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Investigating Effects of Direction of Sampling on the Tensile Properties of Cows Leather Treated with Sulphonated Synthetic Fatliquor of Different Concentrations

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Abstract

Diverse applications of collagen-based materials such as leather have sparked research interest that seek to investigate the effect of fatliqours on their physical and mechanical properties. As the applications of these collagen materials increases such as in the field of medicine, footwear and upholstery, more studies are required to gain more insight on how their quality and durability can be improved. Leather being one of the collagen-based material is a by-product of the meat industry, made from animal hides and skins after undergoing processes such as pre-tanning, tanning, post tanning, and finishing operations. These processes play a vital role in giving and preserving important leather properties. This study investigated effects of direction of sampling on the tensile properties of cows leather treated with sulphonated synthetic fatliquor of different concentrations. Two pieces of leather were divided into five sheets, where four sheets were fatliquored with 5%, 10%, 20% and 25% sulphonated synthetic fatliquor (Lisuline Cufb) while the remaining sheet acted as control experiment. For tensile strength and elongation, eight samples were cut in a dumb-shell shape, four along the backbone direction and the remaining four, perpendicular to the backbone direction from each sheet, while for tear strength, eight rectangular samples with a template hole were obtained from each sheet, four along the backbone direction and the remaining four were cut perpendicular to the backbone. For reliability and consistency of the results, the samples were prepared in four replicates and subjected to standard conditions for twenty-four hours before being subjected to Instron machine testing. Results showed that samples cut parallel to the backbone recorded higher tensile strength than those sampled perpendicular to the backbone. The values for percentage elongation and tear strength were higher for samples cut perpendicular to the backbone than those sampled parallel to the backbone. Comprehensive information about the effects of direction of sampling on the tensile properties of cows leather treated with sulphonated synthetic fatliquor of different concentration will inform the leather industries on the need to consider sampling direction to reduce variability in the mechanical properties of leather for the production of leather materials that are durable with better mechanical properties that will meet the standards for international markets.

Subject Areas

Functional Materials

Keywords

Collagen, Fatliqour

1. Introduction

The leather industry is one of the oldest known to mankind, dating back to the fall of man in the Garden of Eden [1]. Over the centuries, it has evolved into a highly significant economic sector, particularly in developing countries, where it possesses the capacity to generate substantial income and employment. Globally, countries have sought to harness this industry's immense potential through value addition, with the goal of moving up the leather value chain from raw hides to finished leather products [2].

Kenya, recognizing this untapped potential, has for several decades invested in the leather sector [3] [4]. National and county governments have implemented numerous initiatives, including the establishment of leather industrial parks and the imposition of high export taxes on semi-processed leather to incentivize local value addition [5]. These strategies were designed to promote domestic processing and enhance the quality of leather products. However, despite these efforts, economic returns have been minimal due to persistent challenges related to quality assurance and limited technological responsiveness in leather processing [6].

Leather production involves complex chemical and mechanical processes that affect the structure and performance of the end product. These stages include pretanning, tanning, and fatliquoring [7]-[9]. Among these, fatliquoring is particularly crucial, as it enhances the softness and flexibility of collagen fibers, resulting in leather that is flexible, pliable and comfortable to use [10].

These properties are crucial in high-demand application sectors such as footwear, where leather must conform to the shape of the foot while maintaining durability, and in automotive upholstery, where leather must maintain softness and resilience under varying temperatures and mechanical stresses. In furniture and upholstery, soft and supple leather enhances comfort, adding aesthetic value, making quality a major concern for global competitiveness.

Numerous studies have investigated the role of fatliquors in determining key mechanical properties of leather. Research by [11] [12] has demonstrated the influence of fatliquoring on tensile strength, tear resistance, and percentage elongation. Despite the effort made by the government, leather produced locally in Kenya continues to face quality challenges. There is a growing concern to improve processing techniques, specifically those that directly affect the mechanical and tactile properties of leather. This is vital for the successful implementation of the Kenya Leather Development Council Strategic Plan (2023-2027), which emphasizes the production of high quality leather capable of competing in global markets.

