Blue:

Extreme Environment Microorganisms:

Microorganisms that can degrade synthetic plastics have been found in extreme environments such as high temperatures, alkaline conditions, high salt concentrations, and cold temperatures. These bacteria are known as thermophilic, alkaliphilic, halophilic, and psychrophilic bacteria. To find the most effective microorganisms for plastic degradation, scientists often screen these extreme environments.

Benefits of Extreme Environment Microbes:

Enzymes from extremophiles, like thermophiles and halophiles, have longer life cycles and can be stored at room temperature without losing activity. This makes them useful sources for plastic-degrading enzymes. Additionally, extreme environments with high temperatures or salinity are often contaminated with plastic, and exploring the microbiomes of extremophiles can lead to the discovery of plastic-degrading microorganisms and enzymes.

Thermophilic Bacteria for PE Degradation:

Chelatococcus sp. E1 is a type of bacteria that can break down polyethylene (PE), a common type of plastic. This bacterium was discovered in a compost sample and is known to be thermophilic, meaning it thrives in high-temperature environments. Interestingly, when PE is exposed to higher temperatures before being broken down by Chelatococcus sp. E1, it becomes more easily biodegradable. Additionally, this bacterium is particularly effective at breaking down higher molecular weight PE and shifting the distribution of molecular weights to the lower side.

Pretreatment for Enhanced Biodegradation:

In order to make plastic waste easier to break down by bacteria, it is important to pretreat it first. This can help to reduce its toxicity and make it easier for bacteria to attach to. There are different ways to pretreat plastic waste, including exposing it to high temperatures, using a process called photooxidation catalysis, or using enzymes from microbes to break it down. These pretreatments can help to improve the efficiency of plastic biodegradation.

Temperature Treatment for PET Optimization:

To make it easier for bacteria to break down plastic waste, it is important to treat it first. This can be done by exposing it to high temperatures or using enzymes from microbes. These treatments can improve the efficiency of plastic biodegradation. For example, elevated temperatures have been found to enhance PET degradation, while thermally pretreated HDPE by Klebsiella pneumoniae has been shown to efficiently achieve HDPE biodegradation.

Pretreatment with Additives and Photocatalysis:

To help bacteria break down plastic waste more easily, it is important to treat it first. This can be done by using enzymes from microbes or exposing it to high temperatures. These treatments can improve the efficiency of plastic biodegradation. For example, elevated temperatures can improve the breakdown of PET, while thermally pretreated HDPE by Klebsiella pneumoniae can efficiently achieve HDPE biodegradation. You can also pretreat plastics by mixing them with biodegradable additives or through co-polymerization to enhance their weight reduction during degradation. Another effective method is photocatalysis, which uses catalysts like iron salts under specific conditions to break down high molecular weight plastics like PS.

Pink:

**Description**

Plastic pollution is a significant issue, with various types of plastics being degraded by microbes. Understanding the interactions between enzymes and plastics is crucial for developing efficient biodegradation technologies. Genetic engineering and enzyme optimization can enhance plastic degradation efficiency, contributing to environmental sustainability.

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Plastics can be categorized into two types: biodegradable and nonhydrolyzable. Nonhydrolyzable plastics, such as PE, PP, PVC, and PS, are composed of C-C bonds that make them resistant to biodegradation. However, microbes can break these plastics down into smaller molecules through redox reactions, which they can then use as a carbon source. PET, PS, and PE (HDPE, LDPE) are some examples of nonhydrolyzable plastics. While PET has limited microbial degradation potential, bacteria like Ideonella sakaiensis 201-F can effectively hydrolyze PET using enzymes. PS is difficult to biodegrade, but certain gut microbiome bacteria have shown promise in degrading it. PE, on the other hand, is highly resistant, but bacterial consortium and fungi have demonstrated the ability to degrade HDPE and LDPE.

Biodegradable plastics, as the name suggests, are plastics that degrade over time. Examples of biodegradable plastics are PCL, PBSA, PBS, and PLA, which contain ester linkages, making them susceptible to microbial enzyme systems. Thermophilic actinomycetes and thermotolerant bacteria have been found to break down PCL. Aspergillus sp. strain ST-01 efficiently degrades PCL, secreting catalase and protease enzymes.

The degradation of plastics by microbes is an important area of study that can help us find sustainable solutions to the problem of plastic pollution. One such microbe is Aspergillus sp. strain ST-01, which has been found to effectively break down PCL and release catalase and protease enzymes in the process.

Certain microorganisms are capable of breaking down plastics and microplastics. Enzymes like cutinases, esterases, and lipases are produced by both bacteria and fungi and play a crucial role in breaking down polymers such as PE, PET, and PP. Fungal cellulase systems can also help depolymerize cellulose and convert it into its monomeric constituents. Depolymerases are especially effective in breaking down different types of polymers like PET and PE. The ability of fungal hyphae to distribute and penetrate is critical to their initial colonization and subsequent depolymerization.Further research in this field is crucial for developing effective technologies to biodegrade plastics and reduce their impact on the environment.

When it comes to biodegrading plastics and microplastics, microorganisms produce a variety of enzymes that play important roles in breaking down the polymers. Hydrolyzing the polymers into smaller, more manageable components is key to the process. Different types of enzymes have been identified as critical components in the biodegradation of plastics and microplastics.

