length at break (mm)} - \text{Initial length (mm)}) \times 100}{\text{Initial length (mm)}}$$

The test for slit tear strength (tear load) involved a rectangular leather sample with a small slit cut in the middle of it. The sample was then pulled apart by a clamp attached to its base and another clamp inserted through the slit. The point at which the slit started to tear was defined as the slit tear strength. The slit tear strength was expressed in relation to average leather thickness [16].

$$Tear\ resistance\ (N/mm) = \frac{\text{Force at tear (N)}}{\text{Skin thickness at tear (mm)}}$$

The tension of the test leather samples when a load was applied across the sample by a steel ball from the flesh side was measured [17]. A lastometer was used to perform the test procedure in which clamps hold the rim of the circular leather sample, leaving the central portion free to move. The force was applied via the steel ball which was advanced manually at a steady rate. The amount of distension (mm) and applied force (N) was recorded when the grain surface first cracked and the steel ball burst through the sample.

Shirkage temprature of leather samples was determined using thermo-mechanical analyzer (TMA). This methods was used typically to measure the temperature at which collagen fibers irreversibly contract, which indicated denaturation levels.Absorption of water (%) by leather was determined according to the standard procedure [18] for light or flexible leather using Kubelka method after 24 hours. It is the measure of weight of water absorbed per known weight of sample leather and was calculated based on the following formula.

$$Fat\ content\ (\%) = \frac{\text{Weight of absorbed sample (g)} \times 100}{\text{Weight of initial sample weight (g)}}$$

Leather Chemical Quality Test

Chemical quality test such as fat, moisture/volatile matter, and chromium content were determined at wet blue stage. At this stage, skins are semi-processed leathers which have been tanned by fixing chromium salts during the tanning process. The moisture or volatile matters content of skin samples was determined using standard method [19] by oven drying of a test sample at 102oC to a constant weight and the percentage moisture content was calculated as:

$$Moisture\ content\ (\%) = \frac{\text{Initial sample wt. (g)} - \text{Sample wt. after drying (g)} \times 100}{\text{Initial sample weight (g)}}$$

The fat content of the moisture-free samples was determined using standard Soxhlet extraction according to official method of analysis [20]. The fat content was taken to be the percentage weight of substances extracted from the samples using the solvent dichloromethane. After distilling the solvent from the flask, the extracted materials were dried at 102±2°C to constant weight, removed from the oven and cooled in the desiccators for 30 minutes and weighed. The percentage fat was calculated using the following formula:

$$Fat\ content\ (\%) = \frac{\text{Extracted sample wt. (g)} \times 100}{\text{Initial sample weight (g)}}$$

The chrome-oxide (Cr2O3) content of the leather after tanning, defined by the quantity of the chromium compound was determined by oxidizing the leather ash and iodometric titration of the hexavalent chromium ions based on official method of analysis (SLC-208 1996c). The chromic oxide content of the leather is calculated as a percentage of the original leather weight.

Statistical Analysis

All the collected data were initially organized and processed by Microsoft Excel 2010 and then subjected to analysis of variance using JMP statistical software (JMP®, Version pro 16. SAS Institute Inc., Cary, NC, 1989–2023) to test the effects of breed and diet on the measured parameters.. The interaction effects of diet and breed were included as the main effects in the model provided that they were significant. The treatment means of all parameters were separated using Tukey's honestly significant difference test (HSD), and the significance was considered to be 5% ($P<0.05$). The mean values and the standard errors of the means (SEMs) are reported. The statistical model applied for the above data set was:

$$Y_{ijkl} = \mu + D_i + C_j + B_k + (D \times B)_{ik} + E_{ijkl}$$

Where;

Yijkl = the response variable; μ = overall mean; Di = effect of being on diet i (T1 to T3); Cj = effect of being in block j (Block 1-6); Bk = effect of being in breed k (Afar and Bati goats); (D × B) ik = interaction between breeds and diet levels and Eijkl = random error. The interaction and main effects' least-square means were presented and discussed based on their existence.

Results

Physical Quality of Leather

Genotype exerted a significant influence on skin length, width, and surface area, while feeding level significantly affected skin width and area but not length (Table 2). Bati goats, characterized by their larger body size, exhibited longer and more extensive skin areas compared to Afar goats. Correspondingly, Bati goats had greater fresh and dry skin weights than their Afar counterparts. Similarly, goats supplemented with higher concentrate levels consistently demonstrated significantly larger skin dimensions ($P < 0.05$).

