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APPLICATION OF IONIZING RADIATION IN THE PRESERVATION AND CONSERVATION OF TAXIDERMIED ANIMAL SKINS IN NATURAL HISTORY MUSEUMS

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Abstract: The great interest in the development of research involving ionizing radiation aims to significantly increase the conservation of the skins of taxidermized animals, both for scientific collections and on display, causing their infection and disinfestation, without altering their originality, reducing the use of chemical products, presenting a safe and efficient technology. The preservation of taxidermied mammals has been widely used for educational, scientific and Museum display purposes. However, prolonged exposure to environmental factors or the excessive use of chemicals to store these materials in the collection can affect the integrity of the skin of these animals. In this study, we investigated the effects of gamma radiation on the structure and composition of the skin of taxidermied mammals, with the aim of contributing to a better understanding of conservation processes and the potential risks they may entail. Taxidermy is an animal preservation technique that has been used for centuries, allowing specimens to be arranged in their natural form and/or preserved for scientific studies. Samples of skin from animals from the Brazilian flora were selected, deer, coati, prawn and bison, and these samples were irradiated at doses of 1, 3, 5, 10 and 15 kGy. After gamma irradiation, they were characterized by colorimetry, scanning electron microscopy (SEM), optical microscopy (OM), infrared microscopy (FTIR) and mechanical analysis. The results show that the doses of gamma irradiation that the samples were subjected to did not compromise their physical and chemical integrity. This indicates the possibility of using gamma radiation for disinfestation and disinfection.

Keywords: Taxidermy 1, Gamma Radiation 2, Preservation 3, disinfestation 4.

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APLICAÇÃO DA RADIAÇÃO IONIZANTE NA PRESERVAÇÃO E CONSERVAÇÃO DE PELE DE ANIMAIS TAXIDERMIZADOS EM MUSEUS DE HISTÓRIA NATURAL

Resumo: O grande interesse no desenvolvimento da pesquisa envolvendo a radiação ionizante tem como objetivo aumentar significativamente a conservação das peles de animais taxidermizados, tanto para os acervos científicos como em exposição, visando sua desinfecção e desinfestação, sem alterar sua originalidade, diminuir o uso de produtos químicos, apresentar uma tecnologia segura e eficiente. A preservação de mamíferos taxidermizados tem sido amplamente utilizada para fins educacionais, científicos e exibição em museus. Entretanto, a exposição prolongada a fatores ambientais ou o uso excessivo de produtos químicos para o acondicionamento desses materiais no acervo, pode impactar a integridade da pele desses animais. Neste estudo, investigamos os efeitos da radiação gama na estrutura e composição da pele dos mamíferos taxidermizados, com o objetivo de contribuir para uma melhor compreensão dos processos de conservação e potenciais riscos que possam ocasionar. A taxidermia é uma técnica de preservação de animais que tem sido empregada há séculos, permitindo que exemplares sejam exibidos em sua forma natural e/ou conservados para estudos científicos. Foram selecionadas amostras de peles de animais da flora brasileira, cervo, quati, gamba e bisão, essas amostras foram irradiadas nas doses 1, 3, 5, 10 e 15 kGy. Após a irradiação gama, foram caracterizadas por colorimetria, microscopia eletrônica de varredura (MEV), microscopia ótica (MO), microscopia no infravermelho (FTIR) e analises mecânica. Os resultados apresentam que as doses de irradiação gama que as mostras foram submetidas não comprometeram a integridade físico química das mesmas. Isso indica a possibilidade do uso para da radiação gama para desinfestação e desinfecção.

Palavras-chave: Taxidermia 1, Radiação Gama 2, Preservação 3, desisfestação 4.

1. INTRODUCTION

The practice of taxidermy is essential for the preservation and display of animals in natural history museums, however, taxidermied skins are susceptible to various deterioration agents [1]. Among them are pests, light radiation, temperature, humidity, pollution and dirt. The objective is to determine safe dose intervals that do not cause damage to the material. Prevention is crucial to prevent damage caused by pests.

Once contamination of the collection or of any specimen is confirmed, immediate actions are necessary to minimize damage and stop contamination, as biological agents of deterioration develop quickly and delays in intervention can result in extensive and irreversible losses [2].

The application of radiation, both ionizing and non-ionizing, can have beneficial or harmful effects depending on the intensity, duration and type applied. It is essential to ensure that specimens are not exposed to harmful levels of radiation, as this may accelerate deterioration, fading or cause irreparable damage to the skin and structure of animals.