This study aimed to investigate the effects of direction of sampling on the tensile properties of cow's leather treated with sulphonated synthetic fatliquor of varying concentrations to understand its effect on the structural and mechanical properties of leather. Enhancing leather quality through such scientific approaches not only improves its applicability in sectors like footwear, automotive interiors, and furniture upholstery, but also supports environmental sustainability by reducing waste and promoting longer product lifespans. Development of higher quality leather are in line with national goals of value addition, industrial growth, and placing Kenya as a competitive participant in the global leather market.

2. Materials and Methods

Two wet blue pieces of leather were procured commercially from Kenya Industrial Research and Development Institute (KIRDI), Nairobi (Kenya) while sulphonated synthetic fatliquor (Lisuline Cufb) was procured from ChemKleen Products Limited, Kenya as fatliqour. The two wet blue pieces of leather were prepared for fatliquoring using the standard tannery chemicals process (See **Tables 1-3**).

Table 1. Neutralization process.

Process/Step	% Chemicals	Temp (˚C)	Time	Remarks
Wetting back	100% H_2O, 0.2% soap, 0.2% formic	25	1 hr.	Moisture level (10 - 14)
Neutralization	1% sodium formate 0.2% Bicarbonate	25 25	10 min 1 hr.	P.H.6
Drain & Washing	100% H_2O	25	10 min	Drain
Basification	0.5% Bicarbonate	25	20 min	P.H.6

The two pieces of leather were then divided into five sheets, where four of the sheets were retanned using mimosa.

The four sheets were each fatliquored with different concentration using standard tannery chemicals.

Table 2. Retanning process.

Process/Step	% Chemicals	Temp (˚C)	Time	Remarks
Retanning	8% Mimosa	60	1hr	Penetration complete through x-section
Fixation	0.2% formic acid	25	1 hr	Fixation done
Drain &Washing	100% H_2O	25	20 min	Drain

Table 3. Fatliquoring process.

Process/Step	% Chemicals	Temp (˚C)	Time	Remarks
Fatliqouring	80% H_2O	60		Drum speed = 3 rpm
	0.5% Bicarbonate	25	10 min	PH 6.0
	5%, 10%, 20% and 25%	25	Each conc. 1 hr.	Penetration complete through x-section
Fixation	0.5% formic acid	25	30 min	Add 0.5 % formic acid
	0.5 % formic acid	25	30 min	P.H 3.5
Drain & washing	100% H_2O	25	20min	Drain

3. Methods

Tensile testing

For tensile strength and elongation, eight samples were sampled in dumb-shell shape, four along the backbone direction and the remaining four, cut perpendicular to the backbone as illustrated in Figure 1.

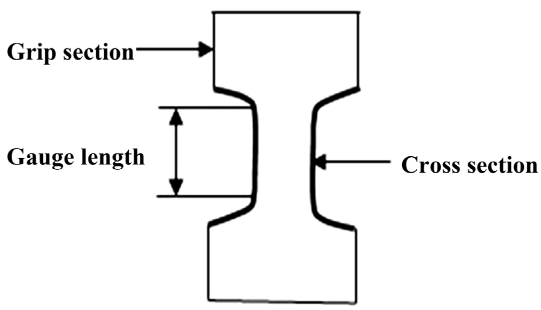

Figure 1. Schematic illustration of a standard tensile strength test sample.

For tear strength, eight rectangular samples of dimensions 50mm long and 25 mm wide with a template hole were obtained from each sheet for tear strength measurements as illustrated in Figure 2.

After sampling, all the samples were conditioned in a standard atmosphere of 23/50, temperature of 23˚C ± 2˚C, and humidity of 50% ± 5% R.H. for 48 hours before testing as specified by ISO 2419:2024 standard. Using a digital Vernier caliper, the initial thickness, t and width, W of each sample were obtained as specified by ISO 2589:2016.