The increased skin weights observed in goats receiving the highest diet level can be attributed to accelerated growth rates and higher subcutaneous fat accumulation associated with improved nutrient intake. Skins from highest supplemented level goats were approximately 90 g heavier ($P < 0.05$) relative to those on lower supplementation levels. However, when fresh skin weight was normalized to slaughter weight, no significant differences were detected between breeds or across feeding regimes.

Table 2: Fresh and dry skin weight of Afar and Bati goats supplemented with three levels of concentrate mix

Variables		Concentrate levels			Breeds			P value		
	T1	T2	T3	SEM	Afar	Bati	SEM	B	C	B x C
Area (m^2)	0.48^{b}	0.55^{ab}	0.60^{a}	0.21	0.52^{b}	0.61^{a}	0.21	0.01	0.03	0.25
Length (cm)	79.1	84.9	86.4	1.52	83.1^{b}	87.3^{a}	1.51	<0.01	0.21	0.39
Width (cm)	60.1^{b}	64.4^{ab}	69.2^{a}	0.41	$62\ 1^{b}$	$69\ 6^{a}$	0.42	<0.01	0.02	0.25
Fresh weight (kg)	1.40	1.42	1.44	0.02	1.40	1.44	0.02	0.56	0.60	0.48
Dry weight (kg)	0.98^{c}	1.02^{b}	1.07^{a}	0.21	0.99^{b}	1.08^{a}	0.22	0.04	0.54	0.41
FW/(% SBW)	8.5	8.7	8.8	0.46	8.2	8.7	0.46	0.21	0.15	0.29

^{a,b,c} within breed and diet in the same row, means with different superscript letter differ significantly ($p < 0.05$); Treatment 1 = 200 g/d; T 2 = 300 g/d; T3 = 400 g/d concentrate mixtures ; B= breed; C= concentrate; FW= Fresh weight; SBW= slaughter body weight; SEM = standard error of mean .

Physico-Mechanical Quality of Leather

Tensile strength, elongation, thickness, mean force, distension at burst, distension at crack, bursting load, and cracking load of the leather varied significantly among genotypes. However, except for tear strength, elongation, and distension at burst, these parameters were not significantly affected by dietary supplementation levels (Table 3). Tear strength, distension at burst, and elongation were significantly influenced ($P < 0.05$) by the level of concentrate supplementation, with leather from goats receiving the highest supplementation (T3) demonstrating greater resistance to tearing and increased elongation compared to those from T1 and T2 groups. Notably, breed did not have a significant effect on tear strength. Overall, the results indicate that genotype has a more pronounced impact on leather quality traits than dietary supplementation.

Table 3: Physical properties of leathers made from Afar and Bati goats supplemented with three levels of concentrate mix

Variables		Concentrate levels			Breed			P value		
	T1	T2	T3	SEM	Afar	Bati	SEM	B	C	B x C
T. strength (N/mm^2)	19.21	19.22	20.14	0.14	18.13^{b}	21.91^{a}	0.13	0.01	0.33	0.38
Elongation (%)	45.07^{b}	46.33^{ab}	49.11^{a}	0.03	44.16^{b}	49.52^{a}	0.03	0.01	0.01	0.22
Thickness (mm)	1.20	1.20	1.21	1.38	1.23	1.14	1.39	0.12	0.21	0.24
Tear strength (N/mm)	26.0^{b}	26.9^{ab}	28.4^{a}	3.71	26.11	28.6	2.13	0.19	0.02	0.38
Mean force (N)	41.7	42.6	44.1	2.13	35^{b}	44.2^{a}	1.83	0.01	0.41	0.31
Distension at burst (mm)	12.9	13.2	14.2	2.31	12.1^{b}	14.5^{a}	1.26	0.01	0.06	0.37
Distension at crack (mm)	11.01	11.62	12.51	0.17	12.2^{b}	13.7^{a}	2.31	0.02	0.62	0.24
Bursting load (N)	471.9^{b}	479.5^{ab}	488.7^{a}	9.39	488.2	484.3	9.27	0.13	0.03	0.29
Cracking load (N)	266..2	266.7	269.9	5.39	270.1	267.3	5.31	0.12	0.35	0.42
Shrinkage T^0 (^{0}C)	119.2	118.4	119.	2.42	117.7	118.5	2.43	0.23	0.11	0.44
Water absorption (%)	174	175.9	174.2	3.35	162.8	170.4	4.16	0.15	0.38	0.34

