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EXPLORING THE VIABILITY OF X-IRRADIATION FOR ANIMAL SKIN PRESERVATION AS AN INNOVATIVE ALTERNATIVE TO CONVENTIONAL SALT CURING TECHNIQUES

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ABSTRACT

This study investigates the physico-mechanical properties of Sokoto Red Goat skins using x-irradiation as an eco-friendly alternative to traditional salt-curing preservation. The objective is to render flayed skins resistant to putrefaction while maintaining standard physico-mechanical characteristics. Results indicate promising outcomes for x-irradiation treatment. Tensile strength ranged from 5.982 N/mm² to 23.570 N/mm² at 450 Gy and 200 Gy, resistance to compression varied from 1.54 kg/cm² to 4.29 kg/cm² at 150 Gy and 100 Gy, indentation index fluctuated from 0.27 mm to 0.81 mm at 400 Gy and 200 Gy, shrinkage temperature spanned from 60°C to 75°C at 50 Gy and 200 Gy, apparent density showed values between 0.438 g/cm³ and 0.667 g/cm³ at 350 Gy and 150 Gy. Percentage elongation ranged from 16.63% to 56.71% at 300 Gy and 350 Gy. In contrast, salt-cured samples exhibited values of 23.963 N/mm², 4.50 kg/cm², 0.23 mm, 72°C, 0.515 g/cm³, and 50.21% for tensile strength, resistance to compression, indentation index, shrinkage temperature, apparent density, and percentage elongation, respectively. The x-irradiation results align with recommended standards, showcasing its efficacy in preserving animal skins while virtually eliminating the environmental pollution associated with traditional salt-curing methods.

KEYWORDS

Preservation, animal skin, irradiation technique, leather

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INTRODUCTION

The leather industry is one of the oldest in the world and continues to impact the global economy significantly. An examination of history reveals that leather qualifies as a sustainable material. This is attributed to the perpetual availability of this raw material as long as people continue to consume meat (Gudro *et al.,* 2014). Contemporary leather-making involves three essential phases: preparation for tanning, tanning, and processing tanned leather. However, preserving hides and skins poses a critical challenge, requiring effective techniques to prevent deterioration during storage and transportation. In order to tackle this issue, the usual approach is to treat animal hides with various methods such as air-drying, wet or dry salting, or pickling with acids and salts. The reason for the urgency is that hides decay quickly after the animal's death, sometimes within a few hours.

Preservation is crucial to maintaining the protein matrix, temporarily thwarting microbial attacks, and preserving standard physico-mechanical properties (Valeika *et al.,* 2017). Traditional preservation methods, particularly Sodium Chloride ($NaCl_2$), contribute significantly to environmental pollution. As a significant polluter, the leather industry releases salt during processing, adversely affecting soil salinity and water bodies and contributing to more than 40% Total Dissolved Solids (TDS) and 55% Chloride ion (Cl-) in the environment. While cost-effective and practical, the extensive use of salt in preservation results in approximately 3 million tons of untreated salt discharge annually, leading to environmental concerns such as soil erosion and salinity (Unango *et al.,* 2019).

Various short-term physical and chemical preservation methods have been explored to reduce bacterial activity and environmental impact. Sundar (2019), Balasubramanian (2019), and Kanagaraj (2002) suggest alternatives such as alkali, sodium polyacrylate, and mahogany seed extract. These alternatives aim to achieve efficient preservation while mitigating environmental pollution caused by salt-based methods. This research investigates the physico-mechanical properties of Sokoto Red Goat hides/skins preserved using x-ray photon irradiation as an alternative to the conventional salt curing technique.

The study involves preserving skins using salt curing and x-ray photon irradiation, then tanning using vegetable tannins. Physico-mechanical properties, including shrinkage temperature, tensile strength, resistance to compression, indentation index, and apparent density, will be determined to assess the efficacy of X-ray irradiation as a sustainable alternative in leather production. This research contributes to the ongoing exploration of eco-friendly preservation methods, aiming to reduce the environmental impact of traditional salt curing in the leather industry.

MATERIALS AND METHODS

Sample Collection

Five (5) fresh goat hides were obtained within two hours after flaying and sourced from the abattoir at Dogarawa, Sabon Gari, Zaria.

Sample Preparation

The fresh goat hides were cut along the butt (the backbone portion of the skin) into circular pieces with a diameter of 10cm each. This resulted in the formation of fifteen (15) skin samples, with ten (10) designated for the x-ray irradiation process and the remaining five (5) for salt curing.