1.1. Taxidermied animals

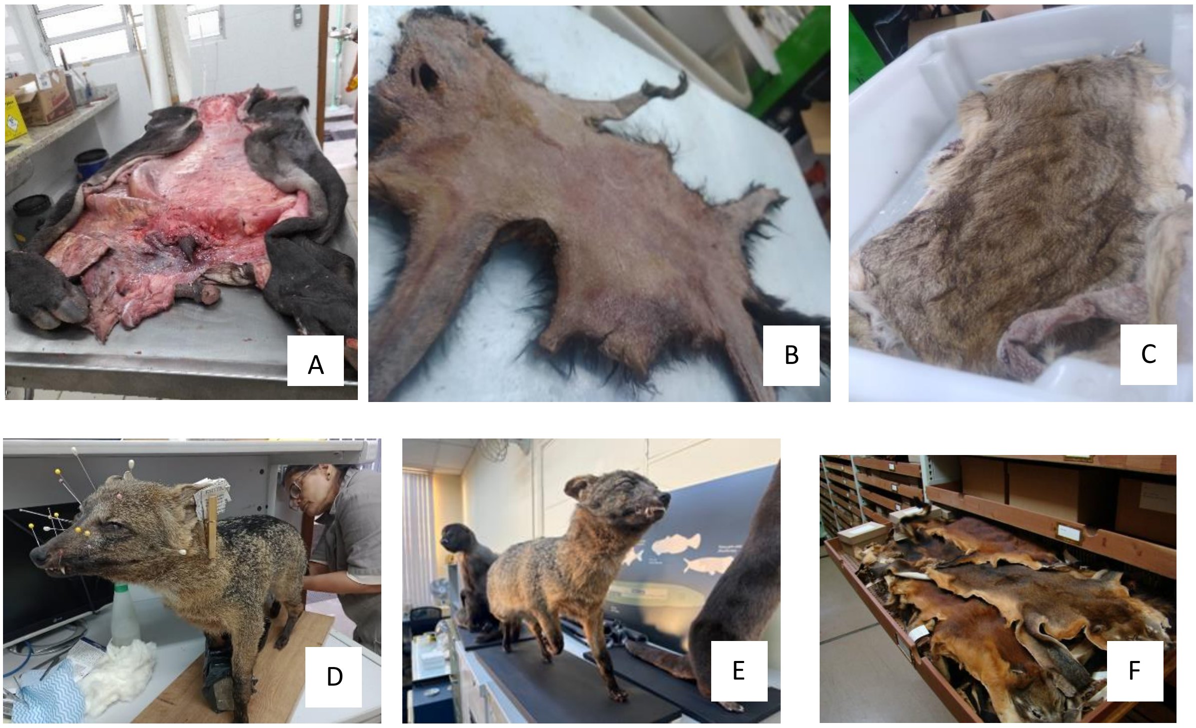
The process of mammalian taxidermy is an art and science that involves preserving and assembling the bodies of animals for display or study. Taxidermy is performed by professionals called taxidermists, who have skills in anatomy, sculpture, painting and preservation techniques.

1.2. Taxidermy

Taxidermy aims to promote the preservation of different dead species, in process to be extinct or not keeping the natural characteristics from the animal when finalized. Thus, it requires from the taxidermist knowledge about various subject (biology, art, legislation and anatomy) enabling the final products, made from animals which died naturally or run over, promotes environmental awareness [3].

Taxidermy consists of preparing an animal's skin for scientific study or display, figure 1. Whatever the animal, method or purpose of taxidermization, the following principles apply [4].

Figure 1: A) Removal of internal organs; B) Cleaning and disinfection; C) Skin preparation; D) Assembly of the mannequin; E) Artistic taxidermy exhibition; F) Scientific Taxidermy Exhibition.



1.3. Study of Taxidermied Mammal Skins

The examination of taxidermied mammal skins provides a unique opportunity to analyze the morphological and adaptive characteristics of different species within the class Mammalia. This study focuses on the skins of four distinct mammals: the coati (Nasua nasua), the deer (Cervus elaphus), the bison (Bison bison), and the opossum (Didelphis marsupialis). These specimens were selected due to their diversity in terms of habitat, behavior, and evolutionary adaptations [5-6-7].

The coati, belonging to the Procyonidae family, has dense fur adapted for both arboreal and terrestrial life. Its fur is a crucial feature for its daily activities and protection against various environmental conditions. Dorsal and nuchal hairs are curved to wavy, length (3-4cm) and medium thickness, typically bicolored (predominantly white with black distal third). Smaller, more rectilinear ventral hairs. The tails are also bicolored, but with white restricted to the proximal third and, therefore, black predominates [4]. The coati's skin is covered with dense, soft fur. Coat color varies, but is generally grayish-brown over most of the body, with a white facial mask extending from the muzzle to the forehead and around the eyes.

The deer, represented by the red deer, displays a fur that varies in density and color throughout the seasons, adjusting to climatic changes and environmental challenges. Dorsal and nuchal hairs are small (2cm), ventral and caudal hairs are medium (2-4cm), straight to slightly curved, of medium thickness, reddish-brown (brown) in color and the proximal third is beige. The ventral hairs are lighter (yellowish-brown to beige). Coloring often helps with camouflage and can change with the seasons to better blend into the environment. Deer coats perform several functions, including regulating body temperature, camouflaging against predators, and attracting mates during mating season. These varied coat characteristics are adapted to the specific environment and behavior of each deer species.

The bison, a large herbivore native to North America, features thick and resilient fur, ideal for enduring the cold climates of temperate habitats. Its fur provides thermal insulation and is a distinctive characteristic of the species. The skin of a bison, also known as the American buffalo, is characteristic and adapted to withstand the harsh climatic conditions of the North American plains. The bison's skin is generally dark brown to grayish brown. The color can vary according to the season, with the fur tending to be darker in winter and lighter in summer.

The opossum, a marsupial from the Didelphidae family, has fur that varies in color and texture, adapted to a wide range of environmental conditions, from tropical forests to more open areas. The opossum's skin performs several functions, including thermal insulation, camouflage, and visual communication with other members of the same species. It's important to note that opossums are marsupials, meaning they carry their young in an abdominal pouch, called a marsupium, which is covered in soft, warm skin rather than hair. Opossums have grayish or almost black fur. The ears are light in color, and the body color is gray, with two layers of hair, the lower one with light hair and the upper one with thick black hair. On the head you can see three black stripes, one central and two over the eyes. The species stands out for its large, black, hairless ears. The dorsal region has two layers of hair, an inner layer with light-colored hair and an outer layer with longer, black or gray hair. The ventral region is light in color.

1.4. Gamma Irradiation

The gamma radiation coming from Cobalt-60 does not have enough energy to destabilize the nucleus of the atom, that is, it is a radiation whose energy is below the activation threshold of most elements, unlike what occurs, for example, in bombardment by neutrons inside a nuclear reactor, which can leave traces of radioactivity in the material. The main characteristic is high penetration; low dose rate, the dose absorbed by the products is the fundamental parameter to be controlled; longest irradiation time: hours/days. When administered correctly, gamma radiation does not alter the structure of the treated materials, preserving their original characteristics [8]. The treatment is carried out at room temperature, there is no quarantine period after irradiation. For other works, researchers study the conditions of the object to be irradiated (properties, dimensions, state, etc.) to define the dose and time spent in the Cobalt-60 chamber. For each desired benefit, the minimum dose and maximum dose applicable to the product, and the feasibility of application in the irradiator, are decided. Gamma radiation offers an advanced and effective approach to the conservation and preservation of collections, ensuring the protection and longevity of valuable and sensitive materials. With proper use, it can play a crucial role in maintaining historical, cultural and scientific collections [9-10-11].