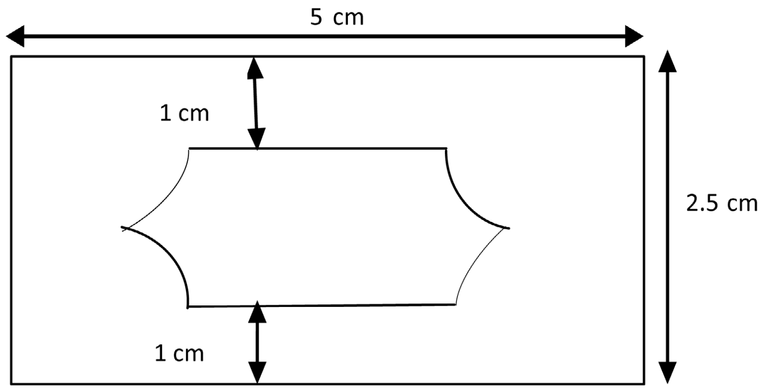

Figure 2. Schematic illustration a standard sample for tear strength testing.

Tensile strength and percentage elongation measurements was done according to ISO 3376:2020, where eight samples were clamped, one at time at the cross-sectional area of the gauge at a uniform jaws separation speed of 100 mm/min. The machine was set to run until the sample was torn apart, the highest force reached during tearing was recorded in Newtons. The elongation of the sample was also recorded directly from the scale.

Tear strength measurement was done according to by ISO 3377-2:2016 where Pneumatic grips were replaced in the jaws of the Instron testing machine after which eight samples were clamped in the grips one at a time, the machine was run until the sample was torn apart, and then highest force reached was recorded.

4. Results and Discussion

Data were analyzed statistically by Microsoft Excel ©2019 for t-test assuming equal variance and expressed as p to assess the significance. The alpha (α) was set at 0.05. Hence, significance of the null hypothesis was rejected whenever $p \leq \alpha$. The results for tensile strength, percentage elongation, and tear strength for samples cut both parallel and perpendicular to the backbone, fatliquored with Lisuline Cufb of different concentrations, and those not fatliquored are presented in **Tables 4-7** and **Figures 3-5**.

Table 4. Tensile strength (N/mm^2) of samples cut parallel and perpendicular to the backbone.

Sample code	Orientation	0%	5%	10%	20%	25%
A	Parallel	27.45	31.25	36.65	39.50	28.70
	Perpendicular	16.26	20.00	24.87	28.65	25.57
B	Parallel	25.85	30.75	33.57	43.75	27.25
	Perpendicular	18.25	22.78	25.57	29.25	23.37
C	Parallel	26.64	29.88	34.50	38.00	30.25
	Perpendicular	18.40	21.65	24.75	27.76	24.47

Continued

D	Parallel	27.86	31.67	33.24	39.08	27.40
	Perpendicular	18.61	20.48	24.4	29.78	23.6
Average	**Parallel**	**26.95**	**30.89**	**34.49**	**40.08**	**28.4**
	Perpendicular	**17.88**	**21.23**	**24.90**	**28.86**	**24.25**

From Table 4, the values for tensile strength ($p = 0.035551$) for specimens sampled parallel to the backbone were numerically higher than those sampled perpendicular to the backbone. The results for tensile strength are in agreement with those reported by [13] who found that samples taken parallel to the backbone had a higher tensile strength than samples taken perpendicular to the backbone. The variation in tensile strength can be explained by how collagen fibers are arranged under applied strain. When samples cut parallel to the backbone are subjected to a force, the force applied will be in alignment with collagen fiber orientation, hence orientation of collagen fibers towards the strain axis will be minimal. In a case where samples cut perpendicularly to the backbone are subjected to an applied force, the force will act across the fibers causing greater fiber orientation because the collagen fibers will try to re-orient in the direction in which the force is applied force and these may causes greater damage to collagen fibers causing deformation, hence reduction in tensile strength.

Table 5. Percentage Elongation (%) of samples cut parallel and perpendicular to the backbone.