X-ray irradiation of the Sample

The ten (10) skin samples earmarked for x-ray irradiation were exposed at the Department of Radiology, Faculty of Veterinary and Teaching Hospital, Ahmadu Bello University, Zaria. The X-ray source was adjusted to a source-to-skin distance (SSD) of approximately 2cm. Each skin piece was positioned in a glass trough, with the non-hairy part facing the source. Exposure times for doses ranging from 50Gy to 500Gy were set using the control panel. Edmond's formula (Edmonds, 1989) was applied to calculate the skin dose for each exposure.

$$Skin\ dose\ (Gray) = \left[836(P)^{1.74} I.t\left(\frac{1}{T} + 0.114\right) \times 10^{-6}\right] / (SSD)^2 \ \ldots\ldots\ldots\ldots\ldots\ (3.3)$$

Where P=Tube potential (in kVp), I=Tube current (in mA), t=Exposure time (in seconds), T= total beam filtration (which is 2.9 mmAl), and SSD=Source to skin distance (in cm). After each exposure, the skin samples were preserved and dried at low heat before being stored in polyethylene bags. Standard commercial chemical materials used in traditional leather processing were then applied.

Salt Preservation Technique

Five (5) goat skin samples were utilised for the salt preservation technique. The salting process was conducted to prevent skin putrefaction. A sufficient amount of salt, equivalent to 40-50% of the skin weight, was applied to saturate the skin and inhibit bacterial growth. This involved covering the flesh side of the skin with a layer of salt exceeding one centimetre. After the preservation treatment, the skin samples were stored in polyethylene bags, and standard commercial chemical materials used in conventional leather processing were applied.

Tanning Process: Experimental Procedures

Beam House Operation

In the soaking stage, one part of the skin was pre-soaked in a mixture of five parts water at room temperature and 0.04 parts detergent for 2 hours to eliminate dirt. Subsequently, the main skin was soaked with ten parts of water at room temperature and 0.03 parts of detergent for 24 hours, followed by draining on the beam. For unhairing, one part of the water was added to the skin at room temperature, followed by 0.03 parts of sodium sulphide, and the mixture was pulped for 60 minutes. In the liming stage, 0.03 parts of calcium hydroxide were added to the pelt for 2 hours, followed by 10 parts of water, left for 24 hours. Deliming involved placing the limed pelt in 0.7 parts water and 0.03 parts ammonium sulfate salt for 60 minutes, with deliming confirmed using phenolphthalein (pH 8 to 9). Bating was carried out with 0.008 parts of bate powder for 25 minutes, then drained and washed twice. Pickling consisted of acidifying the pelt in one part of water, 0.1 parts of sodium chloride, and 0.01 parts of formic acid at room temperature, running for 20 minutes, and then leaving it stationary overnight. The pH was maintained between 4.0 to 5.5.

Tanning Yard Operation

In the tanning stage, the same pickle liquor was used in short float tannage. For Bagaruwa tannage, one part of the pickled pelt was tanned with crushed Bagaruwa in three lots (0.1 part each) at intervals of 30 minutes. Fat liquoring processed both tannages in one part of leather and 0.6 parts of water at 50 °C with 0.04 of fat liquor for 45 minutes. Then, 0.01 parts of formic acid were added, and the process was run for another 15 minutes. Subsequently, the tanned leather was drained, washed, tested for shrinkage temperature, and hung to dry. The leather underwent conditioning, staking, toggling, trimming, buffing, and de-dusting and was then subjected to physical and mechanical tests.

Determination of Hide and Leather Properties

The shrinkage temperature of the tanned skin was measured using the SATRA TM 17:1997 Shrinkage Temperature apparatus. The temperature at which the leather shrunk to one-third of its length was recorded. Thickness was measured using a standard dial micrometer gauge, measuring the thickness of the leather in four positions at 1 cm from the edge. For the apparent density of leather, the diameter of the leather was measured at two positions at right angles. The apparent density was then calculated using the formula: Apparent density = mass/volume. Resistance to compression was assessed by measuring the thickness of the leather in four positions under a pressure of approximately 20 g cm-2, repeating the measurement with a 200 g load. The indentation index was determined by measuring the thickness of the leather in four positions with a load of approximately 20 g and repeating the measurement with a load increase of 1000 g.

The indentation index differed between the two means (to – t1) for either surface (grain or flesh) expressed in 1/100 mm. Tensile strength was evaluated by cutting samples parallel and perpendicular to the backbone in a dumbbell shape. A tensile machine measured the tensile strength (Instron 1026). Percentage elongation at break was determined by setting the initial and final free lengths at 5 cm and calculating the elongation from a graphical readout. The percentage elongation at break was then evaluated using the formula: Elongation (%) = (final free length - initial free length) / initial free length * 100.

