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INFLUENCE OF CHROMIUM SULPHATE AND MIMOSA (ACACIA DEALBATA) POWDER ON THE QUALITY ATTRIBUTES OF LEATHER PRODUCED FROM THE RUMEN OF CATTLE, SHEEP AND GOAT

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ABSTRACT

The study was carried out to investigate the feasibility of converting the rumen of ruminant animals into leather. Rumen samples from cattle, sheep and goats where subjected to two tanning methods: chromium sulphate and mimosa powder, with five (5) replicates under controlled conditions. Chromium sulphate tanning procedures involved cleaning, liming, de-liming, degreasing, fleshing, drenching, pickling, tanning, basification, aging, re-tanning, neutralization and fat liquoring while the mimosa powder tanning procedures included: cleaning, liming, de-liming, degreasing, fleshing, drenching, tanning and fat liquoring. The mechanical operation like fixing, staking and toggling were also carried out for both tanning procedures. The resulting leathers underwent a series of tests which included: thickness, tensile strength, percentage elongation, ball burst test, water absorption, shrinkage temperature, stitch and tear, permeability to water vapour and apparent density. The results obtained showed that thickness, tensile strength, percentage elongation, shrinkage temperature and water absorption differed significant ($P<0.05$) across the treatments. However, it was observed that stitch and tear, ball burst test (maximum load and maximum distention), apparent density and permeability to water vapour were not significantly ($P>0.05$) affected. The outcome of this study establish that rumen from cattle, sheep and goat can be processed into leather for many end uses. Leather quality is affected by rumen type and tanning agent. Cattle rumen tanned with chromium sulphate exhibited the best performance while mimosa powder tanned rumen leathers offers a sustainable and natural alternative. Due to its unique texture, rumen leather can be crafted into various items including key cases, purses, bracelets and many more.

Keywords: Rumen, Tanning, Chromium Sulphate, Mimosa Powder, Leather

INTRODUCTION

Leather making is an important industrial sector worldwide that provides different finished quality of leather and leather product (Debora *et al.,* 2022). It is conventionally produced from raw hides after being subjected to various physical and chemical manufacturing process (Maher *et al.,* 2021). Historically, leather has been recognized as a sustainable material. As long as people consume meat, the raw materials for leather production will remain available (Akawu *et al.,* 2023).

Leather manufactured from the outer coverings of rare species of animals and other parts of animals that are not commonly used for making leather are known as novelty or exotic leather (Umme *et al*., 2015) e.g. rabbit skin, lizard skin, tiger skin, deer skin, crocodile skin, alligator skin, rumen etc. Novelty leathers are processed almost in the same manner as cattle's hide but because of their unique fiber structure, types of uses and having extra ordinary lucrative grain surface, they have to be given some special treatments (Farhad *et al.*, 2020).

Until the approach of Chromium sulphate (CS) tanning, there were very few options available for tanners such as aluminum tanning, smoke tanning, oil tanning and vegetable tanning (Karanam *et al.,* 2019).

Tanning is an art by which putrescible animal hides and skins are preserved from decay and converted into non-perishable substance known as leather (Sarka, 1962 and Mehmet *et al.*, 2012).

Mimosa powder (MP) which is a vegetable tanning agents involves treating the hides and skins with barks containing tannins (Kaloka and Moreki, 2011). Vegetable tanning agent is considered the "green tanning agent" because of its biodegradation (Jianzhong *et al*., 2009). According to Faxing *et al*. (2005) and Bi (2006), MP tanned leather has excellent fullness, moldering properties, wear resistance, air permeability and solidness. The use of the salts of the metal chromium was adopted in the nineteenth century and CS tanning became the main tanning agent for modern footwear and fashion leathers because it endowed leather with a comfortable feel and high hydrothermal stability (Choa *et al.*, 2014).

