International Journal of Science and Research (IJSR)
ISSN (Online): 2319-7064
Index Copernicus Value (2013): 6.14 | Impact Factor (2013): 4.438

Tensile Properties of Indigenous Kenyan Boran Pickled and Tanned Bovine Hide

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Abstract: ***Tensile properties of pickled and tanned indigenous Kenyan Boran bovine hide and how they are influenced by tanning and sampling direction were determined. Freshly flayed bovine hide was commercially procured and conventionally prepared prior to tanning. The hide was then cut into two identical halves; one half was left at pickled stage and the other was chrome-tanned at Kenya Industrial Research and Development Institute. Specimens were cut in both parallel and perpendicular sampling directions using press knife in template. Eight rectangular samples, each of dimensions 50 mm and 25 mm in template, were cut from each sampling direction in dumb-bell shape. The specimens were then conditioned in standard atmosphere of temperature 23 ± 2 °C and humidity of 50 ± 5% R.H. for 48 hours prior to testing. Tensile strength, tear strength and percentage elongation were tested using Instron Testing Machine (Model 1101) at a jaws separation speed of 100 mm/min and gauge length of 100 mm. Tanning significantly increased tensile strength but decreased tear strength and percentage elongation. Specimens cut parallel to the backline had significantly higher tensile strength than perpendicularly cut specimens whereas perpendicularly sampled specimens had higher tear strength and elongation than parallel sampled specimens.***

Keywords: Boran bovine hide, tensile properties, tanning, pickled hide

1. Introduction

Boran cattle breed are among the predominant indigenous breeds in most African countries. In Kenya, the breed forms the indigenous cattle in the arid and semi-arid pastoral communities in the Northern part where 70% livestock population is reared ([1-2]; Mwinyinyihija, ministry of Livestock Development, Kenya, Unpublished Results; Haile et al, ILRI, Nairobi, Kenya). The dark pigmentation and black points are some of the outstanding adaptive traits of this breed that protect it against sunburns of the hot arid and semi-arid area ([3]; Haile-Mariam et al, Swedish University of Agricultural sciences, Uppsala, Sweden, PhD Dissertation) . Its smooth, loose but motile and shiny coat/skin is another trait associated with reflection of high proportion of solar radiation [4]. Their reasonable large body, thick skin and well-marbled beef with even fat cover make this breed a promising source of beef and bovine hide for the production of quality leather. The hides, skins, leather and leather b-products have greater potential to generate higher percentage value of revenue compared to beef (FAO, Viale delle Terme di Caracalla, Rome Italy; Haile et al, ILRI Nairobi, Kenya, Unpublished communication).

Bovine hides and skins are the raw materials for tanning industry for production of leather, a consumer product with wide range of applications [5-7]. The main constituent of the hide is the collagen, a fibrous protein that forms almost 99% of its weight [7-8]. The fibrous collagen is formed by type I collagen and its various applications are attributed to its versatile properties like tensile strength and ability to undergo chemical modification [8-10]. This has widened its applications in fields such as biomedical, food industry, clothing, upholstery, and footwear and leather goods industry [9, 11]. However, the performance properties of leather depend on the origin of the raw material, how it is prepared for chemical modification and how it's processed to make leather [12,13]. Origin of the raw material, animal breed, sex and age are among the factors that influence the quality of hide and the resulting leather ([7]; UNIDO, 2004). Breed determines the quantity of collagen fibre constituents such as rigid native triple-helices, diameter of the collagen fibril and their Orientations Index (OI) and fibril network of collagen [14-19]. Stronger hide has its fibrils arranged parallel to the plane of the leather surface [17]. Hence the quality of animal hide is dependent on the animal breed and the environmental conditions of the animal [12].

The main functional performance measurable properties are physico-mechanical properties such as tensile properties [17]. Tensile strength determines the structural resistance of leather to tensile forces hence its state and usability (SATRA Testing equipment catalogue, personal communication, 2011; Ethiopian Standards Agency, Addis Ababa, Ethiopia). It also informs the entire process of manufacturing goods from leather as consumers can determine both the routine quality and serviceability assessment of the material [17]. Percentage Elongation determines the elasticity of the material especially upper leather and footwear upper should possess high flexibility to prevent the appearance of cracks and tears in the ball area (SATRA Testing Equipment Catalogue, personal communication, 2011; Ethiopian Standards Agency, Addis Ababa, Ethiopia). High elasticity allows the material to withstand the elongation stresses to which it is subjected during footwear lasting, especially on the toe area [13].