^{a,b,c} within breed and diet in the same row, means with different superscript letter differ significantly ($p < 0.05$); T= tensile; SEM = Standard error of mean

Chemical Quality of Leather

Moisture and fat content in the leather from both goat breeds were significantly influenced ($P < 0.05$) by genotype and dietary supplementation levels (Table 4). Leather derived from goats fed the T3 diet exhibited higher fat content compared to those receiving the T1 and T2 diets ($P < 0.01$). Moreover, fat content was significantly greater ($P < 0.05$) in Afar goats relative to Bati goats. Conversely, chromic oxide content remained unaffected by both genotype and supplementation level ($P > 0.05$).

Table 4: Chemical qualities of leathers made from skins of Afar and Bati goats supplemented with three levels of concentrate mix

Variables		Concentrate levels			Breeds			P value		
	T1	T2	T3	SEM	Afar	Bati	SEM	B	C	B x C
Moisture (%)	12.6^{a}	12.1^{b}	11.2^{c}	3.15	11.3^{b}	12.7^{a}	3.14	0.03	0.02	0.29
Fat (%)	3.79^{c}	$.4.89^{b}$	5.76^{a}	0.14	$.5.83^{a}$	3.92^{b}	0.13	0.01	0.01	0.28
Cr2O3 (%)	3.12	2.99	2.98	0.35	3.23	3.16	0.33	0.46	0.48	0.36

^{a,b,c} within breed and diet in the same row, means with different superscript letter differ significantly ($p < 0.05$); Cr2O3 = Chromic oxide; SEM = standard error of mean;

Discussion

Physical Quality of Leather

The quality of hides and skins used for leather production is fundamentally determined by the physico-chemical characteristics of the raw material [21]. Key parameters such as skin weight, dimensions, and elasticity also serve as important grading criteria. In the present study, Bati goats demonstrated larger skin measurements including length, width, and overall area, relative to Afar goats, likely reflecting their comparatively greater body size.

According to the Indian Standard [22], goat and sheep skins are categorized by area, which is generally estimated from skin length, into five classes: kid (less than 71 cm), small (71–82 cm), medium (82–90 cm), large (90–102 cm), and extra-large (above 102 cm). Based on these standards, the skins from the two Ethiopian indigenous breeds evaluated here fall within the medium size category. Notably, the skin lengths observed in this study exceeded those reported for Indian Kanni Adu and Osmanabadi goats, which measured 69.45 cm and 70.42 cm, respectively [23].

The average fresh skin weight recorded in this study was lower than the values reported by Dereje *et al.* [7] for Short-eared Somali, Bati, and Hararghe Highland goats, which were 1.47, 1.64, and 1.80 kg, respectively. However, the dry skin weights observed here (0.91, 1.01, and 1.04 kg) were relatively comparable to those previously reported. The greater dry skin weight found in Bati goats in this research may be attributed to their skins containing a higher proportion of structural (dry) matter, possibly due to a denser collagen fiber network or lower water content compared to Afar goats. This concurs with findings by Raghava Rao *et al.* [24], who noted that some goat breeds naturally develop tighter collagen structures, which may serve as an adaptive mechanism for improved environmental protection.

Conversely, the increased skin weights observed in goats receiving diet T3 supplementation are likely a result of enhanced growth performance and increased fat deposition in the skin attributable to higher nutrient intake. This observation aligns with Dereje *et al.* [7], who reported heavier raw skins in Bati goats linked to improved dietary intake and subsequent fat accumulation. In addition, earlier studies by Oliveira *et al.* [6, 25, 26] have demonstrated that feed quality and genetic factors influence skin size and quality in Lori and Black Bengal goat breeds. Supporting these findings, Bellof and Pallauf [27] identified a positive correlation between nutrient density and skin quality in Merino Land sheep.