The gamma radiation dosage required for the irradiation of taxidermized animals' skin can vary depending on several factors: including skin type; the size of the specimens; the condition of the skin; the purpose of irradiation. Gamma irradiation is primarily used for disinfection and preservation, but precise doses can vary. For disinfection, where the aim is to eliminate pathogenic microorganisms such as bacteria and fungi, a relatively low dose of gamma radiation may be sufficient, generally in the dose of 1 to 10 kilograys (kGy).

2. MATERIALS AND METHODS

2.1. Materials

Whole mammal skins from the coati (QT), deer (CV), bison (BS), and opossum (GB), all taxidermied and in an open state, donated from the collection of the Museology Section of the USP Zoology Museum. Materials also include a scalpel, scissors, plastic bags, labels, a stylus, clips, cardboard templates (animal doll), pins, adhesive tape, a leather thinning beveler, and a press.

2.2. Methods

The samples were irradiated using the ionizing radiation process using doses of gamma rays (cobalt-60). For this, the installation of the Cobalt-60 Multipurpose Irradiator, from the CETR-IPEN Radiation Technology Center, was used. Doses of 1,3,5,10 and 15 kGy were applied, with a dose rate of 5-6 $kGy.h^{-1}$. Skin samples were selected for characterization before and after irradiation. Points were also indicated on the skin samples to perform the Colorimetry analysis; these points were fixed to guarantee the reproducibility of the analysis.

2.3. The analytical techniques used for the characterizations

To thoroughly understand the effects of gamma irradiation on the taxidermied mammal skins, several analytical techniques were employed. These techniques are essential for evaluating changes in the physical and chemical properties of the skins, as well as for ensuring the accuracy and reproducibility of the results.

2.3.1 Colorimetric Analysis

The analytical technique of Colorimetry was applied to measure color. Color differences were defined by numerical comparison between non-irradiated samples and samples irradiated at different doses. The CIELAB system was used to describe the color numerically and the Deltas (Δ) and Delta E (ΔE) were calculated, which indicates the magnitude of the total color difference. Figure 2 shows how the point for reading the samples was determined.

Figure 2: A) Animal skin with the mold B) Colorimeter C) Point fixed for analysis

2.3.2 Scanning Electron Microscopy (SEM)

The micrographs for morphological analysis of the surface of the selected samples were obtained by Scanning Electron Microscopy (SEM) using backscattered electrons (BSE) and secondary electrons (ES) on the Jeol JSM-6701F electron microscope, with field emission at 1kV and 6kV and coupled to the Thermo EDS detector, from the Center for

Materials Science and Technology CECTM/IPEN. Optical microscopes from the same center were also used. The sample was prepared through metallization:

2.3.3 Infrared Spectroscopy – FTIR

The samples were analyzed by Fourier-Transform Infrared Spectroscopy (FTIR) before and after ionizing radiation processing to evaluate changes or formation of organic chemical groups. The measurements were run on a Thermo Nicolet Nexus 670 spectrometer via ATR using a MCT detector, at the CECTM/IPEN.

2.3.4 Mechanical Tests

Comparative studies were carried out on the basic mechanical resistance properties between irradiated and non-irradiated samples. In this study, we explored the methods and techniques used to carry out tensile tests using the Instron 5567 Universal Testing Machine. Using this approach, we sought to investigate the maximum point of elasticity before 0kGy radiation and after gamma radiation with 10kGy, load sensitivity, increase in speed until rupture, which consisted of applying a force to the sample causing it to stretch until it fractured. material. Providing valuable insights into the mechanical behavior of analyzed samples. The samples were measured to determine thickness and length and the speed used was 2mm per minute Mega Pascal, for the analyzes the average of five samples was used for each analysis

3. RESULTS AND DISCUSSIONS

3.1. Colorimetry

Readings were taken in the same location and position and at room temperature, with cumulative doses of O at 15 kGy; The three coordinates of the CIELAB System were used, where: L* refers to the luminosity of the object to be evaluated, which can vary from black to white; a* is the measurement of chromium on the red-green axis; It is b* is the measurement of chromium on the yellow-blue axis. To analyze the behavior of colors after the radiation process. Figure 2 shows how the point for reading the samples was determined. In figures 3, 4, 5 and 6, the points measured in the samples can be seen, which present values that fall within the criteria of noticeable changes. Color tolerance is the acceptance limit of how large the color difference between the samples and the standard can be, using the L* a* b* values can correlate the differences with your visual perception.

The comparative standards were non-irradiated samples of each skin type. It is observed that the samples analyzed did not exceed ΔE > 3, indicating that the applied radiation dose did not cause any noticeable change. It can be seen in figures 3, 4, 5 and 6 that gamma irradiation at the doses submitted did not significantly interfere with the colors of the analyzed samples. Each animal species has its own unique color characteristics and coat patterns. Furthermore, individual variations may exist within the same species. As emphasized by PAPAVERO, 1994 [12], colors play a preponderant role in descriptions and are important for the identification of the vast majority of terrestrial life groups; they are indispensable for the recognition of subspecies, morphs, etc.

