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Evaluation of Mechanical Properties of Goat Leather Tanned using *Acacia xanthophloea*

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Article

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ABSTRACT

Acacia xanthophloea is a tree in the Fabaceae family with wide distribution mainly around Laikipia in Central Kenya and major parts of the Rift Valley town of Naivasha, Kenya. A number of trees under the Fabaceae family are renowned as sources of vegetable tannins for leather processing. Despite recent advances in research, locally available vegetable tanning materials have not been widely exploited in Kenya for commercial tanning purposes. This study aimed to evaluate the mechanical properties of goat leather tanned with crude extracts of *Acacia xanthophloea* from Naivasha, Kenya. Crude extracts of *Acacia xanthophloea* combined with pre-tanning and tanning procedures were used to produce leather. The commercial mimosa was used as a control. The leather tanned with crude extracts of *Acacia xanthophloea* had a thickness of 0.81 ± 0.11 mm, tearing strength of 37.87 ± 2.09 N, tensile strength of 27.50 ± 7.51 N/mm^2, percentage elongation of 18.00 ± 6.67, grain crack of 6.19 ± 0.20 mm and grain burst of 7.10 ± 0.27 mm. The crude extracts of *Acacia xanthophloea* confer good tanning and give the leather a reddish tinge, whereas some mechanical properties attenuated, compare favourably with the control (mimosa). *Acacia xanthophloea* which is abundantly available in Kenya with scarce use can potentially be cultivated and refined as a commercial source of tannins.

KEYWORDS

Acacia xanthophloea, tanning, goat leather, mechanical properties, crude extracts, tannins

INTRODUCTION

Processing of hides and skins into leather is one of the key agro-processing industries in Kenya. Its potential towards commodity development addresses pertinent issues of socioeconomic importance and positively impacts rural development, creation of wealth and employment [1]. Tanning is a very important process in the leather industry as it brings out the required characteristics in the raw materials, which are essential for the quality of the finished product [2]. It is a crucial part of leather manufacturing operations that stabilizes the proteins in raw skin or hides through either the use of minerals or vegetable tanning agents and largely determines the characteristics of the finished product [3]. Tannins can be defined as water-soluble polyphenolic compounds with molecular weights ranging from 500 to 3,000 Da (gallic acid esters) and up to 20,000 Da (proanthocyanidins), that can form reversible and irreversible complexes with proteins, polysaccharides, alkaloids, nucleic acids, and minerals [4]. About 90% of the tannins produced globally are used in the production of leather [5]. Further, vegetable tannin can be of three different categories such as complex tannin, condensed tannin, and hydrolyzable tannin [3]. Condensed tannins are flavan-3-ol biopolymers that generate anthocyanidins and catechins as end groups when heated in alcohol solutions of a strong mineral acid. Gallotannins and ellagitannins are examples of hydrolysable tannins. Gallotannins are galloyl esters of glucose or quinic acid whereas ellagitannins are generated from hexahydroxydiphenic acid [6].

In leather processing, different kinds of tanning methods, materials and chemicals may be used. Chrome tanning is the most prominent in leather production globally [7,8]. Other forms of tanning include; vegetable tanning, aldehyde tanning, oil tanning, mineral tanning and combination tanning. Vegetable tanning materials continue to draw interest in leather processing because of their non-toxic form and the perceived environmental credentials because of the less environmental pollution associated with their use. Moreover, plant tannins are readily abundant in nature and are a renewable source. In addition, vegetable tanning agents contain tannin, non-tannin, and gum. Based on their origin, vegetable tannins are known to confer unique attributes that produce compact, full and easily embossable leather [2]. Vegetable-tanned leather possesses better water permeability, stability, strength and moulding properties [9]. The growing global demand for vegetable-tanned leather continues to put much pressure on the conventional sources of commercial tannins such as mimosa, divi-divi and quebracho. Hence there is a need to look for alternative sources of tannins to diversify production. Some indigenous African tree species have been found to contain appreciable quantities of tannins, which could be exploited commercially [10]. A study by Cheloti et al. evaluated the tanning potential of *Acacia xanthophloea* and found its viability as a good source of tannins for leather tanning [11]. However, there is limited study on the evaluation of mechanical properties of leather tanned using *Acacia xanthophloea* extracts. A study by China et al. showed the viability of *A. xanthophloea* bark extract as a tanning agent with properties similar to *A. mearnsii* (a commercialized source of tannins) [12]. Sources of vegetable tannin and the difference in functional groups present in the tannin could affect the tanning efficiency and properties of tanned leather [13,14].

