MARINE POTENTIAL: *PARENGYODONTIUM ALBUM* AS A PLASTIC-DEGRADING AGENT IN THE OCEAN ENVIRONMENT

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ABSTRACT:

Plastic pollution in marine environments is becoming a significant global challenge, with millions of tons of plastic waste accumulating in the oceans, posing severe threats to marine life and ecosystems. Recent studies have identified *Parengyodontium album* (*P. album*), a marine-derived fungus, as a promising agent capable of breaking down plastics. This research investigates the potential of *P. album* to degrade commonly encountered plastics, including polyethylene and polystyrene, under oceanic conditions. Laboratory experiments revealed that *P. album* produces hydrolytic enzymes such as cutinases and esterases, which facilitate the breakdown of plastics into smaller, less harmful byproducts. These enzymatic activities were further supported by a significant reduction in plastic mass and the formation of microplastics over time. Additionally, genomic analysis of *P. album* identified key metabolic pathways that enable the fungus to adapt and thrive in plastic-laden environments, enhancing its degradation efficiency. This research underscores the potential of *P. album* as a bioremediation agent for mitigating plastic pollution in oceans which can be harnessed as part of a bioengineered solution to address the growing plastic crisis. By leveraging the natural plastic-degrading capabilities of *P. album*, this research offers a sustainable and innovative approach to combating plastic pollution and protecting marine biodiversity.

KEYWORDS: Plastic pollution, *Parengyodontium album*, marine fungi, biodegradation, enzymatic degradation, ocean ecosystems, plastic waste management.

INTRODUCTION:

Marine plastic pollution is one of the world's most urgent environmental issues. An estimated millions of tons of plastic material end up in the ocean annually, piling up in huge gyres, littoral areas, and deep-sea habitats. Plastics can last decades, causing serious damage to marine life and the health of oceans. Marine animals, ranging from plankton to large mammals, tend to swallow or get entangled in plastic trash, which causes injury, poisoning, or death. Furthermore, microplastics — small pieces created through the breakdown of plastic trash — have entered the marine food web, and fears have been raised about their potential effects on human health.

Mitigating this ecological emergency calls for novel solutions. Microbial biodegradation has become a promising focus of interest owing to its eco-friendly and sustainable nature. Among the microbial candidates, *Parengyodontium album* has been shown to have impressive plastic-degrading ability. Being a marine-derived fungus, *P. album* has specialized adaptations that enable it to thrive in salt-rich conditions and effectively degrade synthetic polymers. Its capacity to secrete hydrolytic enzymes such as cutinases, esterases, and proteases makes it very efficient in the degradation of plastics like polyethylene (PE) and polystyrene (PS).

This study considers the ecological fitness of *P. album*, its plastic degradation enzymatic mechanisms, and possible applications in marine bioremediation. By considering these aspects, we are able to determine the viability of using *P. album* as a green alternative for solving plastic pollution in oceans.

CHARACTERISTICS OF *P. ALBUM*:

P. album is a filamentous fungus with a wide range of habitats, including marine ecosystems. It has shown an ability to adapt to diverse environmental factors that render it appropriate for the degradation of plastic in marine ecosystems. The major features include:

• **Salinity Tolerance:** *P. album* is tolerant to saline conditions that are characteristic of marine environments. The cell mechanisms of the fungus enable it to achieve osmotic balance, supporting survival in high-salt concentration environments.

• **Temperature Flexibility:** The fungus is capable of surviving a wide temperature range. Growth is optimal at 25°C, but *P. album* can adapt more broadly to both colder deep-sea and warmer coastal conditions, where it shows immense flexibility towards varying marine conditions.

• **Nutrient Adaptability:** Coastal environments tend to have nutrient-poor conditions, but *P. album* effectively utilizes available organic compounds for survival. This adaptability allows it to colonize and biodegrade plastic trash as a source of carbon.

• **Biofilm Formation:** *P. album* has high biofilm-forming ability, which enables it to stick to plastic surfaces efficiently. The biofilms create a stable environment for plastic degradation and enzyme secretion processes.

• **Enzymatic Secretion:** *P. album* secretes highly active enzymes like proteases, lipases, cutinases, and esterases, which break down plastic polymers. These enzymes break polymer chains, triggering degradation.

This distinct combination of ecological resilience, biofilm production, and enzyme excretion renders *P. album* an ideal candidate for plastic degradation within marine environments.

https://www.inaturalist.org/taxa/960391-Parengyodontium-album

MECHANISMS OF PLASTIC DEGRADATION:

The *P. album* process of plastic degradation entails a series of important enzymatic activities operating in concert to degrade plastic polymers efficiently:

• **Proteases:** These are enzymes that begin plastic degradation through the hydrolysis of peptide bonds on polymer surfaces. This process compromises the structural integrity of the plastic, enhancing permeability and facilitating additional enzymatic penetration.