Figure 3: Colorimetry curve of the coati sample (QI)

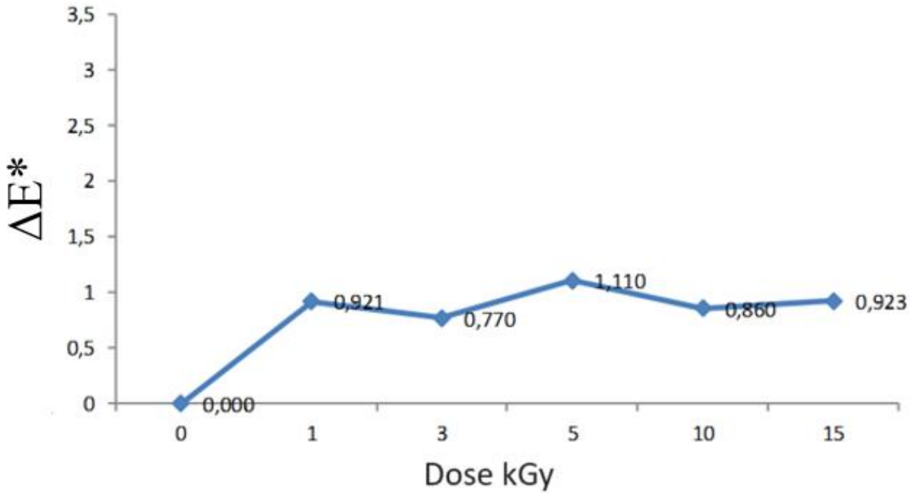


Figure 4: Colorimetry curve of the deer skin sample (CV)

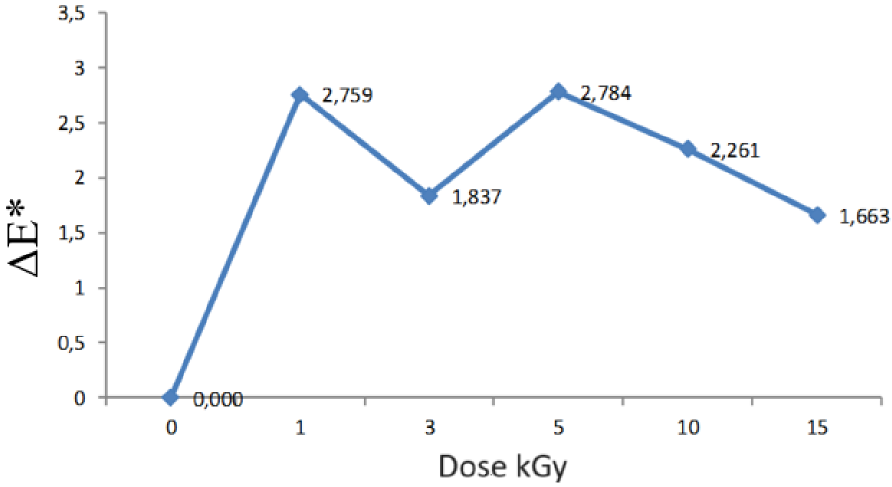


Figure 5: Colorimetry curve of the bison skin sample (BS)

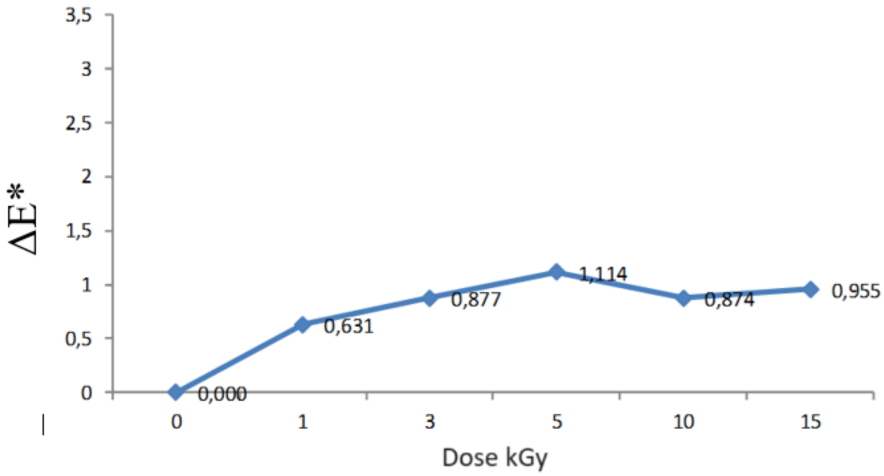
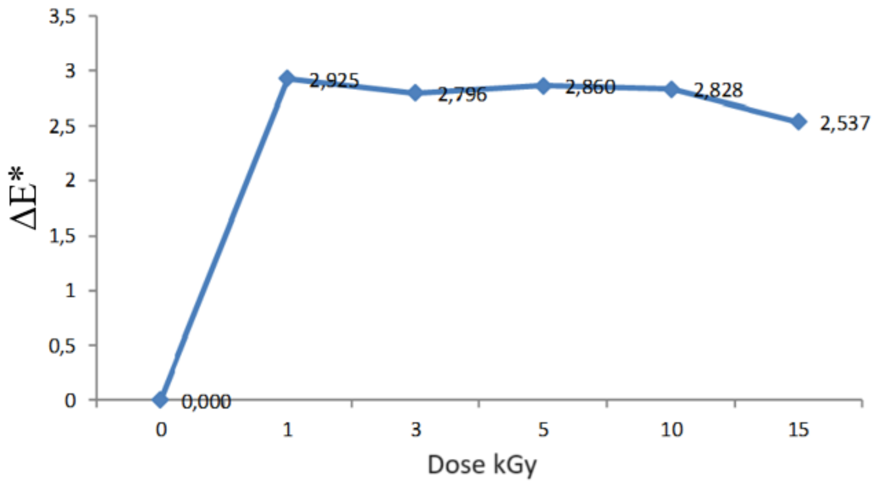


Figure 6: Colorimetry curve of the opossum skin sample (GB)



3.2. Scanning electron microscopy (SEM) and Analysis Optical analysis (MO)

During the analysis, it was possible to observe the presence of contaminants or residues of chemical substances used, the shape of the hair and its distribution on the skin, observed details of the follicles and the density of the hair. No changes were found after using gamma radiation. Some general aspects were observed, such as colors, uniformity of the fur and skin, in addition to any discoloration or change in appearance, structure and possible signs of wear or damage that affect the external appearance.