The rumen is the first chamber of the ruminant stomach. It is the largest chamber and has regular contractions to move food around for digestion, eliminate gases through eructation and send food particles back to the mouth for re-mastication. The rumen breaks down food particles through mechanical digestion and fermentation with the help of symbiotic microbes (Umme *et al.*, 2015). Whereas hide /skin leather has a uniform appearance, rumen leather has great variation in structure. It is textured and grooved because of the ridges of the smooth muscle pillars and papillae formation that line the stomach walls (Mandy, 2018).

Despite the slaughter of nearly 7 million cattle annually in Nigeria, majority of the hide is consumed as *ponmo* (the local term for edible hide) especially in the southern part of Nigeria. Therefore, most leather produced in Nigeria is from sheep and goats skin. This scenario has seriously increased the competition on the use of the animal hides and skin between man and the tanneries (Amakon, 2006).

Until now, rumen leather has little awareness especially in Africa, coupled with little or no technical know-how on the production techniques which has resulted into the use of hide and skin as the principal source of leather.

The hide and skin used in leather production is frequently marred or damaged during the life of the animal; damage caused by parasite, abrasion, dung, injection and tattoo affect the quality of the leather (Haines, 1978) but not the rumen which is an internal organ. This therefore means that, the rumen of the animal could be used to produce quality leather irrespective of the quality of the hides/skin.

Leather from rumen has high economic importance, market value, beauty and flexibility (Umme *et al.,* 2015). Rumen leather is more flexible than the conventional hide and skin although has similar qualities and production techniques (Umme *et al.,* 2015).

The aim of the study was to investigate the feasibility of turning the rumen of ruminant animals into leather.

MATERIALS AND METHODS

Experimental site

The study was conducted at the Nigerian Institute of Leather and Science Technology Zaria. Zaria is located at Latitude $11^0$12'N, Longitude $7^0$33' E and Altitude of 610m above sea level within the Northern Guinea Savanna (Metrological Unit, Institute of Agricultural Research, Ahmadu Bello University, 2016).

Collection of rumen / tanning recipes

The rumen of healthy cattle, sheep and goats were purchased from reputable local abattoirs within Zaria metropolis. The purchase was done very early in the morning post evisceration. The rumens were washed and transported to the Nigerian Institute of Leather and Science Technology for the tanning process. The recipes used for this study are: A full cattle rumen, five full sheep rumen and five full goat rumen.

Procurement of chemicals

All the chemicals used for the research including the chromium sulphate (CS) tanning agent were obtained from the Nigerian Institute of Leather and Science Technology (NILEST) tannery except mimosa (*Acacia dealbata*) powder which was sourced from Sharada industrial estate phase 1, Kano, Kano state.

The procured chemical are: Sodium chloride, water, sulphuric acid, formic acid, acetic acid**,** chrome**,** fat liquor**,** sodium bicarbonate, calcium hydroxide, bathing powder**,** detergent**,** sodium sulphide, ammonium sulphate and CS.

Rumen leather production

The steps and procedures carried out in the production of rumen leathers was as reported by Umme *et al* (2015). The weight of the rumens were obtained and percentages of chemicals used were based on the weight of the rumens.

The rumens were properly cleaned with water and weighed. The rumens were treated with 150%

Water and 3% lime Ca $(OH)_2$. This was done to achieve liming of the rumens. The rumens were agitated for 4 hours. The pelts were washed thoroughly with water and weighed.

The pelts were de-limed by treating with 50% water and 2% NH_3SO_4. They were agitated for 1 hour. The pH was 8. The pelts were degreased by washing with water and treating with 50% water and 1% degreasing agent (alcohol). They were agitated for 30 minutes and washed with enough water. Fleshing was achieved by using hands to remove the fat on the pelts so as to aid proper penetration of the tanning agents. Drenching was done by treating the pelts with 100% water and 7% NaCl. It was agitated for 10 minutes. 0.5% formic acid (1:10) was added and agitated for 30 minute. The pH was 4.3, it was left overnight. After drenching, the pelts were divided into two equal treatments with five replicates each for the tanning trial. The drenching liquor was also divided into two equal halves with each halve containing samples of treatment 1 and 2 respectively.