Physico-Mechanical Quality of Leather

The leather thickness values recorded in this study were lower than those reported by Dereje [7] for Bati (1.32 mm), Hararghe Highland (1.56 mm), and Short-eared Somali goats (1.23 mm). In the current study, average leather thickness ranged from 0.55 to 0.60 mm, which is greater than the 0.46, 0.47, and 0.43 mm documented for leathers from Abergelle, Arsi-Bale, and Wey-to-Gujii goat skins, respectively [28]. Anteneh *et al.* [29] observed that dietary supplementation influences leather thickness in Rutana, Gumuz, and Washera indigenous Ethiopian sheep breeds, with increased concentrate supplementation resulting in thicker leather. While their study found no significant breed effect, in contrast, breed differences were notable in the present investigation.

The tear strength measurements for both breeds and dietary groups exceeded the minimum standard for shoe upper leather (>25 N/mm) but fell below that specified for garment leather (>35 N/mm) as per BASF [30]. Conversely, tensile strength (18.13–21.19 N/mm^2), elongation (44.16–48.52%), and tear strength (26.11–28.60 N/mm) values obtained in this study satisfied the requirements for shoe upper leather, which include minimum thresholds of 15 N/mm^2 for tensile strength, 40% for elongation, and 25 N/mm for tear strength [28]. These findings demonstrate that indigenous Ethiopian goat skins possess excellent strength properties.

During leather tanning, distension at crack and distension at burst tests are commonly employed to evaluate a leather's perfor-

mance under multidirectional forces, reflecting both its strength and ability to stretch before the upper grain layer initially cracks and eventually bursts [31]. In this study, leather from Bati goats required greater ball burst force to initiate cracking and bursting compared to leather from Afar goats. This is likely attributable to a thicker grain layer within the corium and a denser, more interwoven collagen fiber network in Bati skins, resulting in stronger, more elastic, and stretch-resistant leather. Supporting evidence from histological analyses indicates that the grain layer in Ethiopian indigenous goats varies between 18% and 43%, with scanning electron microscopy revealing a range of 19% to 31% [28].

Moreover, the observed variation may be linked to the higher fat content in Afar skins, which is associated with reduced leather extensibility. Fat can obstruct structural components such as hair roots and pigments, resulting in a denser, less open fiber structure that limits distension properties [31].

The distension at grain break and burst values reported in this study align with the 13.5–14.2 mm range documented for Bati, Hararghe Highland, and Short-eared Somali goats [7]. Breed had no significant effect on distension at grain break or burst, nor did genotype influence the load required to crack or burst the grain layer of leather from either breed. However, the level of concentrate supplementation did affect the load needed to burst the grain layer. Specifically, crust leather from goats in the T3 treatment group exhibited a higher burst load compared to those in the T2 and T1 groups, consistent with previous findings in goats [7, 8, 31].

The load values for grain break and burst obtained here were lower than the respective values of 546.9, 561.2, and 552.7 N (grain break), and 544.3, 561.2, and 539.8 N (grain burst) reported for Bati, Hararghe Highland, and Short-eared Somali goats by Dereje *et al.* [7]. The average shrinkage temperature measured exceeded 100°C for both leather samples, surpassing the Ethiopian Quality Standard Authority's minimum requirement of 90°C for chrome-tanned leather [32].

Overall, this study demonstrates that leather from both goat breeds exhibited distension at grain crack and burst values greater than the minimum standards of 6 mm and 10 mm, respectively, established for quality shoe upper leather [33].

Chemical Quality of Leather

Skins with a balanced chemical composition neither excessively high nor low in fat and moisture tend to respond better during the tanning process, facilitating uniform and thorough absorption of tannins or chromium salts, which results in finer, tighter-grained leather [31]. In this study, leather from Afar goats tended to have higher fat content compared to that from Bati goats. This elevated fat level appeared to adversely affect some physical quality characteristics of the leather, such as thickness, tensile strength, distension at burst, and distension at crack.

Supporting Stosic's [31] findings, excessive fat in skins can impede the even penetration of tanning agents, producing greasy and less stable leather. The author noted that fat contents exceeding 5% may lead to poor chemical penetration if degreasing is not performed. Similarly, the reduced strength observed in leather from Anglo-Nubian goats in Brazil has been attributed to their higher skin fat content relative to other goat types [34].