Combining the results of SEM, figure 7, 8, 9, 10 and optical analysis figure 11, 12, 13 and 14 provides a comprehensive view of the condition and characteristics of the taxidermied skins and shows that no changes occurred after gamma radiation at a dose of 10 kGy. SEM offered a detailed view of the morphology and internal structure, while optical analysis provided information on the visual appearance and general condition of the sample. Together, these techniques help evaluate the quality of the taxidermy, the non-alteration of the use of gamma radiation and the integrity of the skins.

Figure 7: SEM, coati A) radiation with 0kGy (x500); B) radiation 10kGy (x500); C) radiation with radiation 0kGy (x250); D) radiation with 10kGy (x250).

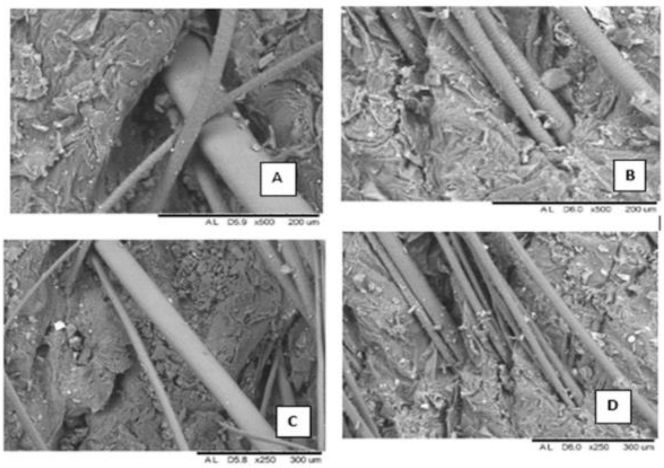


Figure 8: SEM, bison A) radiation with 0kGy (x500); B) radiation 10kGy (x500); C) radiation with radiation 0kGy (x100); D) radiation with 10kGy.

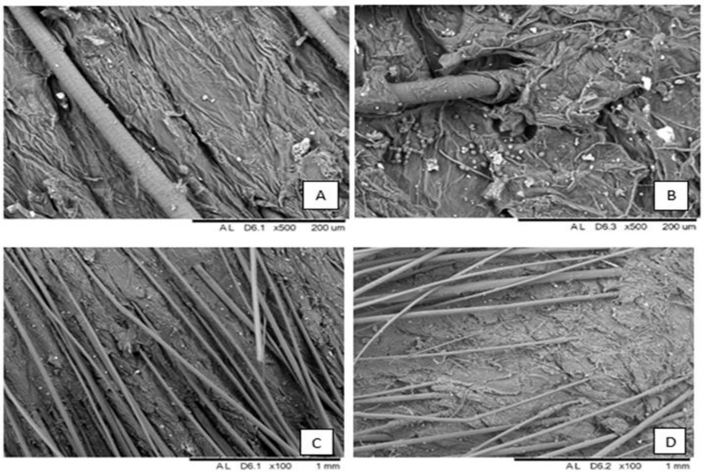


Figure 9: SEM, deer A) radiation with 0kGy (x250); B) radiation 10kGy (x250); C) radiation with radiation 0kGy (x100); D) radiation with 10kGy.

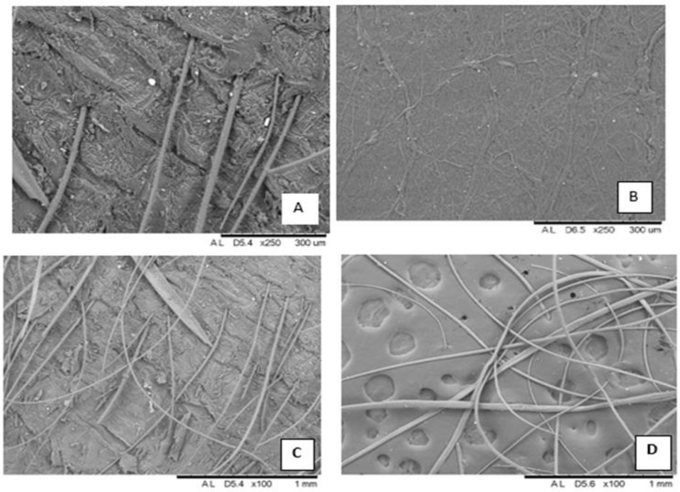


Figure 10: SEM, opossum A) radiation with 0kGy (x250); B) radiation 10kGy (x250); C) radiation with radiation 0kGy (x100); D) radiation with 10kGy.