The importance of the mechanical properties of leather is in the evaluation of the performance characteristics for the specific end-use. This study aimed to evaluate the mechanical properties of goat leather tanned with crude extracts of *Acacia xanthophloea* as a tanning material and explore its suitability for commercial sources. The properties such as thickness, tensile strength, tear strength, percentage elongation and distention at crack and ball burst were conducted on the goat leather and verified with the recommended standard values of shoe upper leather [15-18].

EXPERIMENTAL

Material and Methods

Samples collection and preparation

The goat skins for the tanning process were obtained from the Dagoretti slaughterhouse, Nairobi County, Kenya and cured by wet salting. *Acacia xanthophloea* barks sample was collected from Naivasha, Nakuru County, Kenya and air-dried under a shade for 7 days at room temperature (25 °C). The *Acacia* barks were considered to be dry when there was no further variation in the moisture content over a period of 24 h. Further size reduction was done on the barks which were cut into small chips with overall dimensions not exceeding 5 cm in length and 0.6 cm in diameter. The small chips were then ground using a milling machine and sieved by 1 mm size mesh. The prepared sample was stored in a sealable polyethylene bag and kept at room temperature for the extraction process. About 100 g of the milled barks were then soaked in 1 L of distilled water in a conical flask overnight before commencing the extraction process. The mixture was transferred to a water bath initially at 30 °C while constantly stirred using an overhead stirrer. The residue was subjected to an extraction process using 1 L of distilled water that led to the collection of the first batch of the filtrate after 4 h. The temperature was adjusted to 50 °C and a second batch of the filtrate was collected after 4 h. Finally, the temperature was adjusted to about 80 °C and the remaining quantity was extracted. Thereafter the filtrates were mixed and set aside for the tanning/skin treatment step.

Pre-tanning of the skins

Two goat skins were prepared for tanning using crude extracts of *Acacia xanthophloea* with mimosa as a control. The Pre-tanning step was conducted as enumerated in Table 1 below.

Table 1. Showing recipe for process steps (pre-tanning process)

Operations		Products	%	Run time (min)	Remarks
Soaking	Washing/dirt soak	Water @ 20^{0}C	200	20	Drain and wash with clean water
		Detergent	1		
	Main soak	Water@ 20^{0}C	200	240	
Liming and Unhairing		Water @ 20^{0}C	150	60	
		Sodium sulphide	1.5		
		Lime	1		

Operations	Products	%	Run time (min)	Remarks
Add	Water @ 20⁰C Sodium sulphide Lime	100 1 2	480	pH ≥12.0
Fleshing and scudding				
DWD Deliming	Water @ 20⁰C Ammonium sulphate Sodium metabisulphite	150 2 1	60 mins	Check the pH of the cross-section with phenolphthalein (8.0-8.2)
DWD Bating	Water @ 35⁰C Bate powder	100 1	60 mins	
DWD	Water @ 30⁰C	150	20 mins	

*DWD – Drain - Wash - Drain

Treatment step

Tanning of the skins was done according to the procedures shown in the recipe for process steps in Table 2 below.

Table 2. Showing recipe for process steps (tanning process)

Operations	Products	%	Run time (min)	Remarks
Tanning	*Acacia*/ mimosa (control)	5	300	
Mechanical Agitation Add	*Acacia*/ mimosa (control)	5	300 / leave overnight	Check penetration
Fixation	Formic acid	1	60	Checks pH (4.0-5.0)
DWD	Water@20⁰C	150	20	Drain and horse-up overnight for ageing
Fat-liquoring	Water@60⁰C Fat-liquor	100 7	120	
Fixation	Formic acid	1	60	Check pH. 4.0
DWD				
Horse up overnight				
Toggle drying				