However, contrasting the present results, Dereje *et al.* [7] reported that increased fat content in leathers from Short-eared Somali goats did not negatively affect tensile strength or distension at crack. Likewise, Mengistu *et al.* [36] found that although Blackhead Ogaden sheep skins had significantly higher fat content than those of Horro and Washera sheep, the tensile strength of Blackhead Ogaden leather remained unaffected.

In this study, the fat content of leather from Bati goats was within the acceptable standard range for upper shoe leather (3–5%), whereas the fat content of Afar goat leather slightly exceeded this range. According to LIDI [28], Afar goat skins contained

6.2% fat, which is higher than levels reported for Abergele (5.6%), Central Highland (4.5%), and Begait (5.7%) goats. The elevated fat content observed in this study may be partly attributed to the relatively high dietary supplementation provided to the goats, which likely contributed to fat levels surpassing the optimal 5%. This observation is consistent with previous research by Seid *et al.*[8], Dereje *et al.* [7], and Mengistu *et al.* [39], who found that goats receiving greater supplementation groups produced leather with higher fat content compared to those on lower supplementation groups. Nonetheless, as Stosic [31] emphasized, leather's physical properties such as strength and extensibility are affected by multiple factors beyond fat content, including intrinsic skin characteristics like the amount of fibrous tissue, the grain-to-corium ratio, and the presence of structural elements such as hair follicles and sweat glands.

The optimal moisture content for leather typically ranges between 12% and 14%, which corresponds closely with the moisture levels observed in this study. Leather from Bati goats, known for their lower fat content, exhibited a slightly higher moisture-to--fat ratio. This trend aligns with previous research demonstrating a significant negative correlation between fat and moisture content in leather [35]. The average moisture content recorded here is comparable to values reported by Dereje *et al.* [7], who documented moisture contents of 11.8%, 11.6%, and 12.2% in leathers from Bati, Hararghe Highland, and Short-eared Somali goats, respectively. Likewise, Seid *et al.* [8] reported a moisture content of 12.8% for Arsi-Bale goats, although their study did not specifically assess breed or dietary supplementation effects.

Chromic oxide serves as a crucial chemical marker of leather quality, enhancing resistance to decomposition. Stosic [31] noted that a minimum chromic oxide concentration of approximately 2.5% is necessary to maintain tensile strength and prevent grain damage during the storage of wet blue leather. In the present study, chromic oxide levels in leathers from both goat breeds exceeded this threshold, falling within the acceptable range for safe storage. Concentrate supplementation levels did not significantly influence chromic oxide content, consistent with findings from earlier research [7, 8, 31, 36].

Conclusion

This study demonstrated that most skin dimensions and chemical quality traits, as well as selected physical properties of leather, were significantly influenced by both goat breed and the level of concentrate supplementation. The leather produced from both breeds met the physical and chemical quality standards expected by the leather industry. However, skins from Afar goats generally yielded leather with comparatively lower physical and chemical quality parameters and higher fat content than those from Bati goats. Increasing concentrate supplementation up to 400 g/day improved most physico-chemical properties of leather in both breeds, although it also resulted in elevated fat content.

While higher levels of concentrate supplementation are recommended for producing better quality leather, ensures stronger, more elastic leather that meets international quality standards, it is important to balance this benefits with productivity considerations when developing feeding strategies for feedlot operators and smallholder farmers. It should be noted that the current findings are based solely on male goats (bucks) over a 90-day feeding trial. Further research involving female goats (does) is warranted to elucidate the effects of sex on skin quality traits, given the known influence of physiological factors such as androgen hormones and growth dynamics on leather characteristics. Additionally, the duration of feeding beyond or below 90 days may also impact skin quality and should be investigated in future studies.

Data Availability Statement

The data used in this study are available from the corresponding author upon request to interested.

Ethical Approval

All procedures involving animal care and management were in accordance with the guidelines for the treatment of animals in behavioral research and teaching (Sciencedirect and Behaviour, 2012).

Contributions of the Authors

Anwar carried out conceptualization, research, formal analysis, data gathering, data analysis, writing the original draft, reviewing, and editing. Yesihak played roles in planning, supervision, directing, reviewing, and revising. Whereas Sileshi, Fekede, and Aemiro played the conceptualization; supervision; review and editing roles. The publishable version of the manuscript has been read and approved by all authors.

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Conflicts of Interest or Disclosure statement

The authors declare that there was no conflict of interest.

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