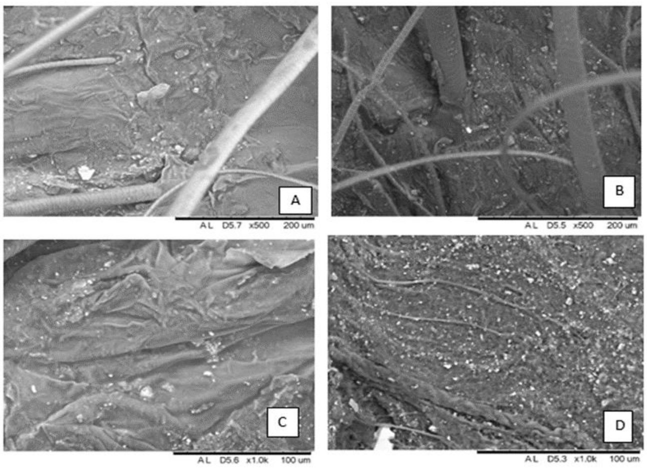


Figure 11: MO**,** bison A) x5; B) x5; C) x5; D) x5

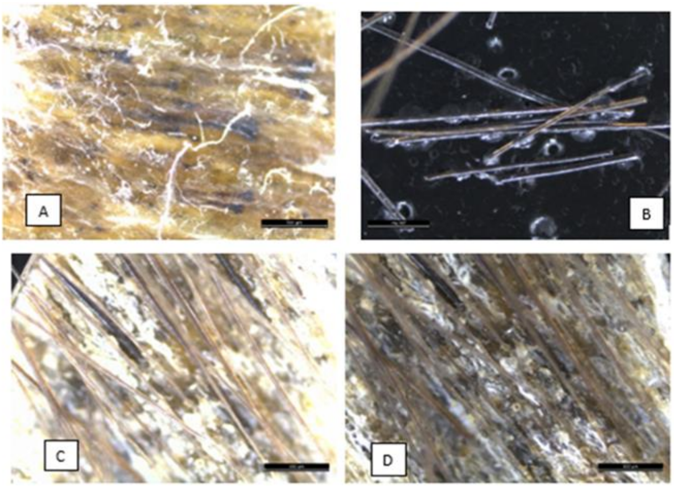


Figure 12: MO**,** coati A) x10; B) x5; C) x10; D) x10.

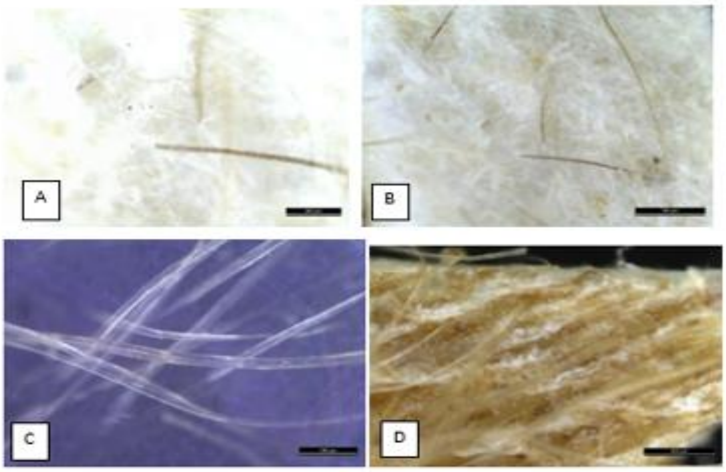


Figure 13: MO, deer A) x5; B) x10; C) x5; D) x10.

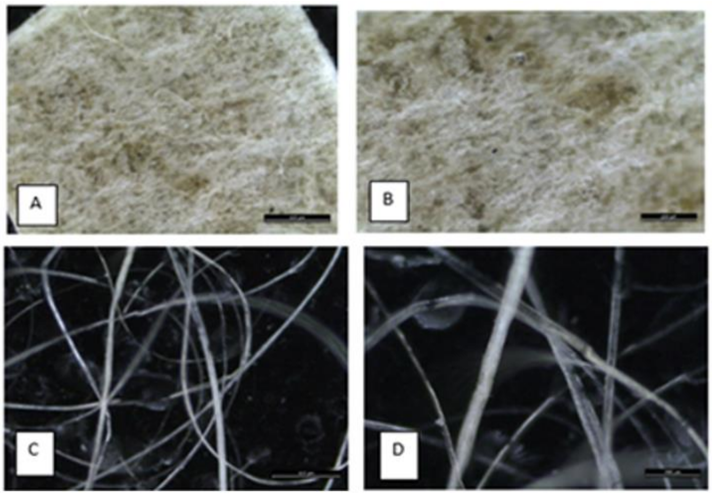
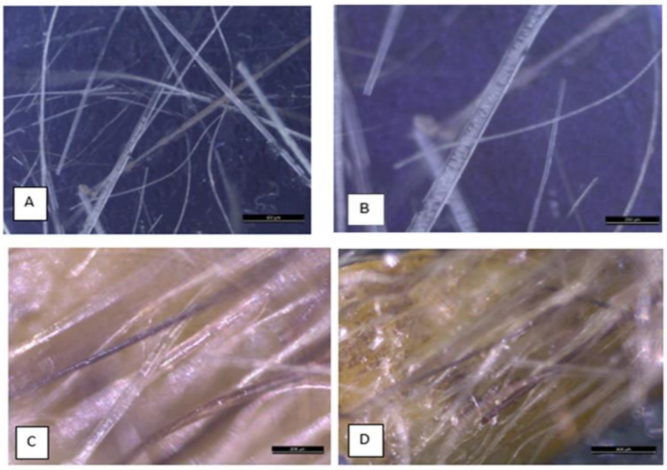


Figure 14: MO, opossum A) x5; B) x10; C) x5; D) x10.

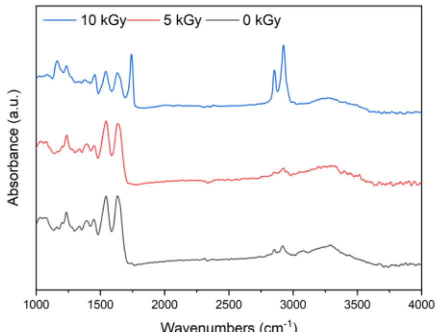


3.3. Infrared Spectroscopy – FTIR

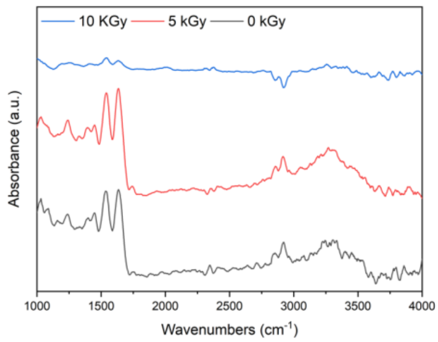
The samples were analyzed by FTIR before and after ionizing radiation processing to evaluate changes or formation of organic chemical groups. The spectra in the range 1000-4000 cm-1 for are presented in Figure 15.

Figure 15: FTIR spectra of coati skin (A), deer skin (B), bison skin (C) and opossum skin (D) samples before (0kGy) and after gamma irradiation doses 5kGy and 10kGy.