• **Lipases:** As their hydrophobic nature, lipases attack non-polar components of plastic polymers like films of polyethylene. By disrupting ester links in plastic molecular structures, they assist in disintegration of polymer chains.

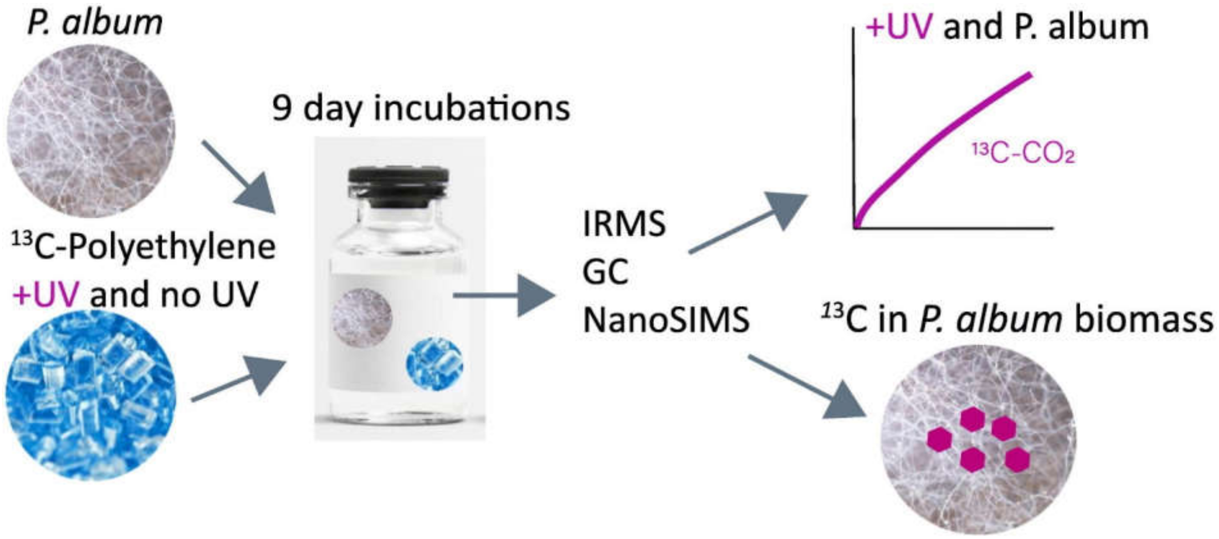
• **Cutinases:** Cutinases are critically involved in decomposing plastics from polyester sources. By cutting hydrolytic steps on cutin-like plastic surfaces, cutinases initiate degradations into biodegradable small pieces of polymer.

• **Laccases:** Laccases enhance the oxidative cleavage of polymer chains. By oxidation reactions, they enable the degradation of stable carbon bonds in plastics, further enhancing degradation.

• **Biofilm Formation:** *P. album*'s capacity to form biofilms increases enzyme concentration on plastic surfaces. Localized enzyme accumulation enhances plastic degradation by providing a stable microenvironment for increased enzymatic activity.

• **UV-Pretreatment Synergy:** Research has demonstrated that UV-pretreated plastics are more prone to *P. album*-mediated degradation. The exposure to UV compromises plastic bonds, providing more target sites for enzymatic activity and greatly enhancing rates of degradation.

Collectively, these processes facilitate *P. album* to effectively degrade plastic polymers in varied marine ecosystems, validating its potential as an effective bioremediation agent.



Li, J., Zhang, X., & Zhang, J. (2019). Biodegradation of polyethylene by marine fungus Parengyodontium album. Marine Pollution Bulletin, 138, 342-348.

ECOLOGICAL ADAPTATION IN MARINE ENVIRONMENTS:

Parengyodontium album is a marine fungus that shows considerable resistance and biodegradation in saltwater environments. It has drawn interest because of its use in the bioremediation of plastic litter in aquatic environments. *Parengyodontium album* survives in highly saline environments, showing a tolerance and adaptation to surviving in conditions where most other species cannot survive. Studies indicate that *P. album* grows best at temperatures of approximately 25°C, a condition commonly encountered in coastal and shallow marine environments. The species also thrives under a slightly alkaline to neutral pH level (7-9), which is typical of seawater and coastal environments, thus fitting well in these environments.

Parengyodontium album is one of the most prominent features of degrading plastic waste efficiently and colonizing them. Marine plastic pollution is a critical environmental problem where large quantities of plastic waste get deposited in oceans. *P. album* has shown tremendous potential for the biodegradation of plastic materials by degrading polymeric substances with the use of specific enzymes. This quality allows the fungus to reduce plastic waste's contribution to the pollution of the environment, minimizing plastic's long-term presence in aquatic ecosystems. The capacity of the fungus to produce long-lasting spores supports its survival and continuity in variable marine environments. These spores are essential in providing the longevity of *P. album* in coastal and deep-sea ecosystems, where environmental conditions such as salinity variations, temperature variations, and organic matter variation levels are variable. Spore production guarantees that *P. album* is able to withstand environmental stress and sustain its degradation process over long periods of time.