Each pelt was weighed before putting into the tanning drums.

Table 1: Treatment 1 (CS) Tanning

Treatments	Chemicals added	Dosage/description	Running duration	Remark
Pickling	Drenching liquor Sulphuric acid	- 0.5% at 1:10 of drenching liquor	30 min	The pH was adjusted to 3
Tanning	(CS)	6% was added to the picking liquor	2hrs	The penetration of CS was checked
Basification	Sodium bicarbonate (Na_2CO_3)	0.5% was added to the tanning liquor	30 min	Uniformity of the leather was checked
Ageing	-	-	48 hrs.	The leathers were properly washed with water after ageing
Re-tanning	Water CS	100% 4%	2 hrs.	Water was used to properly wash the leather after re-tanning
Neutralization	Water Na_2CO_3	100% 0.5%	1 hr.	The pH was 5.2. The leathers were properly washed with water
Fat liquoring	Water Animal Fat	100% at 55ºC 4%	1 hr.	-
Fixing	Formic acid	1% at 1:10 was added to fat liquoring solution	1 hr.	The leathers were properly rinsed with water and hung to dry for 1 day

Staking	-	-	-	This was done on the dry leathers by the aid of a staking machine
Toggling	-	-	-	The leathers where hung on the toggling machine for it to dry properly and to also stretch the leather

Table 2: Treatment 2 (MP) tanning

Treatments	Chemicals added	Dosage/description	Running duration	Remark
Tanning	MP	10% was added to the drenching liquor	30 min	The penetration of MP was checked and the leather was washed.
Fat liquoring	Water Animal Fat	100% at 55ºC 4%	1 hr.	-
Fixing	Formic acid	1% at 1:10 was added to fat liquoring solution	1 hr.	The leathers were properly rinsed with water and hung to dry for 1 day
Staking	-	-	-	This was done on the dry leathers by the aid of a staking machine
Toggling	-	-	-	The leathers where hung on the toggling machine for it to dry properly and to also stretch the leather

Leather analysis (physical test)

Conditioning.

The leather samples for physical test were conditioned according to IUP 3. They were kept in a drying chamber with atmospheric temperature of 20 ± 2^o C and relative humidity of 65 ± 2^oC for 48 hours before carrying out the physical analysis (UNIDO, 1996).

Measurement of thickness

It was measured according to the official method of IUP 4, UNIDO (1996). Four circular cycles were cut from various positions of the leather samples. Standard dial micrometer gauge was used. A triangle was drawn on each sample for the thickness to be measured. The thickness was measured from the positions of the triangle drawn 1cm from the edge. The grain side was placed upper most.

Measurement of tensile strength

The tensile strength of the leather samples was measured according to the official method of IUP/6 (UNIDO, 1996). The samples were cut parallel using a dumbbell shaped press knife. The jaw of the tensile machine was set 50 mm apart, and then the samples were clamped in the jaws, so that the edges of the jaws lie along the mid line. The machine was ran until the specimen brakes and the highest load reached was taken as the breaking load. The reading was evaluated based on this equation.

Tensile strength (kg/cm^2) = $\frac{\text{Breaking load(kg)}}{\text{Thickness(cm)X width (cm)}}$

Measurement of distention and strength of grain by ball burst test

The ball burst test was measured using a lasometer according to the official method of IUP/9 (UNIDO, 1996). A disc shaped specimen of the leather was firmly held with the grain side up between the clamping rings, with the spherical tip of the steel rod just touching the flesh surface. The specimen was moved downward against the rod, distending the grain of the leather immediately above the rod, while the surface was watched for incipient cracking and bursting. The force and distention values at the point at which the grain side of the leather cracked and bursted was observed and the force and distention value was recorded.