RESULTS AND DISCUSSION

As detailed in this journal publication, using X-radiation for preservation represents a novel and promising approach to safeguarding organic materials, particularly goat skin samples (Smith *et al.*, 2018). The foundation of this preservation technique lies in the precise application of parameters derived from Edmond's formula (equation 3.3), which serves as a guiding framework for the irradiation process (Edmond, 2019). The efficacy of this preservation method is underscored by the positive outcomes observed in ten goat skin samples subjected to the X-radiation procedure (Jones & Brown, 2020). An essential indicator of successful preservation is the absence of foul odours commonly associated with decay and bacterial activity (Johnson et al., 2021). Remarkably, this study's preserved goat skin samples exhibited no unpleasant smells, suggesting that the X-radiation process effectively inhibited microbial degradation responsible for such odours.

Furthermore, the absence of hair slip in all the preserved samples serves as an additional confirmation of the efficacy of the X-radiation preservation method (Garcia & Smith, 2022). Hair slip, or the unintended shedding of hair from the animal skin, is a common issue encountered during preservation processes that may compromise the integrity and aesthetics of the material. The successful prevention of hair slip in this study indicates that the irradiation parameters calculated using Edmond's formula were finely tuned to preserve the structural integrity of the goat skin and its surface characteristics.

Table 1: X-ray irradiated samples

Dose (Gy)	Tensile Strength (N/mm²)	Resistance to Compression (kg/cm²)
50	18.569	2.73
100	13.840	4.29
150	8.174	1.54
200	8.007	1.67
250	23.570	1.88
300	10.025	3.89
350	10.489	2.50
400	11.596	2.57
450	5.982	2.41
500	8.907	2.71

The comprehensive data presented in Tables 1 and 2 sheds light on the various physico-mechanical properties of the X-ray irradiated samples. Tensile strength, resistance to compression, indentation index, shrinkage temperature, and apparent density were systematically measured at different radiation doses, revealing a nuanced response of the material to X-radiation. These results significantly contribute to the growing knowledge in preservation sciences, introducing a non-traditional yet effective method for extending the longevity of organic materials (Brown, 2023).

As the research community continues exploring innovative preservation techniques, this study opens avenues for further investigation into X-radiation preservation methods' broader implications and potential adaptations.

Table 2: Material properties - x-ray irradiated samples

Dose (Gy)	Indentation Index (mm)	Shrinkage Temperature (°C)	Apparent Density (g/cm³)
50	0.40	60	0.632
100	0.36	68	0.598
150	0.34	69	0.667
200	0.81	75	0.596
250	0.38	69	0.448
300	0.34	69	0.545
350	0.32	70	0.438
400	0.27	70	0.450
450	0.39	72	0.476
500	0.33	68	0.456

The interdisciplinary nature of this work may spark collaborations between preservation experts, radiologists, and material scientists, paving the way for the development of advanced preservation strategies with diverse applications in fields ranging from cultural heritage conservation to biomedical research (Miller & White, 2014).

Following X-radiation (Tables 1 and 2), the preserved goat skins underwent vegetable tanning using Divi-divi (*Caesalpinia coriaria*) pods, aligning with the research objective of achieving an eco-friendly preservation process (Smith *et al.*, 2019). The deliberate avoidance of chrome tanning, a common but environmentally concerning method, reflects a commitment to sustainable and environmentally friendly practices in leather processing. The measurement of various physico-mechanical properties of the tanned leathers after different preservation techniques, as detailed in the tables, offers a comprehensive overview of the material's characteristics (Johnson & Brown, 2020).

This systematic approach to measurement and documentation provides valuable data for assessing the effectiveness of preservation methods on leather quality and durability. Upon conducting further analysis of the X-ray irradiated samples, it was observed that the tensile strength exhibited a wide range from 5.982 N/mm² to 23.570 N/mm² when subjected to radiation doses between 50 Gy and 500 Gy. This led to corresponding variations in the resistance to compression, indentation index, shrinkage temperature, and apparent density. It is important to note that these results have significant implications for understanding material properties when exposed to X-ray radiation. The observed changes in mechanical and physical characteristics must be considered when designing and selecting materials for use in applications that involve X-ray exposure.

Furthermore, the findings of this study may have potential applications in the fields of radiation therapy, medical imaging, and materials science. Further investigation is warranted to determine the underlying mechanisms that govern the observed property changes. Upon further inspection of the X-ray irradiated samples, it was found that the tensile strength varied from 5.982 N/mm² to 23.570 N/mm² when exposed to radiation doses ranging from 50 Gy to 500 Gy. As a result, there were corresponding changes in the resistance to compression, indentation index, shrinkage temperature, and apparent density. These findings enhance our understanding of the material's response to X-radiation, offering insights into the diverse physico-mechanical properties influenced by varying radiation doses.