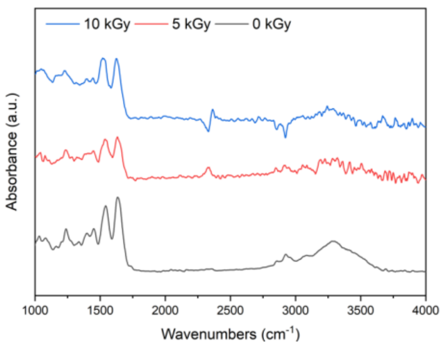
A) Coati skin



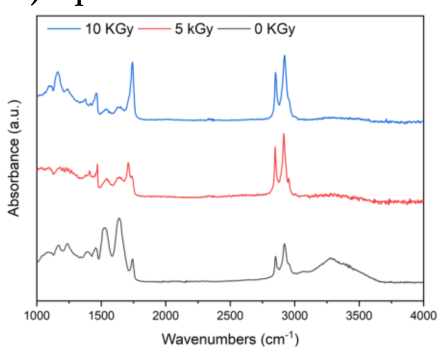
B) Deer skin



B) Bison skin



D) Opossum skin



The FTIR spectra of the coati, deer, bison, and opossum skin samples, both before (0 kGy) and after gamma irradiation at 5 kGy and 10 kGy, exhibit characteristic peaks associated with amide I, amide II, and amide III bands, indicative of the presence of collagen and other proteins [13].

The presence of amide I, amide II, and amide III bands confirms the protein-rich nature of the taxidermied mammal skins [14]. The amide I band, located around 1600-1700 cm^{-1}, is primarily associated with the C=O stretching vibration of the peptide bonds in the protein backbone. The amide II band, around 1500-1600 cm^{-1}, arises from the N-H bending and C-N stretching vibrations. The amide III band, located around 1200-1300 cm^{-1}, is a complex band involving C-N stretching, N-H bending, and other vibrations [15].

The FTIR spectra shows that there are no significant changes in the positions or intensities of the amide bands after gamma irradiation at doses of 5 kGy and 10 kGy. This suggests that the protein structure, particularly the collagen, in the skins remains largely unaffected by the irradiation process. The preservation of the amide bands indicates that the primary structure of the proteins is maintained, which is crucial for the integrity and mechanical properties of the skins.

The absence of significant shifts or alterations in the FTIR spectra further implies minimal cross-linking or chemical modifications induced by irradiation, which could otherwise impact the mechanical properties of the skins.

The FTIR analysis thus provides compelling evidence that gamma irradiation, at the doses employed in this study, does not compromise the structural integrity of proteins within taxidermied mammal skins, reinforcing its potential as a safe and effective preservation technique.

3.4. Mechanical tests

The mechanical tests, which assessed the tensile strength and elongation of the skins before and after irradiation, are presented in Figures 16 to 19.

The obtained results revealed intriguing insights into the impact of gamma radiation on the structural integrity of taxidermied specimens. The evaluation of the skins' resistance to applied force, as measured by a mechanical traction device, provided valuable information about their ability to withstand various stresses without succumbing to damage. The analysis encompassed the deformation trajectories and their evolution during the application of force, offering a comprehensive understanding of the skins' mechanical behavior.

The results, however, presented a dichotomy. The deer and opossum skins, Figures 17 and 19, exhibited a reduction in mechanical resistance following irradiation, potentially attributable to the radiation dose itself or the specific pre-treatment processes these skins underwent. This observation aligns with the subtle color alterations noted in these samples at the initial 1 kGy dose, although these changes remained within acceptable color analysis tolerances. The observed decrease in mechanical strength could be associated with these pre-treatment procedures.

In contrast, the coati and bison skins, Figures 16 and 18, demonstrated a notable increase in mechanical resistance after irradiation. This phenomenon might be linked to radiation-induced cross-linking, where new chemical bonds form between carbon-containing molecules prevalent in these skins. The enhanced mechanical properties suggest a potential benefit of gamma irradiation in reinforcing the structural integrity of certain skin types, contributing to their long-term preservation.

The variations in mechanical responses among different species underscore the complex interplay between radiation, skin composition, and pre-treatment methods. The quality of the taxidermy itself, the preservation techniques employed, and the storage conditions can all influence the skins' resilience and their response to irradiation. The observed differences highlight the necessity for further investigation to elucidate the precise mechanisms underlying these observations and to tailor irradiation protocols to the specific characteristics of each specimen, ensuring their optimal preservation and structural longevity.

Figure 16: Presents the mechanical analysis graph of the coati skin sample (A) rupture resistance (MPA), (B) Distortion (elongation%), subjected to gamma irradiation doses 0kGy and 10 kGy

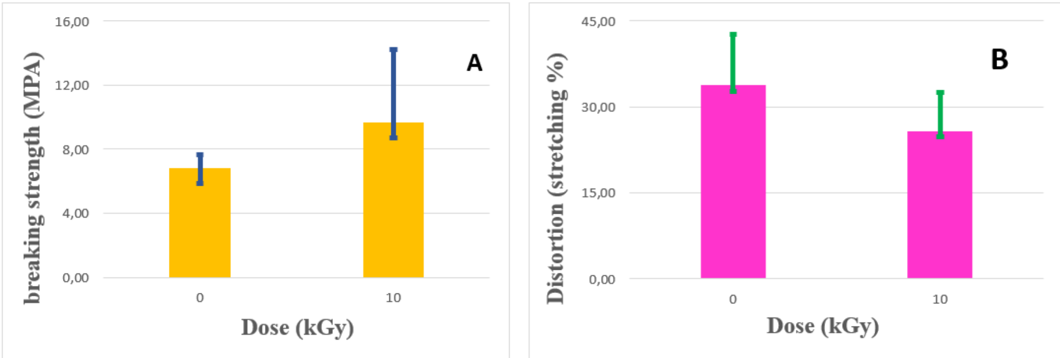


Figure 17 - Presents the mechanical analysis graph of the deer skin sample (A) breaking strength (MPA), (B) Distortion (elongation%), subjected to gamma irradiation doses 0kGy and 10 kGy.