Measurement of percentage elongation at break

This test was measured according to the official method of IUP/6 (UNIDO, 1996). The sample was cut in a dump bell shape. The specimen was clamped between the jaws of the machine 50mm apart. The distance between the jaws was measured to the nearest millimeter and was taken as the initial length of the specimen for the purpose of the test. The distance between the pairs of the jaws was followed as the load increases with the aid of a meter rule. The distance between the pairs of the jaws when the load first reached a specific value was recorded. The length was taken as length of the load. The load and the length were noted and the percentage elongation was calculated as in the formula below.

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

Measurement of stitch and tear

It was measured according to the official method of IUP 8 (UNIDO, 1996).

The leather sample was shaped into rectangular shape and was then cut into two. The two cut pieces were stitched together at both ends. One end which was not stitched was hung on the instrument while loads of 0.5 kg, 1kg, 1.5kg etc. were applied at the other end to pull the stitch joint down to determine the stitch and tear strength of the leather sample, each load was allowed to hang for a period of 10 minutes.

Measurement of apparent density

The thickness was measured as in IUP 5(UNIDO, 1996). The diameter was measured at two positions i.e. at right angles using meter rule both on the flesh and on the grain surface. The mean diameter was calculated and the mass of the sample was measured in grams (g). The apparent density was calculated in g/cm^3.

$$\text{Apparent density} = \frac{\text{Mass(g/cm}^3)}{\text{Volume}}$$

Measurement of water absorption

It was measured according to the official method of IUP 7(UNIDO, 1996). In preparing the specimen for this test, the leather sample was cut in circular disc of 4.4mm diameter and then conditioned according to IUP3(UNIDO, 1996). The thickness of the disc was measured according to IUP4 (UNIDO, 1996). The weight of the disc was taken using a digital scale and placed in the Kubelka apparatus, the apparatus was filled with distilled water and the leather sample was immersed in the water for 1 hour after which the apparatus was turned at right angle to allow the water to drain to the bulb. Complete draining was achieved in 1 minute and the reading was taken. The procedure was repeated for intervals of 2hrs and 24hrs. The temperature of the water was maintained at room temperature. Water absorption (Q) was calculated using the formula bellow.

$$Q = \frac{V_i}{M} \times 100$$

V_1= Volume of water absorbed (ml), M= mass of the test sample (g).

Measurement of Shrinkage temperature

It is the temperature at which the leather starts to shrinks in water or over a heating media (Ali *et al.*, 2013). The shrinkage temperature was measured according to the official method of IUP/16 (UNIDO, 1996) using a micro shrinkage meter. A small strip of fibre was cut from each of the leather samples and placed on a water–groove microscope slide. The slide in-turn was placed on a heating stage along with a microscope mounted above the heating stage. The heating was measured at a constant temperature such that the rate of heating was 2ºC/min. The temperature at which the fibre shrinks to about one- third of its original length was taken as the shrinkage temperature of the leather.

Measurement of Permeability to water vapor

According to ASTM-D 5052 (ASTM, 2010) the water vapor permeability was measured after the test specimen was exposed to moist air on one side and dry air on the other side. The specimen was a circle piece of leather (55 mm in diameter), it was put in the apparatus for 24 hours then let in desiccant at 20 ± 2ºC. The apparatus was prepared previously by cleaning, drying and filling it with distilled water. The specimen was weighed to the nearest 0.001 g, at 0 and 24 hour. Water vapor permeability in grams per square centimeter per hour was calculated by dividing the change in the specimen weight to the specimen area.

$$\text{P(mg/cm}^2\text{/h)} = \frac{\text{Increase in weight in total time(g)}}{\text{Specimen ares(cm}^2) \times \text{Total tim(h)}} \times 100$$

Note**:** The process was repeated for all the other leather samples.

Statistical analysis

All data generated were subjected to two-way Analysis of variance (ANOVA) with repeated measures using the General Linear Model (GLM) procedure of SAS (2004) while the mean separation was done using Duncan Multiple Range test (DMRT) (Steel and Torrie, 1980).

Experimental design

The design of this study is a 3 × 2 factorial design.