Significant research has been done on tensile properties of camel skins, kangaroo, sheep and goats [18, 20-23]. Although there have been previous studies on the strength of bovine hide, there appears little study on the mechanical properties of boran bovine hide especially tensile properties.

2. Methodology

2.1 Sample preparation

A freshly flayed cowhide was commercially procured from Dagoreti Slaughter House, Nairobi, Kenya and prepared following the standard tanning process as given in the Appendix.

2.2 Tensile testing Experiment

Specimens were cut for tensile testing in accordance to the official sampling method and sampling location [24] using a press knife both along the backbone direction and perpendicular direction as shown in figure 1.

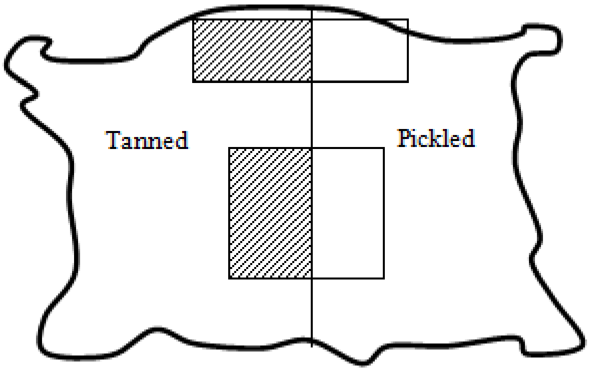

Figure 1: Schematic illustration of the sampling position and method of the pelt

The press knife cuts out the specimen and slot in one operation (template machine) with the angle formed at the cutting edge between the internal and external surfaces of the press knife being about 20°. The depth of the wedge of the cutting knife, *d* is greater than the thickness of the cut leather as shown in figure 2.

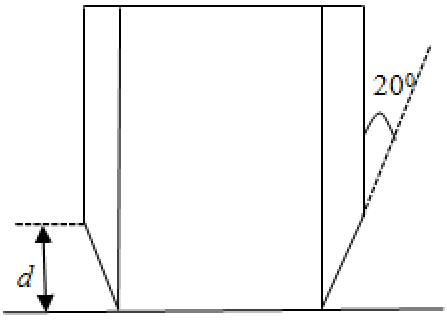

Figure 2: Schematic illustration of the shape of a press knife

For tensile strength and percentage elongation testing, eight samples were cut in dumb-bell shape as shown in figure 3.

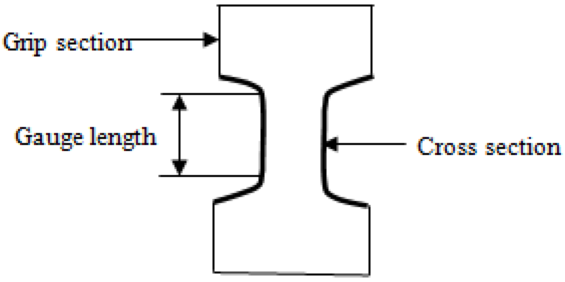

Figure 3: Schematic illustration of a standard tensile sample

For tear strength testing, eight rectangular specimens were cut, each 50 mm long and 25 mm wide with a template hole as shown in figure 4.

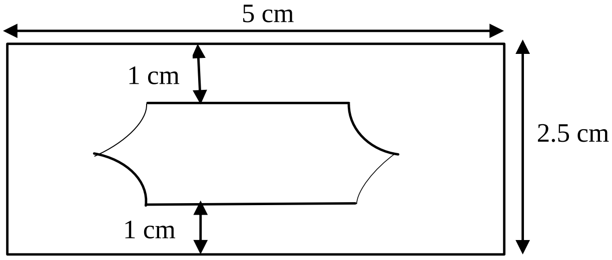

Figure 4: Schematic illustration of a standard sample for tear strength testing

The specimens were then conditioned in a standard atmosphere, 23/50 (temperature of 23 ± 2 °C and humidity of 50 ± 5% R.H.) for at least 48 hours according to [25] standard prior to testing. Thickness (t) and width (W) of each test specimen were measured as specified in [26] standard using digital vernier calipers to the nearest 0.1 mm at areas between the grain side and the flesh side. Tensile strength and elongation were tested according to [27] standard and [38] standard for tear strength methods using Instron Testing Machine (model 1101, UK). The sample was clamped at the cross-sectional area of the gauge in the grips. A uniform jaws separation speed of 100mm/min was selected with a gauge elongation length of 100mm. The machine was run until the specimen was torn apart and the highest breaking load (force) reached during tearing was recorded as the tearing force in Newtons [29]. The machine also records the elongation in mm directly from scale as described by [21]. Few samples were disposed due to slip-faulty during testing. For a moment of testing, the absolute result was obtained only from the successful sample until the maximum loading applied. For tear strength measurements, pneumatic grips were replaced in the jaws of the Instron testing machine and highest force was recorded. The tensile strength was then determined using equation 1:

$$\text{Tensile strength} = \frac{F}{Wt}\ (\text{N/mm}^2)\quad (1)$$

where F is the highest recorded force, W is the width of the test sample and t is the thickness of the sample. Percentage elongation was determined using equation 2:

$$\text{Percentage elongation (\%)} = \frac{L_f - L_i}{L_i} \times 100\quad (2)$$

where L_f is the final free length and L_i is the initial free length of the sample. Tear strength was calculated from equation 3:

$$\text{Tear strength} = \frac{F}{t}\ (\text{N/mm})\quad (3)$$

3. Results and Discussion

3.1 Effect of Sampling Direction

All data were analyzed statistically by Microsoft Excel 2013 in t-test assuming unequal means and expressed as p to assess the statistical significance. From figure 5 and figure (6), specimens sampled perpendicularly to the backbone direction have higher tear strength (p = 0.225 and 0.00508) than parallel sampled specimens, implying that numerically higher tear force is required to tear both pickled and tanned hide respectively.

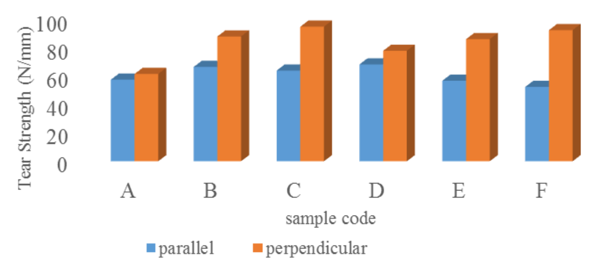

Figure 5: Tear strength of tanned hide

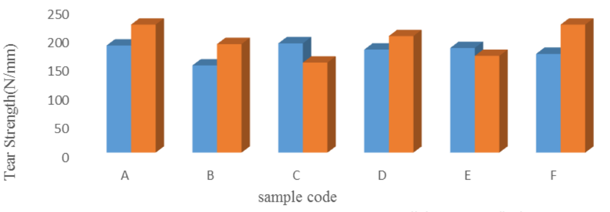

Figure 6: Tear Strength of pickled bovine hide

Similarly, as seen from figures 7 and 8, the elongation degree is higher when the specimen is sampled perpendicularly than in the parallel (p = 0.0173 and 0.00114) for pickled and tanned hide respectively, demonstrating that hide has greater elasticity in this direction, a fact exploited in shoemaking, where the leather is stretched over the form in this direction.

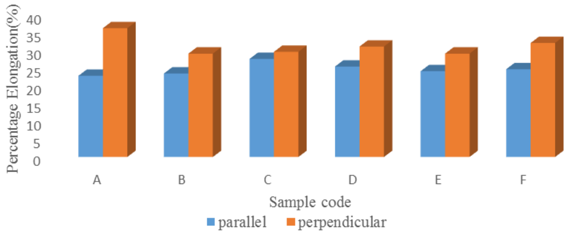

Figure 7: Percentage Elongation of tanned bovine hide

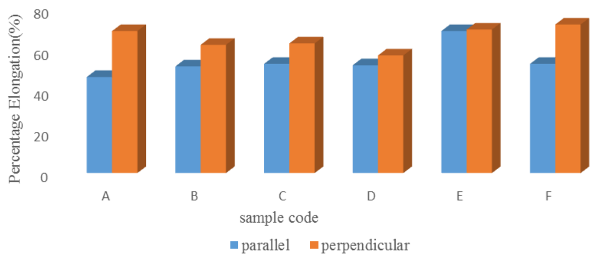

Figure 8: Percentage elongation of Pickled bovine hide

However, tensile strength for specimens sampled parallel to the backbone is numerically higher than perpendicularly sampled specimens (p = 0.00304 and 0.020986) for both pickled and tanned hide respectively as shown in figures 9 and 10.

