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Assessment of the Viability of Antimicrobial Peptides as Gamma Ionizing Radiation Sensitive Materials in Nuclear Applications

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1. Introduction

The historical association of nuclear science with energy, medicine, security and defense has evolved with technological advances, revealing new horizons and challenges. In response to this evolving scenario, a research initiative proposes a multidisciplinary approach that integrates the synergy of nuclear knowledge with biotechnology. This collaborative effort explores the potential of antimicrobial peptides (AMPs), specifically those derived from the fermentation process using the bacterium *Paenibacillus polymyxa,* recent studies highlight unique characteristics.

The research involves subjecting AMPs to ionizing radiation from gamma nuclear sources. The antimicrobial activity of these peptides will be evaluated before and after exposure to radiation, as the various targeting mechanisms of AMPs make them effective against a wide range of threats, including multidrug-resistant bacteria and emerging pathogens. In this way, the study aims to interpret the results based on the viability of AMPs, identifying their potential applications in nuclear science as radiation-sensitive materials in biosensors, allowing rapid and accurate measurements of gamma radiation levels. Therefore, this convergence between nuclear science and AMPs presents opportunities to address critical issues such as nuclear safety, radiobiology, and detection. In summary, the research seeks to combine traditional nuclear knowledge with the versatility of AMPs, striving to improve and innovate nuclear applications. The ultimate goal is to provide innovative solutions to the contemporary challenges associated with radiation, safety and detection.

Keywords: Biotechnology; Antimicrobial Peptide; Gamma radiation; Biosensor.

2. Methodology

The methodology applied to the use of the antimicrobial peptide encompasses several interconnected stages given its complexity and scope. Thus, it includes sequential procedures from the activation of the lyophilized bacteria to the irradiation of the peptides. This includes the activation of the lyophilized bacteria, the subsequent reproduction of the bacteria, fermentation in bench scale (with volumes up to 1 liter) and fermentation in bench bioreactor (with volumes up to 3 liters. Subsequently, isolation and purification procedures of the peptide are carried out, followed by its detailed characterization. To evaluate the antimicrobial activity of the peptide, analysis procedures are performed before and after irradiation of the antimicrobial peptide (AMP) with gamma radiation.

To better understand the entire phenomenon involved, it is necessary to understand that the interactions of ionizing radiation with biological media require a deep dive into its fundamental properties. This requires a distinction between "radiation" as a general term that encompasses various subatomic particles that travel at nearly the speed of light and "ionizing radiation" specifically. While "radiation" encompasses diverse phenomena, from heat-inducing microwaves to cosmic ray nuclei, "ionizing radiation" focuses only on particles or waves capable of ionizing atoms and molecules. This ionization capability sets ionizing radiation apart from non-ionizing radiation, underpinning its unique interactions. Generally, radiation types are grouped by their mass, energy, and potential to induce chemical reactions and/or physical phenomena when they strike other matter. X-rays and gamma rays have even shorter wavelengths, meaning that gamma photons have higher energy and are more penetrating than X-rays. Therefore, gamma and X-rays indirectly ionize a substrate through interactions with a wide variety of molecules present in cells (usually water) to generate reactive oxygen species (ROS).

Gamma photons are highly energetic and have no mass, meaning they pass completely through a biological medium and lose a very small amount of energy as they move. In this condition, a gamma photon, as it passes through the electron clouds of atoms in a cell, transmits some amount of energy. If the energy transferred is greater than the ionization energy of the atom with which it interacted, an electron will be ejected from its orbit and a reactive species will be produced. Since cells are composed mainly of water, gamma rays emitted by Cobalt-60 (1.17 and 1.33 MeV), for example, easily ionize water and create highly reactive hydroxyl radicals. Highly reactive hydroxyl radicals quickly interact with surrounding molecules, thus creating a chain reaction of free electrons with a volume sufficient to allow for the detection of gamma radiation.

In rapid detection through biosensors, living organisms such as bacteria and macromolecules such as proteins and enzymes are selected based on their specific characteristics of generating variations in physical and chemical properties when exposed to ionizing radiation. In this group of macromolecules, the PAM targeted by this research has the potential to revolutionize the field of nuclear detection, mainly due to its ability to maintain its antimicrobial activity in radioactive environments. In this context, there is evidence of the ability to generate early warning, enabling rapid detection. Additionally, biosensors can be deployed in sensitive areas for real-time monitoring, further optimizing the speed and efficiency of threat detection, both emerging biological and nuclear.

3. Results and Discussion

Antimicrobial peptides are molecules made up of amino acids like proteins, but with a lower molecular weight compared to proteins. These peptides can be produced by living organisms, such as bacteria. In this context, antimicrobial peptides (AMPs) produced by *Paenibacillus polymyxa* show great potential for biomedical, biotechnological and nuclear applications. Studies such as that of Serrano (2014) identified promising peptides with significant antimicrobial activity. More recent research, such as that of Lima et al. (2022), explored the resistance of AMPs to ionizing radiation, evaluating their efficiency threshold after exposure. Such studies provide valuable information on the ability of AMPs to maintain their antimicrobial activity in radioactive environments.

AMPs have several mechanisms of action that make them effective against a variety of pathogens, including multidrug-resistant bacteria and emerging biological agents. This characteristic makes them promising candidates for the development of new antimicrobial agents and diagnostic tools, as well as for application as radiation detectors. The miniaturization and portability of PAM-based devices enables the integration of biosensors for real-time analysis and rapid response, making them ideal for detecting and combating biological and nuclear threats in environments subject to ionizing gamma radiation.

The combination of rapid detection provided by biosensors with the potent and broad-spectrum action of AMPs, particularly their unique ability to maintain antimicrobial activity in radioactive environments, paves the way for the development of an innovative biosensor. Early detection of biological and nuclear agents is crucial to saving lives and enabling effective mitigation measures. The deployment of biosensors in sensitive areas allows for real-time monitoring, increasing security and the ability to respond to imminent threats.

4. Conclusions

The present study investigated the interaction of gamma ionizing radiation with antimicrobial peptides derived from the bacterium *Paenibacillus polymyxa*. Through detailed analysis of PAMs in scale production and subsequent irradiation by gamma nuclear sources, it was possible to evaluate their antimicrobial activity before and after exposure to ionizing radiation, in order to reveal a crucial property such as the peptide's ability to retain its antimicrobial functionality not only in irradiated environments, but also under biological threats. The results obtained so far indicate that the peptides have a threshold of tolerance to gamma ionizing radiation, conserving their antimicrobial activity after exposure. This promising characteristic makes them potential candidates to be used as sensitive materials in biosensors in order to detect gamma ionizing radiation.

Future investigations will continue to explore the practical applications of peptides as biosensors in nuclear detectors and their efficacy in antimicrobial activity against highly contagious pathogens. The development of such devices could revolutionize the field of nuclear detection, providing fast and accurate detection of ionizing radiation in a variety of environments, from nuclear medicine to public safety.

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