*DWD – Drain - Wash - Drain

Evaluation of the physical properties of Acacia-tanned leather

In this study, samples of standard dimensions were cut and conditioned, following ISO 2418 [19] and ISO 2419 [20] standard procedures. The mechanical properties of *Acacia*-tanned goat leather were evaluated by thickness, tensile strength, percentage elongation, tear strength, ball crack and ball burst tests. Thickness was measured using Instron 1026 according to the official method (IUP/4, 2016) [15], the tensile strength and percentage elongation was measured using Instron 1026 according to the official method (IUP/6, 2020) [16], tear strength was measured using Instron 1026 according to the official method (IUP/8, 2016) [17] and ball crack/ball burst test was measured using a lastometer according to the official method (IUP/9, 2015) [18]. All the tests were performed in triplicates for both parallel and perpendicular to the backbone and reported the mean with standard deviation in this study.

RESULTS AND DISCUSSION

Thickness

From Table 3 below, the goat skins presented a thickness of 0.81 ± 0.11 mm (leather samples cut across/perpendicular to the backbone and leather samples cut along/parallel to the backbone) for the *Acacia* tanned leather as compared to the one tanned with mimosa that presented a thickness of 1.38 ± 0.94 (leather samples cut across/perpendicular to the backbone and leather samples cut along/parallel to the backbone). The results were comparable to a study by Zengin et al. [21]. The *Acacia*-tanned leather recorded a lower thickness than the minimum recommended of 1.2 mm as per the Kenyan Bureau Standards (KEBS) for thickness for shoe upper leather. The variation in thickness between *Acacia*-tanned leather and commercial mimosa could be attributed to the presence of a higher molar mass of non-tans in mimosa as compared to the *Acacia*-tanned leather that led to plumping of the mimosa-tanned leather [3].

Table 3. Qualitative indexes of tanned leather with *Acacia xanthophloea* crude extract and mimosa

Parameter	Tanning method		Minimum recommended value
	Tanned with crude bark extract of *Acacia xanthophloea*	Tanned with a mimosa (control)	
Thickness (mm)	0.81 ± 0.11	1.38 ± 0.94	1.2 mm
Tensile strength (N/mm^2)	27.50 ± 7.51, (→), 22.44 ± 2.12, (↓)	27.79 ± 0.69 (→), 22.62 ± 1.00 (↓)	10 N/mm^2
Elongation (%)	12.64 ± 0.87 (→), 18.00 ± 6.67 (↓)	45.83 ± 3.29 (→), 53.93 ± 5.05 (↓)	30-80

Key: (↑) = Leather samples cut along/parallel to the backbone; (→) = Leather samples cut across/perpendicular to the backbone

Tensile strength test

The tensile strength of the leather tanned by the crude bark extract of *Acacia xanthophloea* was 27.50 ± 7.51 N/mm^2 (leather samples cut along/parallel to the backbone) and 22.44 ± 2.12 N/mm^2 (leather samples cut across/perpendicular to the backbone) while leather tanned with commercial mimosa recorded tensile strength of 27.79 ± 0.69 N/mm^2 (leather samples cut along/parallel to the backbone) and 22.62 ± 1.00 N/mm^2 (leather samples cut across/perpendicular to the backbone) as shown in Table 3 above. The recorded measurements of tensile strength in this study were all way above the expected minimum of 10 N/mm^2 for shoe upper leather as per the Kenya Bureau of Standards (KEBS) specifications for tensile strength of upper leather and compares favourably with the previous research [21]. Tensile strength determines the structural resistance of upper leather to tensile forces hence its state and usability [3].

Percentage elongation test

The percentage elongation of leather is another physical property measured when assessing the leather quality and this has a relationship with the elasticity. Elongation refers to the ability of a leather product to lengthen/stretch when stress is applied to it and represents the maximum extent to which the leather can stretch without breaking. As shown in Table 3 above, leather tanned with *Acacia xanthophloea* had a lower percentage elongation of 12.64 ± 0.87 (leather samples cut across/perpendicular to the backbone), 18.00 ± 6.67 (leather samples cut along/parallel to the backbone). The low performance in percentage elongation for *Acacia*-tanned leather emphasizes that the leather has not had enough elasticity required for making shoe uppers. Elongation is an important property to be considered when choosing garment leather because a low elongation value results in easy tear while a high elongation value causes leather goods to become deformed very quickly or even lose usability [21]. Good quality leather should have a percentage elongation of 30-80 as per the Kenya Bureau of Standards (KEBS) specifications for elongation of the upper leather. Elongation of leather is affected by pre-tanning, tanning and post tanning process which always differs from one tanner to another [3].