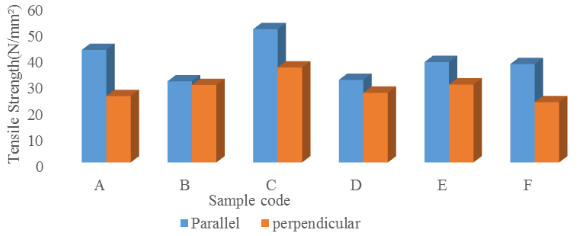

Figure 9: Tensile Strength of Tanned bovine hide

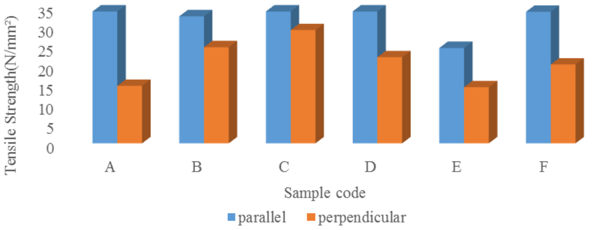

Figure 10: Tensile strength of pickled bovine hide

When fibres are aligned more in a direction normal to the stresses applied, then the tensile strength expected is low [18]. The values for tensile strength and percentage elongation are in agreement with those reported by Sivasubramaniana *et al.* [30] for cattle hide. Nevertheless, the results contradict those reported by Oliveira *et al.* [31] that both tear and tensile strengths are significantly higher when the sample is perpendicularly sampled than parallel sampled. For both tensile and tear strengths, these variations might be explained by the anisotropic arrangement of the collagen fibres in the hide matrix [31-32]. The degree of alignment of the collagen fibrils in the plane determines tear strength. High tear resistant materials have majority of their fibrils contained within parallel planes with little or no crossover between the top and bottom surfaces [33]. In the perpendicular sampling direction, percentage elongation decreased with increased thickness. It can be pointed out that, when the samples for the tearing analysis are taken in parallel direction, the direction of tearing is perpendicular and when the samples are taken perpendicularly the tearing direction is parallel.

There were variations in values of tensile and tear strengths and percentage elongation for samples taken from different positions as a function of distance from the backline, as shown by figures 5 to 10. Leather being an anisotropic material, its fibre bundles are oriented in diverse directions depending on the distance from the backbone, direction of sampling and the type of animal [14]. Samples taken closer to the backbone had higher tensile strength than those taken a distance from the backbone implying the influence of sampling position with respect to the backbone. These results agree with results obtained with Merino sheep leather that showed a consistent decrease as the distance from the backbone increased [34].

3.2 Effect of Tanning

Numerical values for both elongation and tear strength are higher in pickled than tanned hide (p = 0.000236 and 0.085 respectively in parallel and p = 0.093 and 0.176), whereas the values for tensile strength are numerically higher (p = 0.105 in parallel and 0.0344 in perpendicular) in tanned than in pickled leather regardless of the sampling directions as shown in figures 11-16.

