

MODELING BIOLOGICAL RESPONSES TO SPACE RADIATION: EVALUATING E. COLI AND S. CEREVISIAE FOR RADIATION SHIELDING EFFICACY IN DEEP SPACE

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ABSTRACT

In space environments, ionizing radiation poses a significant threat to biological systems, leading to mutations and cellular damage that could impair human missions directly (affecting humans) or indirectly (affecting onboard organisms). This study explores the utility of *Escherichia coli* and *Saccharomyces cerevisiae* as models for understanding radiation-induced damage and protective mechanisms. Using MATLAB SimBiology, we simulated their responses to galactic cosmic rays (GCR) and solar particle events (SPE), evaluating DNA repair processes, antioxidant production, mutation rates, and proliferation under varying shielding and antioxidant conditions.

The study highlights key biological differences influencing radiation resilience: *S. cerevisiae*'s diploid genome provides genetic redundancy that enhances its DNA repair capabilities, while *E. coli*'s haploid genome makes it more vulnerable to radiation-induced damage. Statistical analysis (ANOVA) revealed that *S. cerevisiae* was significantly impacted by shielding types, with plasma and hybrid shielding consistently reducing mutation rates. Conversely, *E. coli* exhibited relative genetic stability, with no significant differences in mutation rates across shielding groups. Functional tests showed that *E. coli* required high shielding and antioxidant support to achieve rapid proliferation under radiation stress. Our findings highlight the superior resilience of *S. cerevisiae* and the potential of tailored shielding strategies, such as plasma and hybrid methods, to protect biological systems from radiation. These insights contribute to developing bio-based protective measures and microbial resilience strategies for long-duration space missions. While the study underscores the potential of integrating physical and biological defenses, further research is needed to explore microbial bioengineering applications and validate these findings in experimental and spaceflight environments.

INTRODUCTION

Current strategies for radiation protection focus heavily on physical and chemical shielding. However, these methods face challenges, particularly in space and medical environments where traditional shielding is limited by weight, cost, and potential side effects. Recent research suggests that microorganisms like *Escherichia coli* and *Saccharomyces cerevisiae*, known for their resilience under high-radiation conditions, could offer alternative solutions for human radiation protection [1]. These microorganisms produce antioxidants that combat reactive oxygen species (ROS), possess efficient DNA repair mechanisms, and form biofilms that act as physical barriers. Leveraging these properties offers a novel, biologically inspired approach to radiation protection. Microbial systems could potentially serve as protective supplements, genetic models for DNA repair enhancement, sources for biofilm-inspired shielding materials, and probiotic supports for the human microbiome. Such applications could revolutionize radiation protection strategies by providing adaptive, regenerative, and integrative biological defenses against ionizing radiation [2]. Long-duration space exploration missions expose astronauts to high levels of ionizing radiation, primarily from galactic cosmic rays (GCR) and solar particle events (SPE), which can lead to severe biological damage including oxidative stress, DNA double-strand breaks,

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