Sample code	Orientation	0%	5%	10%	20%	25%
A	Parallel	15.2	18.9	21.4	28.5	21.7
	Perpendicular	20.5	26.89	29.66	34.43	29.87
B	Parallel	17.2	19.1	23.10	26.40	23.10
	Perpendicular	23.48	28.94	31.23	35.67	28.63
C	Parallel	18.30	19.7	23.06	27.80	20.50
	Perpendicular	22.76	28.75	32.00	34.32	29.3
D	Parallel	16.53	20.23	26.03	28.23	21.78
	Perpendicular	23.00	27.89	31.23	35.81	28.13
Average	**Parallel**	**16.81**	**19.48**	**23.40**	**27.73**	**21.77**
	Perpendicular	**22.44**	**28.12**	**31.03**	**35.06**	**28.98**

From Table 5, samples cut perpendicular to the backbone recorded higher values for percentage elongation ($p = 0.019238$) than those sampled parallel to the backbone, hence null hypothesis was rejected. The difference in percentage elongation values can be explained by changes in orientation of collagen fibers when a force is subjected on samples cut in different direction. When samples are cut parallel to the backbone, the collagen fibers align in direction of applied force, which offers greater resistance to stretching, hence reduction in elongation [14]. On the other hand, when a force is and applied to samples cut perpendicularly to the backbone, they cause collagen fibers reorientation resulting in greater extensibility of fibers, hence increase in elongation strength [9].

Table 6. Tear strength (N/mm) of samples cut parallel and perpendicular to the backbone.

Sample code	Orientation	0%	5%	10%	20%	25%
A	Parallel	168.40	184.00	200.5	208.1	180.30
	Perpendicular	190.2	240.00	249.5	262.40	200.9
B	Parallel	153.60	178.00	194.00	220.2	176.50
	Perpendicular	187.1	236.30	253.0	264.40	194.7
C	Parallel	160.50	187.10	204.40	208.8	172.50
	Perpendicular	190.7	220.50	260.1	263.7	199.1
D	Parallel	162.83	184.03	200.63	210.03	173.10
	Perpendicular	200.33	236.27	254.2	265.5	200.23
Average	**Parallel**	**161.33**	**183.28**	**199.88**	**211.78**	**175.6**
	Perpendicular	**192.08**	**233.27**	**254.2**	**264.00**	**198.73**

Samples cut perpendicular to the backbone recorded higher values for tear strength ($p = 0.035055$) than those sampled parallel to the backbone, hence null hypothesis was rejected. The variations for tear strength can be explained by the changes that occur in its orientation [15]. When collagen fibers are aligned in one direction, they are stronger in that direction but when a force is applied to them in perpendicular direction the strength reduces.

Table 7. Average results obtained for samples cut parallel and perpendicular to the backbone.

Concentration	Orientation	Tensile Strength	% Elongation	Tear strength
0%	Parallel	26.95	16.81	161.33
	Perpendicular	17.88	22.44	192.08
5%	Parallel	30.89	19.48	183.28
	Perpendicular	21.23	28.12	233.27
10%	Parallel	34.49	23.40	199.88
	Perpendicular	24.90	31.03	254.2

Continued

20%	Parallel	40.08	27.73	211.71
	Perpendicular	28.86	35.06	264.00
25%	Parallel	28.4	21.77	175.6
	Perpendicular	24.25	28.98	198.73

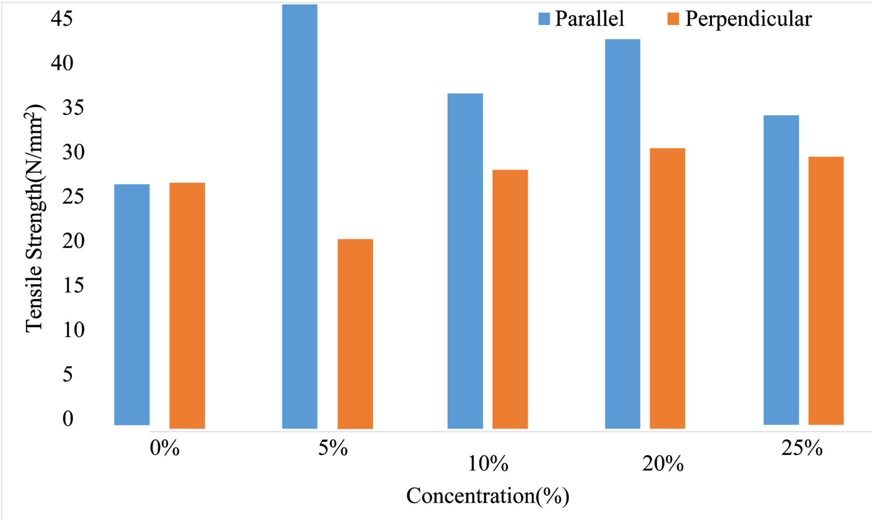

Figure 3. Effect of sampling direction on tensile strength of hide treated with Lisuline Cufb and control sample (Average).