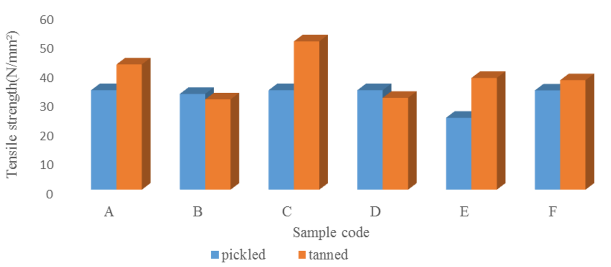

Figure 11: Tensile Strength of pickled and Tanned hide in parallel sampling

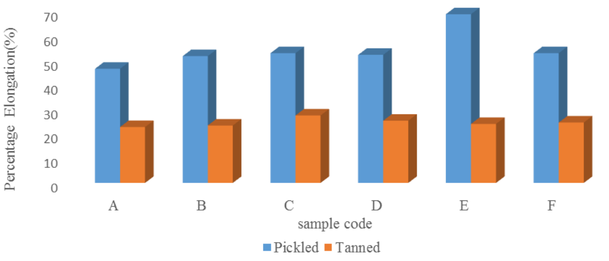

Figure 12: Percentage Elongation of pickled and Tanned hide in parallel sampling

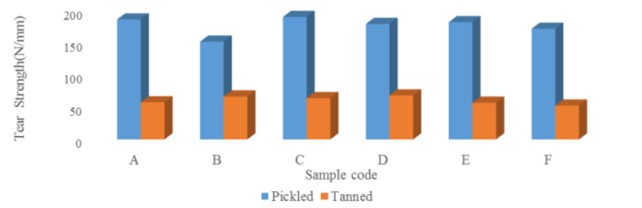

Figure 13: Tear Strength of pickled and tanned pelt in parallel

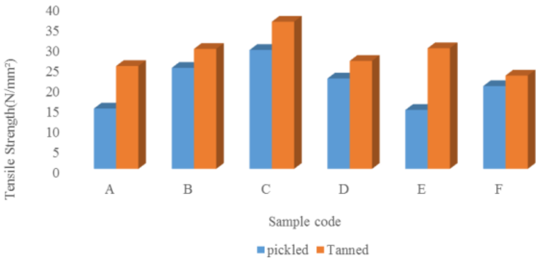

Figure 14: Tensile strength of pickled and tanned hide in perpendicular sampling

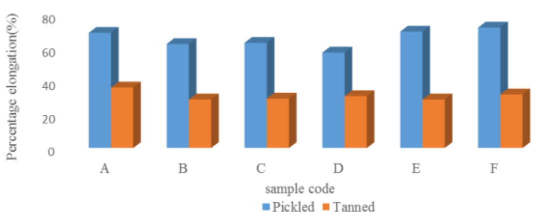

Figure 15: Percentage Elongation of pickled and tanned hide in perpendicular sampling

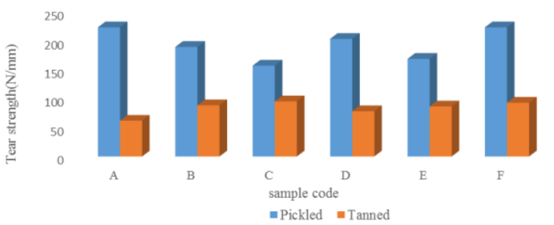

Figure 16: Tear strength of pickled and Tanned hide in perpendicular sampling

The standard means for tensile strength, tear strength and elongation of pickled hide were 26.61N/mm^2, 185.12 N/mm and 60.13% respectively while those of tanned hide were 33.48 N/mm^2, 72.27 N/mm and 28.02% respectively. These results agree with those reported by Ventre *et al*. [35] for soaked calfskin and leather. Different values of tensile strength between the pickled and tanned hide can also be explained by the fact that the cross-sectional area of the pickled hide is higher than for tanned hide due to the osmotic swelling effect of liming. Here, the collagen fibre bundles are loosened. This decreases the load bearing collagen fibre concentration per given area in the natural tissue in a water swollen state since the tensile strength is inversely proportional to cross-sectional area. The swelling also pushes the collagen fibres apart increasing the angle of weave hence decreasing the load transfer leading to a lower tensile strength. On the other hand, the chemical process of tanning introduces additional crosslinks into the collagen between the adjacent polypeptide chains [36]. This binds active groups to the functional groups of proteins [37] causing resistance to slippage of chains over each other and hence increasing the tensile strength [38].

4. Conclusion

The results have shown that tanning increases the tensile strength but significantly reduces both percentage elongation (elasticity) and tear strength of bovine hide. In addition, the percentage elongation and tear strength of samples cut perpendicular to the backline are significantly higher than for samples cut parallel to the backline. However, tensile strength for samples cut perpendicularly is significantly lower than for samples cut parallel to the backline. The measured values of tear strength, tensile strength and percentage elongation have shown that indigenous Kenyan Boran bovine hide are of relatively good quality based on the minimum quality standards by United Nations Industrial Development Organization (UNIDO) and British Standards.

5. Acknowledgements

This work was supported by a research grant, "6th Research Grant 2014/2015," by the National Commission for Science, Technology and Innovation (NACOSTI), Kenya. The procurement, processing and Instron testing was done at the Leather Development Centre, Kenya Industrial Research and Development Institute (KIRDI) with the technical assistance of Mr. Thomas Kilee and Mr. Larvin Sasia. The authors also acknowledge Prof. Ndiritu Gichuki and Mr. Kemei Solomon of Physics Department, Egerton University, for their assistance in proofreading this manuscript and Mr. Kabula Timothy for the financial assistance in the procurement of samples for this work.

6. Competing Interests

Authors have declared that no competing interests exist.

7. Authors' Contributions

All the four authors participated in the designing of the study, literature searches, data analyses, reading and approving final draft of the manuscript.

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Arthur S. Onyuka received B.Sc. and PhD in Leather Technology from University of Northampton, UK in 2004 and 2010 respectively. He is currently at Kenya Industrial Research and Training Institute as a Senior Research Scientist (Leather Division). Current areas of interest and research include mineral free tanning methods, product development, technology transfer and environmentally sound technologies.