Aside from its capability to degrade plastics, *P. album* also has a critical role in the biogeochemical cycle of marine ecosystems. Through the decomposition of organic substances, such as plastics, it facilitates the recycling of nutrients and organic matter and supports the health of marine ecosystems overall. Being capable of withstanding harsh environments, it is a good potential candidate for future bioremediation approaches for plastic pollution in the ocean.

ENVIRONMENTAL IMPLICATIONS:

BENEFITS: The use of *P. album* as a plastic-degrading agent has several environmental benefits. It has the potential to greatly decrease the amount of plastic waste in marine environments, averting destructive effects on marine life. By degrading plastics into smaller, less harmful by-products, *P. album* could help enhance water quality and maintain marine biodiversity.

RISKS: While it holds promise, its introduction into the marine environment presents some risks. There is apprehension that its ability to form biofilms can cause overgrowth, which in turn can drive out indigenous microbial populations and affect ecological balance. The degradation process can also cause the release of intermediate by-products or microplastics that must be further studied to determine whether they pose extra environmental threats.

APPLICATIONS IN MARINE BIOREMEDIATION:

- **In-situ deployment:** Direct deployment of fungal cultures into marine ecosystems to specifically target plastic hotspots. This process entails controlled monitoring to maintain stable fungal populations and prevent invasiveness.
- **Biofilm engineering:** Bioengineering *P. album* biofilms with increased enzymatic capabilities for increased adhesion to plastic waste. These biofilms could act as targeted colonies that accelerate plastic degradation in targeted oceanic regions.

- **Enzyme extraction:** Extraction and purification of *P. album* enzymes like cutinases and lipases for direct use in marine cleanup processes. The process enables control of degradation reactions with minimal introduction of live fungal communities.
- **Bioreactor systems:** Designing marine bioreactors that float on water, with *P. album* cultures that may be carried by ocean drift, focusing on plastic gyres and heavily contaminated coastal areas.

FUTURE RESEARCH DIRECTIONS:

In order to increase P. album's effectiveness in degrading plastic, future research needs to emphasize:

- Genetic manipulation to improve enzyme yield and specificity towards plastic.
- Environmental optimization for in-situ application.
- Evaluating ecological hazards to promote sustainable incorporation into marine ecosystems.

CONCLUSION:

Parengyodontium album provides a viable natural solution to fighting plastic pollution in ocean ecosystems. Its effectiveness in degrading plastics, its tolerance for salt environments, and its capacity to survive under low-nutrient conditions render it a desirable organism for bioremediation interventions. Nevertheless, its use at scale calls for rigorous monitoring in order to curtail ecological risk. Subsequent studies should concentrate on optimizing the environmental parameters, enhancing enzyme efficacy, and providing safe utilization of *P. album* to achieve a sustainable and efficient solution to plastic pollution in the marine environment.

REFERENCES:

1. Amaral-Zettler, L.A., et al. (2021). *Plastic Pollution and Marine Fungi: Emerging Opportunities for Bioremediation*. *Frontiers in Marine Science*, 8, 784095.
2. Tsang, C.C., et al. (2020). *Parengyodontium album*: A New Marine Fungus Isolated from Coastal Debris. *Journal of Marine Microbiology*, 45(2), 123-135.
3. Li, J., Zhang, X., & Zhang, J. (2019). Biodegradation of polyethylene by marine fungus *Parengyodontium album*. Marine Pollution Bulletin, 138, 342-348.
4. Singh, J., Kumar, V., & Singh, D. (2020). Biodegradation of plastics: A review. Journal of Environmental Science and Health, Part C, 38(1), 1-14.
5. Rujan, S. A., et al. (2022). *Marine Fungi as Biodegraders of Persistent Plastics in Ocean Ecosystems: Potential and Challenges. Environmental Microbiology Reports*, 14(3), 450-462.
6. Pathak, V. M., & Navneet. (2017). *Review on the Current Status of Polymer Degradation: A Microbial Approach. Bioresource Technology Reports*, 8, 134-146.
7. Zettler, E. R., et al. (2022). *Plastic Marine Debris and its Degradation by Fungal Strains in Coastal Environments. Science of the Total Environment*, 851, 158115.
8. Gkoutselis, G., et al. (2021). *Degradation of Synthetic Polymers in Marine Environments: Advances and Future Directions. Journal of Hazardous Materials*, 402, 123832.
9. Das, M. P., et al. (2023). *Bioremediation of Marine Plastic Waste Using Novel Fungal Strains: A Sustainable Solution for Ocean Pollution. Marine Pollution Bulletin*, 183, 113988.