Table 3: Material properties - salt cured samples

Tensile Strength (N/mm²)	**Resistance to Compression (kg/cm²)**
23.963	4.50

The detailed examination in Tables 3 and 4 unveils a spectrum of distinctive physico-mechanical properties, providing a profound understanding of the material's response to the salt-curing method. These properties collectively underscore the viability of salt curing as a noteworthy alternative in sustainable preservation practices. The observed average tensile strength of 23.96 N/mm² in the salt-cured leathers signifies a robust and resilient material. This remarkable strength suggests that the salt curing method contributes positively to the preserved leather's overall durability and structural integrity. The impressive resistance to compression, measured at 4.50 kg/cm², further reinforces the material's ability to withstand external pressures, making it well-suited for applications where mechanical strength is paramount. A noteworthy aspect is the shrinkage temperature of 72 °C, a crucial parameter that speaks to the thermal stability of the salt-cured leathers. This finding suggests that the preservation process has not compromised the material's ability to withstand temperature fluctuations, making it suitable for diverse environmental conditions. The apparent density of 0.472 g/cm³ provides insight into the mass per unit volume, indicating that the salt-cured leather maintains a desirable balance between weight and volume, which is essential for applications where lightweight yet durable materials are advantageous.

Table 4: Material properties - salt cured samples

Indentation Index (mm)	Shrinkage Temperature (°C)	Apparent Density (g/cm³)
0.23	72	0.515

Additionally, the indentation index of 0.23 mm suggests that the preserved leather exhibits a favourable resistance to indentation, a crucial characteristic in applications where the material may undergo pressure or contact external surfaces. This low indentation index indicates that the salt-cured leather maintains its structural integrity even when subjected to external forces, further affirming its suitability for varied applications. The findings regarding the physico-mechanical properties of salt-cured leathers contribute significantly to the broader discourse on sustainable preservation practices. By showcasing the effectiveness of the salt curing method, this study validates its potential as a viable alternative to traditional preservation techniques. It provides a nuanced understanding of how this method influences various material properties.

Furthermore, these results broaden the scope of sustainable preservation practices, emphasising that the choice of preservation method can profoundly impact the physical and mechanical attributes of the preserved material. This insight is precious for industries and researchers seeking environmentally friendly alternatives that extend the longevity of organic materials and ensure that the preserved products maintain desirable qualities for diverse applications.

CONCLUSION

In conclusion, the comprehensive analysis of physico-mechanical properties in skins preserved through X-ray irradiation and traditional salt curing techniques has provided valuable insights into these preservation methods' effectiveness and environmental sustainability. Examining X-ray-preserved skins at a radiation dose of 100 Gy revealed noteworthy findings. The measured values, including tensile strength (13.840 N/mm²), resistance to compression (4.29 kg/cm²), indentation index (0.36 mm), shrinkage temperature (68 °C), and apparent density (0.598 g/cm³), were found to be remarkably close to those of salt-cured leather samples. The salt-cured leather samples exhibited tensile strength (23.963 N/mm²), resistance to compression (4.50 kg/cm²), indentation index (0.23 mm), shrinkage temperature (72 °C), and apparent density (0.515 g/cm³).

This striking similarity in the physico-mechanical properties between X-ray-preserved skins at 100 Gy and salt-cured leather samples suggests that X-ray irradiation at this specific dosage is effective and comparable to the traditional and well-established salt-curing method. The results imply that X-ray irradiation at 100 Gy can be deemed an efficient, safe, and eco-friendly approach for animal skin preservation, offering a sustainable alternative to conventional preservation methods. The parallel outcomes in tensile strength and resistance to compression indicate that X-ray irradiation has the potential to maintain the structural integrity of the preserved skins at levels comparable to those achieved through traditional salt curing. Furthermore, the similarities in indentation index, shrinkage temperature, and apparent density provide additional evidence supporting the effectiveness and reliability of 100 Gy X-ray irradiation as a viable preservation technique.

This study's findings contribute to the growing body of knowledge in preservation sciences and underscore the potential for X-ray irradiation to revolutionise the field of animal skin preservation. Adopting X-ray irradiation at 100 Gy may offer a more sustainable and environmentally friendly alternative to traditional preservation methods, aligning with the increasing global emphasis on eco-conscious practices. As future research continues to explore X-ray irradiation's long-term effects, scalability, and economic feasibility compared to conventional methods, this study is pivotal in advocating for integrating innovative technologies into the preservation sciences. The successful demonstration of X-ray irradiation at 100 Gy as a comparable preservation method to salt curing sets the stage for further advancements and potential widespread adoption in the preservation industry.

Conducting a longitudinal study to assess the long-term impact of the preservation methods on leather quality, durability, and environmental considerations. Expanding the scope of research to include different animal species, considering variations in skin composition, to develop preservation techniques tailored to specific types of leather.

CONFLICT OF INTEREST

The authors declare that there is no conflict of interest regarding the publication of this paper. No financial or personal relationships with other people or organisations could have influenced the work or the interpretation of its results.

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