Experimental model

$Y_{ijk} = \mu + A_i + B_j + (A \times B)_{ij} + e_{ij}$

Where Y_{ijk}= overall observation.

μ= Overall mean

A_i = Rumen types.

B_j= Tanning Agents.

$(A \times B)_{ij}$= Interaction.

e_{ij}= Random error.

RESULTS AND DISCUSSION

Table 3: Physical properties of rumen leathers tanned with Chromium Sulphate or Mimosa Powder

Tanning Agents	Chromium Sulphate			Mimosa Powder			SEM	P-value	M.V
Rumen types	Cattle	Sheep	Goat	Cattle	Sheep	Goat			
Av.Thickness (mm)	1.81^a	1.11^b	1.02^b	1.46^{ab}	1.02^b	1.59^a	0.13	0.0116	> 0.5
Av. Tensile strength(N/mm^2)	18.65^a	3.94^b	3.37^b	4.02^b	4.80^b	2.28^b	1.80	0.0005	> 12
Av. Elongation (%)	29.49^a	9.83^c	23.31^{ab}	12.22^{bc}	15.35^b	19.28^{ab}	3.13	0.0355	> 40
Av. Stitch and tear(kg/cm)	24.38	10.53	13.19	19.76	11.53	11.54	2.83	0.6236	30
Av. Maximum load(mm)	6.82	3.93	6.24	6.05	4.24	6.05	0.91	0.9482	-
Av. Maximum distention(mm)	15.32	8.85	10.68	8.24	10.02	15.70	1.63	0.5270	7
Av. Shrinkage temperature(ºC)	137.33^a	107.67^c	115.00^b	87.67^d	84.67^d	86.33^d	2.24	0.0002	75
Av. Apparent density(g/cm^3)	0.44	0.58	0.34	0.21	0.25	0.30	0.07	0.1513	0.38-0.51

Av. Water vapour permeability ($mg/cm^3/hr$)	3.21	7.29	1.48	4.89	9.84	1.48	0.33	0.0678	-

SEM: Standard error of the mean
[ab]Means along the same row with different superscript are significantly different(p>0.05)
M.V=Minimum value, Source (Kuria, 2015 and BASF, 2007).
Av: Average.

Physical properties of rumen leathers tanned with Chromium sulphate (CS) and Mimosa powder (MP) were summarized on table 3. Stitch and tear, maximum load and maximum distention (ball burst test), apparent density and water vapour permeability were not significantly different ($P > 0.05$) irrespective of which rumen type and tanning agent interact.

Significant differences ($P < 0.05$) were observed in the interaction between the two independent factors; rumen sources and tanning agents on the thickness, tensile strength, percentage elongation and shrinkage temperature of the rumen leather.

The thickness of the goat, and sheep rumen tanned with CS and that of sheep tanned with MP were observed to be lower ($P < 0.05$) than those of cattle rumen tanned with CS and goat rumen tanned with MP. However, the cattle rumen tanned with MP was not statistically different ($P > 0.05$) from any other rumen tanned either with CS or MP. All the rumen leathers produced in this experiment had thickness higher than the minimum value of >0.5 reported by Kuria (2015) and BASF (2007) for hide and skin. The variations observed in their thickness may be due to the structural composition of the different rumens (Umme *et al*., 2015).

The tensile strength of leather produced from the interaction of rumen type and tanning agents was observed to be significantly higher ($P<0.05$) on the leather produced from cattle rumen tanned with CS (18.65 N/mm^2) than any other rumen type tanned with any tanning agent. The variations observed in tensile strength for different rumen leathers for this study may be due to the type of feed consumed by the animals and the level of collagen on the rumen papillae (Kuria, 2015). In this study it was only the cattle rumen tanned with chromium that was seen to meet the minimum requirement for tensile strength (> 12) of hide/skin leather. The variations observed in tensile strength for different recipes for this study may be due to the type of feed consumed by the animal and the level of collagen on the rumen papillae (Kuria, 2015). Tensile strength was measured by Nasr (2011) in vegetable tanned leather (MP) to be 11.18 N/mm^2. Nasr (2005) found the estimate strength to be 11.38 N/mm^2 for MP tanned leathers. Tensile strength was measured to be 18.26 N/mm^2 for CS tanned leather (Nasr *et al*., 2013). Wahid *et al.*, *(*2016) reported the tensile strength of CS tanned leather to be 33.34 N/mm^2.