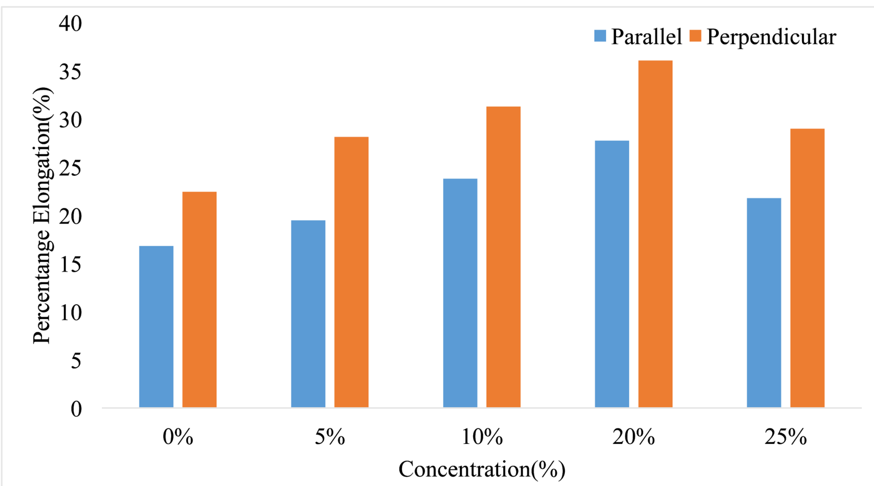

Figure 4. Effect of sampling direction on percentage elongation of leather fatliquored with Lisuline Cufb and control sample (Average).

5. Conclusions

The values for tensile strength for specimens sampled parallel to the backbone were numerically higher than those sampled perpendicular to the backbone. The values for percentage elongation and tear strength for samples cut perpendicular to the backbone were significantly higher than those sampled parallel to the backbone.

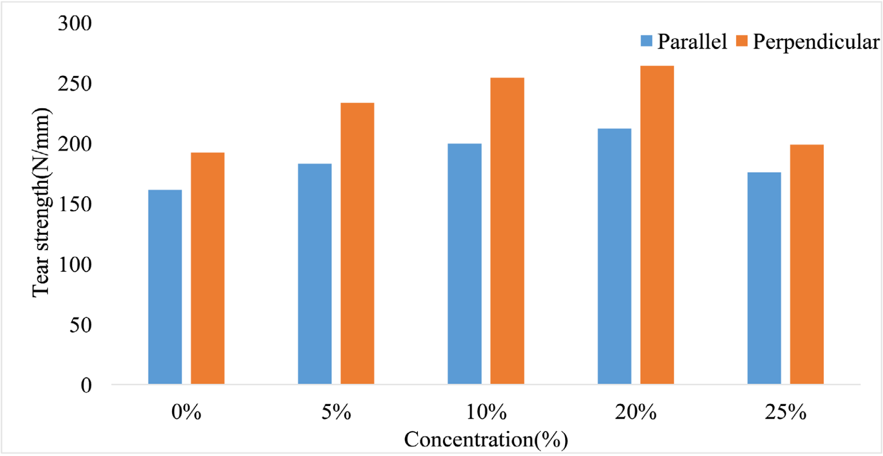

Figure 5. Effect of sampling direction on tear strength of hide treated with Lisuline Cufb and control sample (Average).

The study has some limitations such as only one type of leather was used and only selected range of fatliqour concentration was chosen. The environmental conditions under which samples were conditioned may not reflect variability worldwide. Further research should be done to assess the effect of Lisuline Cufb concentration on different types of leather by assessing its effect on durability.

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Conflicts of Interest

The authors declare no conflicts of interest.

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