Tear strength test

The tear strength of the leather products in use is indicated by the quality standard relating to the tearing load. This study found the tearing strength of the *Acacia*-tanned leather to be lower than the recommended standard tear strength as shown in Table 4 below. The *Acacia*-tanned leather showed tear strength of 37.87 ± 2.09 N/mm and 60.02 ± 2.66 N/mm for commercial mimosa. The minimum tearing strength should be at least 55 N/mm as per the Kenya Bureau of Standards (KEBS) specifications for the tear strength of upper leather. The observed variation could be attributed to the structural properties of skin/hides and may vary depending on the origin, sex and chemical modification of the skin/hides [3].

Table 4. Qualitative indexes of tanned leather with *Acacia xanthophloea* crude extract and Mimosa

Parameter	Tanning method		Minimum recommended value
	Tanned with crude bark extract of *Acacia xanthophloea*	Tanned with a mimosa (control)	
Tear Strength (N/mm)	37.87 ± 2.09	60.02 ± 2.66	55 N/mm
Distension at grain crack (mm)	6.19 ± 0.20	7.20 ± 0.26	6.5 mm
Distension of the grain ball burst (mm)	7.10 ± 0.27	8.31 ± 0.50	7 mm

Key: (↑) = Leather samples cut along/parallel to the backbone**;** (→) = Leather samples cut across/perpendicular to the backbone

Grain crack and ball burst tests

The grain crack and ball burst tests are other physical properties for testing the quality of leather. In this study, as shown in Table 4 above, *Acacia*-tanned leather showed a distension of grain crack at 6.19 ± 0.20 mm and distension of the grain ball burst at 7.10 ± 0.27 mm while mimosa-tanned leather showed distension of grain crack at 7.20 ± 0.26 mm and the distension of the grain ball burst at 8.31 ± 0.50 mm. The requirements of quality standards in terms of distension at grain crack should be minimum at 6.5 mm and distention at ball burst at 7.0 mm respectively as per the Kenya Bureau of Standards (KEBS) specifications for shoe upper leather. Pre-tanning, tanning and post-tanning processes are known to affect the grain crack and grain burst test which vary from different tanners and they are intended to indicate the grain resistance to cracking during top lasting of the shoe uppers [3].

CONCLUSION

The extraction, tanning and comparison results of this study revealed that *Acacia xanthophloea* bark tannin could be a potential new source of vegetable tannin agent. Tensile strength, grain crack and ball burst were in the recommended range while thickness, tear strength and percentage elongation resulted in leather with marginal attenuated properties from the control (mimosa). Pre-tanning, tanning, post-tanning processes and structural properties of skin/hides could affect the mechanical properties of tanned leather and could therefore have caused marginal attenuated mechanical properties of the goat skins tanned using *Acacia xanthophloea* that did not conform to some of the established minimum standards as was expected. The crude extracts of *Acacia xanthophloea* confer good tanning and give the leather a reddish tinge, whereas some mechanical properties attenuated, compare favourably with the control (mimosa). *Acacia xanthophloea* which is abundantly available in Kenya with scarce use can potentially be cultivated and refined as a commercial source of tannins.

Author Contributions

Conceptualization – Cheloti M, Onyuka A and Sasia A; methodology – Cheloti M and Onyuka A; formal analysis – Wangila P and Kiprop A; investigation – Cheloti M; resources – Kiprop A; writing-original draft preparation – Cheloti M, Sasia A and Mutuku M; writing-review and editing – Induli M and Kundu B; visualization – Masenge E; supervision – Wangila P. All authors have read and agreed to the published version of the manuscript.

Conflicts of Interest

The authors declare no conflict of interest.

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