The interactive effect of sources of rumen and tanning agents was significant on percentage elongation of the leather produced. The value of percent elongation recorded with rumen of cattle tanned with CS was highest ($p > 0.05$) but this value (24.49%) was not statistically different from the values obtained for goat tanned with CS (23.31%) or MP (19.28%). The value of percent elongation of leather produced from rumen of sheep tanned with chromium (9.83%) was the least but this was similar statistically to that of cattle tanned with mimosa (12.22%).

Roigi *et al*., (2012) suggested that good quality leather should have a percentage elongation of ≥ 40%. Generally, the percentage elongation of all the experimental leather produced were below this value. The percent elongation reported for hides tanned with MP by Kanth *et al. (*2009) and Nasir, (2011) was 55% while Kuria (2015) reported a value of 56.08%. In another trial by Nasr *et al.* (2013) using chromium on hide, they reported also a high value of 58.45%. All these values were far higher than what was obtained in this trial. This may be due to the variation of material composition in raw rumen and raw hide/ skin (Umme *et al*., 2015).

Significant difference ($P< 0.05$) was also observed for the shrinkage temperature of the tanned rumens. The combined effect of rumen and chromium required higher ($P>0.05$) temperature to cause a significant shrinkage effect than when rumen combined with mimosa. The CS effect on rumen was noted to be more pronounced ($P> 0.05$) when it was for cattle rumen (137.33^oC) followed for goat rumen (115^oC) and sheep rumen (107.67^oC) in that order. Combining mimosa with any source of rumen lower the required temperature needed to cause shrinkage significantly ($p<0.05$).

Shrinkage temperature provide information about the degree of tanning because the better the cross linking reactions between the collagen fibres and the tannins, the higher the shrinkage temperature (Heiderman, 1993 and Kuria, 2015). Kuria (2016) reported that good quality leather should have a minimum shrinkage temperature of 75^oC and all the rumen leathers in this study had shrinkage temperatures above the minimum value. This is an indication that rumen of animals could make good quality leathers. The high shrinkage temperatures of the experimental leathers may be due to the high amount of fat in the rumen (Umme *et al*., 2015). It could also be as a result good cross linking that occurred between the collagen fibres and the tanning materials that caused the high shrinkage temperature (Heiderman, 1993). The higher values observed for CS tanned rumen leathers over those tanned with MP agrees with Anthony (1998) who reported that the shrinkage temperature of vegetable tanned leathers were usually below the boiling point of water (ranged from 65 to 85^oC), whereas CS tanned leather is usually above this point (more than 110 ^oC). Kuria (2015) and Nasr (2011) reported that the shrinkage temperature of mimosa tanned leather to be 83^oC and 76^oC respectively But Wahid *et al.* (2016) reported a shrinkage temperature of 105^oC for CS tanned leather.

Table 4: Interaction effect of sources of rumen and tanning agents on duration of water absorption

Parameters	Treatments	Duration (hour)	Water absorption (%)
Cattle rumen	CS	1	214.23^{d}
		2	229.63^{d}
		24	236.92^{d}
	MP	1	462.65^{a}
		2	483.56^{a}
		24	499.60^{a}
Goat rumen	CS	1	251.88^{c}
		2	260.81^{c}
		24	286.56^{c}
	MP	1	294.37^{b}
		2	289.06^{b}
		24	303.33^{b}
Sheep rumen	CS	1	196.74^{d}
		2	196.49^{d}
		24	217.69^{d}
	MP	1	330.16^{b}
		2	329.15^{b}
		24	351.52^{b}
		SEM	25.15
		P-value	0.0411