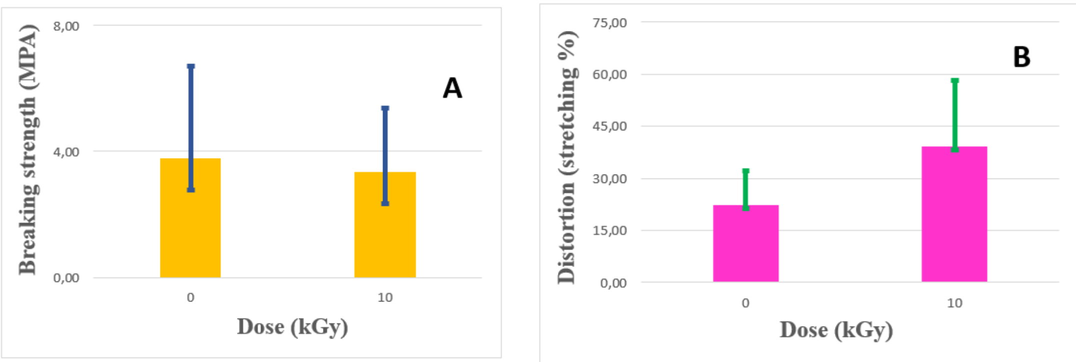


Figure 18 - Presents the mechanical analysis graph of the bison skin sample (A) breaking strength (MPA), (B) Distortion (elongation%), subjected to gamma irradiation doses 0kGy and 10 kGy.

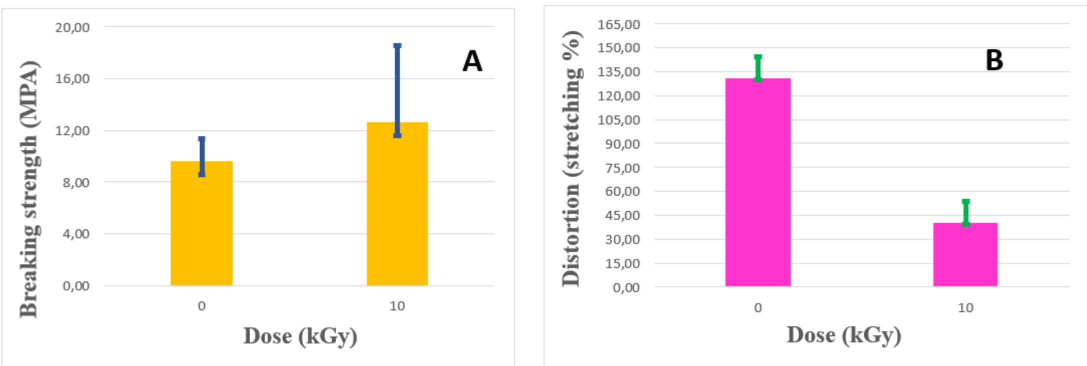
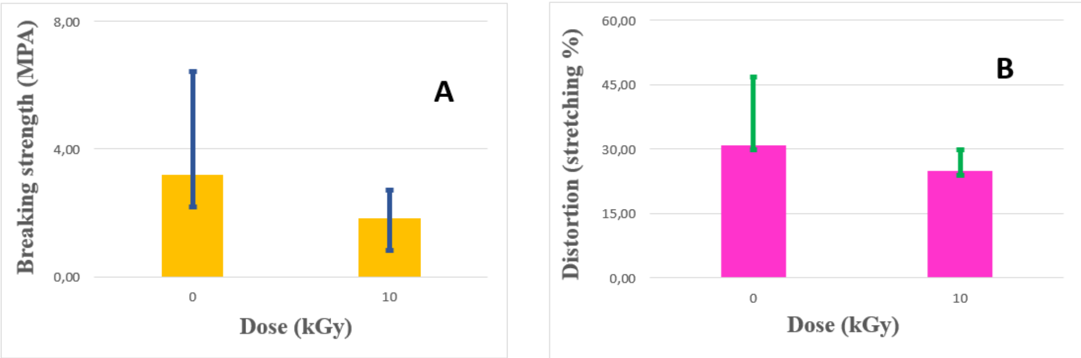


Figure 19 - Presents the mechanical analysis graph of the opossum skin sample (A) breaking strength (MPA), (B) Distortion (elongation%), subjected to gamma irradiation doses 0kGy and 10 kGy.



4. CONCLUSIONS

The present study underscores the potential of gamma irradiation as a valuable tool for the preservation and decontamination of taxidermied mammal skins. The findings from colorimetry, scanning electron microscopy, optical microscopy, and FTIR analysis collectively demonstrate that gamma irradiation, at doses up to 10 kGy, does not induce significant alterations in the physical and chemical properties of the skins. The preservation of color, morphology, and protein structure, as evidenced by these techniques, supports the efficacy of gamma radiation in maintaining the integrity of taxidermied specimens.

However, the mechanical tests revealed a nuanced response to irradiation, with deer and opossum skins exhibiting decreased mechanical resistance, while coati and bison skins showed increased resilience. These variations highlight the intricate relationship between radiation, skin composition, and pre-treatment methods, emphasizing the need for further research to optimize irradiation protocols for diverse taxidermied specimens.

In conclusion, gamma irradiation offers a promising avenue for the long-term preservation of taxidermied collections, ensuring their protection from pests and deterioration without compromising their aesthetic and structural qualities. The ability to tailor irradiation protocols to specific skin types and pre-treatment conditions will be crucial in maximizing the benefits of this technology for the conservation of invaluable natural history specimens.

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CONFLICT OF INTEREST

All authors declare that they have no conflicts of interest.

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