Laccases and Peroxidases:

In addition to the enzymes mentioned earlier, laccases produced by actinomycetes, Rhodococcus ruber, and fungi such as Aspergillus flavus and Pleurotus ostreatus have been found to degrade polyethylene (PE). This is believed to occur through the oxidation of the PE hydrocarbon backbone. Several other fungi, including Fusarium solani, Alternaria solani, Aspergillus fumigatus, Spicaria spp., Geomyces pannorum, Phoma sp., and Penicillium spp., have also exhibited significant plastic-degrading properties for low-density polyethylene (LDPE).

PET, a commonly used thermoplastic material, can be broken down by bacteria like Ideonella sakaiensis 201-F that produce enzymes such as PETase, MHETase, TPA dioxygenase, and PCA dioxygenase. These enzymes effectively break down PET into environmentally safe monomers. The cooperation between PETase and MHETase plays a crucial role in the efficient hydrolysis of PET. Scientists have used genetic engineering to optimize these enzymes for PET degradation, leading to better enzymes that significantly improve the efficiency of PET depolymerization.

Similarly, cutinases have been discovered to be efficient at breaking down PET. LC-cutinase and Thermobifida fusca cutinase have demonstrated high activity in PET degradation, with LC-cutinase showing superior performance. This is exciting news as it further advances the development of more efficient enzymes for PET depolymerization.

Enzymes for PCL and PES Degradation:

Enzymes like lipase can break down thermoplastic crystalline polyester (PCL) into smaller molecules that can be assimilated by microorganisms. Several microorganisms, such as Aspergillus sp. strain ST-01, Pseudomonas, Alcanivorax, Tenacibaculum, thermophilic actinomycetes, and thermotolerant bacteria are efficient in degrading PCL. This means that there are various options available for the effective degradation of PCL, which can further contribute to the development of sustainable solutions for plastic waste management.

Cutinases for PET and PCL:

Scientists have discovered that enzymes such as lipase can break down thermoplastic crystalline polyester (PCL) into smaller molecules that can be assimilated by microorganisms. This means that there are various microorganisms, including Aspergillus sp. strain ST-01, Pseudomonas, Alcanivorax, Tenacibaculum, thermophilic actinomycetes, and thermotolerant bacteria, that can efficiently degrade PCL. Additionally, cutinases such as LC-cutinase have been found to have a specific activity in degrading PET and PCL, with LC-cutinase showing remarkable PET degradation efficiency by breaking it down into TPA and EG. Understanding the role of these enzymes and their interactions with various plastics is crucial for developing efficient plastic biodegradation technologies. Genetic engineering and enzyme optimization hold promise for enhancing the efficiency of plastic degradation processes, contributing to environmental sustainability.

Laccases and Peroxidases:

Recent studies have shown that laccases found in actinomycetes, Rhodococcus ruber, and fungi like Aspergillus flavus and Pleurotus ostreatus have demonstrated a high potential for degrading polyethylene (PE). It is believed that these laccases can oxidize the hydrocarbon backbone of PE, leading to its degradation. This finding is significant as it suggests that laccases can serve as a potential tool for developing efficient plastic biodegradation technologies, which could contribute to environmental sustainability.

Proteases:

Recently, there has been research indicating that some fungi, such as Fusarium solani, Alternaria solani, Aspergillus fumigatus, Spicaria spp., Geomyces pannorum, Phoma sp., and Penicillium spp., have been found to possess significant plastic-degrading properties for LDPE. This discovery is promising as it suggests that certain fungi could potentially be used as a tool for developing effective plastic biodegradation technologies, which in turn could contribute to environmental sustainability.

Enzymes for PET Degradation:

PET, which is a commonly used thermoplastic, can be broken down by certain bacteria like Ideonella sakaiensis 201-F. These bacteria produce enzymes such as PETase, MHETase, TPA dioxygenase, and PCA dioxygenase that are highly efficient at breaking down PET into environmentally friendly molecules. The cooperation between PETase and MHETase is essential for efficient PET breakdown. Scientists have used genetic engineering to optimize these enzymes, resulting in improved versions that greatly enhance PET depolymerization. Additionally, cutinases like LC-cutinase and Thermobifida fusca cutinase are effective in PET degradation, with LC-cutinase showing better performance.

Enzymes for PCL and PES Degradation:

Just like PET, PCL is a type of thermoplastic that can be broken down into smaller, environmentally friendly molecules. This process is facilitated by enzymes produced by certain bacteria and microorganisms. For example, lipase can hydrolyze PCL into smaller molecules, which can then be assimilated by microorganisms like Aspergillus sp. strain ST-01, Pseudomonas, Alcanivorax, and Tenacibaculum. The degradation of PCL can also be achieved by thermophilic actinomycetes and thermotolerant bacteria.

Cutinases for PET and PCL:

Scientists have discovered that enzymes, such as lipase and cutinases, can help break down certain types of plastics, including PCL and PET. These enzymes are produced by bacteria and microorganisms and can hydrolyze the plastic into smaller, biodegradable molecules. One specific enzyme, LC-cutinase,

Scientists are exploring genetic engineering and enzyme optimization as ways to enhance the efficiency of plastic degradation processes, ultimately contributing to environmental sustainability efforts.