SEM: Standard error of the mean
^{abcd}Means on the same column with different superscript are significantly different(p>0.05)
MP: Mimosa powder
CS: Chromium sulphate

Cattle rumen tanned with MP had the highest capacity to absorb water at any given period than any other combination as shown in Table 4. It was observed from the results of this experiment that MP tanned leather absorbs water more than the CS tanned leather. Nasr (2011) determined water absorption after 2 and 24 hours in MP tanned leather to be 131.43 and 147.70 % respectively. The higher water absorption exhibited by MP tanned rumen leather may be due to the natural effect of the MP on leather (Kuria, 2015). Selvarangan *et al*. (1982) determined water absorption after 2 and 24 hours and found it to be 90.4% and 140.1% in mimosa tanned leather, respectively. However, Nasr (2005) determined water absorption after 2 and 24 hours in mimosa tanned leather to be 249.15 and 274.57% respectively. Nasr (2011) also determined water absorption after 2 and 24 hours in mimosa tanned leather to be 131.43 and 147.70 % respectively. Nasr *et al* (2013) determined water absorption after 2 and 24 hours for CS tanned leather and found it to be 196.15 and 239.18% respectively. The high amount of water absorb by these rumen leathers may be due to the structural composition of rumen (Umme *et al*., 2015).

Leather samples produced

Figure 1: Cow Rumen Tanned with CS

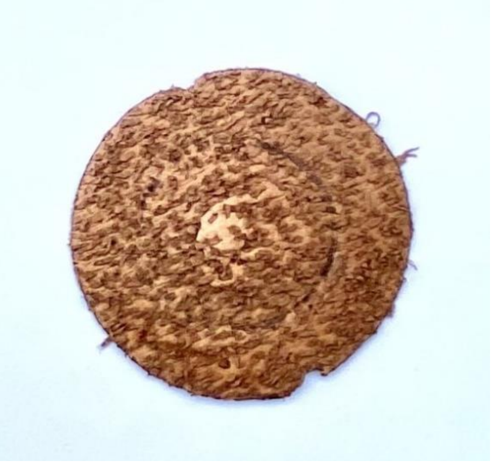

Figure 2: Cow Rumen Tanned with MP

Figure 3: Sheep Rumen Tanned with MP

Figure 4: Sheep Rumen Tanned with CS

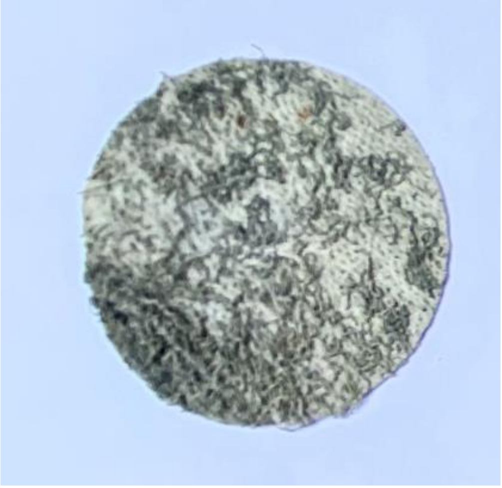

Figure 5: Goat Rumen Tanned with CS

Figure 6: Goat Rumen Tanned with MP

CONCLUSION

The study concluded that thickness (mm), tensile strength (N/m^2), percentage elongation (%), shrinkage temperature (^OC) and water absorption (hr.) varies across the treatments. However, no difference was observed in stitch and tear (kg/cm), ball burst test (maximum load and maximum distention (mm)), apparent density (g/cm^3) and permeability to water vapour ($mg/cm^3/hr$). The outcome of this study establish that the rumen of cattle, sheep and goat can be processed into leather. The physical analysis carried out on the leather samples indicated that cattle rumen tanned with CS gave the best result as against other treatments. However, MP tanned rumen leather remains a viable option for those prioritizes natural look of the leather and sustainable process. This is because it is a natural tanning agent and it is also biodegradable.

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