REVIEW ON EFFECT OF FUNGI ON PLASTIC DEGRADATION

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ABSTRACT: *Plastics are extensively used in day to day lives due to their versatilily, lightweight, flexiblility, moisture resistant, strong, and are relatively inexpensive. Dumping of plastics in the environment is highly hazardous and are major cause of environmental pollution. Accumulation of plastic is the current serious issue that is going around and is needed to be addressed immediately to restore the damages caused by plastic. Different types of plastic degradation strategies are followed. Plastic degradation by bioremediation is of growing importance as they are cheaper and highly effective. Fungi are major organisms that have the ability to degrade plastic. Enzymes from fungi are exploited for their ability to degrade plastics. This study deals with the review of effect of fungi on biodegradation of plastics.*

Key Words: *Plastics, biodegradation, fungi, hazardous, environmental pollution*

Introduction:

Plastics are man-made polymers that are used widely and are economical materials characterized by excellent all-round properties [1]. A plastic material is a synthetic or semi-synthetic organic solid polymers mainly made of carbon, commonly derived from petrochemicals. Plastics are cheaper to manufacture and are easy to use thus finds its application in many industries. Approximately 300 million tons of plastics are manufactured every year. They are light weight and highly durable hence used for various day to day activities [2]. Though it has lot of application it is disadvantageous due to its resistant to degradation leading to accumulation thus creating lot of ecological problems and need thousand years for successful degradation [3]. Accumulation of plastics is a serious threat to environment. In spite of plastic ban in many parts of the world, degradation of accumulated plastic is of utmost important. Accumulated plastics prevent water retention in the soil. Accumulation of plastic in sea and oceans pose a serious threat to aquatic lives. Hence degradation of accumulated plastic is important to prevent plastic from polluting the environment.

Plastic include many kinds of polymers like polyhydroxybutyrate, polyhydroxyalkanoates, polycaprolactone, polylactic acid, poly vinyl alcohol, polyurethanes, nylon and polyethylene [4]. Accumulation of plastics do not allow water and air to go into earth which causes infertility of soil, preventing degradation of other normal substances, depletion of underground water source and danger to animal life. In seas plastic rubbish causes chokes and death of marine organisms.

Microbial degradation has gained a lot of interest on plastic and polythene waste material. The change includes bond scission, chemical transformation and formation of new functional groups [5]. Biodegradation is defined as degradation that may occur due to change in surface properties or loss of mechanical strength, assimilation by microorganism degradation by enzymes, backbone chain breakage and subsequent reduction in the average molecular weight of the polymers [6].

Plastics and Environment

Plastics are very hazardous compounds when dumped in the environment affects animals and humans. In seas plastic rubbish from ropes and nets to the plastic bands from beer packs chokes and entangles many organisms like marine birds, sea turtles, cetaceans, fur seals, sharks and filter feeders [7]. Dumping of plastic prevents water and air entering into the earth as a result leading to soil infertility; ground water source is decreased causing difficulties to living organisms. Accumulation of plastics in sea endangers marine animals. Plastics are petroleum-based polymers that produced about 300 million tons every year and after usage these polymers are introduced to the environment as industrial waste products [8].

Table1: Different types of polymers and their commercial applications

Type of polymer	Uses
Polyethylene	Shampoo bottles, Grocery bags, bullet proof vests [9]

Polylactic Acid	Textile industry, food packaging [10]
Polystyrene	Packaging distilled water, milk, juice, beverages, ice creams, yoghurt [11]
Poly vinyl alcohol	Food packaging, storage [12]
polyvinyl chloride	Raincoats, shower curtains, shoe-heels, handles of screw drivers, combs, toothbrushes, spectacle-frames and -cases, false teeth [13]

Types of Degradation

Plastics are chemically synthesized polymers that are difficult to degrade. Normally, plastic degradation is very slow process and it is a influenced by various environmental factors such as humidity of air, moisture in the polymer, temperature, pH, solar energy; polymer properties and biochemical factors. Many mechanism of degradation of plastics are widely followed [14].

i) Photodegradation

Plastics are subjected to degradation by radiation. The radiation includes UV radiation that causes direct photolysis of plastics. Subjecting plastics to sunlight can cause degradation but at a slow rate.

ii) Thermal degradation

Plastics are subjected to heat that distorts backbone of the polymers. Thermal degradation cause physical changes leading to change in the molecular weight and reduces ductility of plastics.

iii) Oxo-biodegradation

This method involves the usage of photo degradation and oxidation. This reduces the molecular weight of the plastic and subjecting them to degradation.

iv) Biodegradation

Use of living organisms to degrade plastic is known as biodegradation. Microorganisms are exploited for this biodegradation.

Biodegradation of plastic by microorganisms

Biodegradation is defined as a process which occurs due to the action of living organisms (bacteria, fungi, actinomycetes.) leading to its chemical decomposition. In biodegradation the first step is the formation of biofilm by the deposition of microorganisms on the surface of the plastic. Then the polymers are broken down to low molecular weight monomers. The prerequisite for this process to take place is that the microorganism should be able to use the polymer as its sole carbon source. Biodegradation of plastics is performed either aerobic or anaerobic ways. Aerobic degradation results in carbondioxide and water. Anaerobic degradation results in carbondioxide, water and methane as end products [15]. Biodegradation of plastics is influenced by the organism used, the type of pretreatment followed, and characteristics of plastic used. Table 2 lists different degradation of polymer by fungi.

Table 2: List of fungi associated with polymer degradation

Type of polymer	Microorganisms
Polyethylene	*Aspergillus fumigates, Curvularia lunata, Alternaria alternata, Penicillium simplicissimum, Fusarium sp, Phanerochaete chrysosporium, Trametes versicolor, Trichoderma viride, Aspergillus nomius* [16-18]
Polylactic Acid	*F. moniliforme,* Thermomyces lanuginosus and *A. fumigates* [19,20]
Polycaprolactone	*Fusarium solani, Aspergillus flavus, A. niger, A. fumigatus, Chaetomium globosum, Pencillium funiculosum, and Fusarium sp* [21]
Poly vinyl alcohol	*Fusarium, Aspergillus, Phanerochaete chrysosporium, Galactomyces geotrichum, Trichosporon laibachii, Fimetariella rabenhorsti and Fusarium oxysporum. G. geotrichum [22]*
polyurethane	*Chaetomium globosum, Aspergillus terreus, Curvularia senegalensis, Fusarium solani, Aureobasidium pullulans, and Cladosporium sp* [23]
polyvinyl chloride	*Phanerochaete chrysosporium, Lentinus tigrinus, Aspergillus niger, and Aspergillus sydowii* [24]
Polyhydroxybutyrate	*Penicillium, Aspergillus* spp [25]

Factors influencing biodegradation by fungi

Rate of degradation of polymer by fungi is influenced by temperature. Higher soil temperature increases the metabolic rate of fungi leading to higher degradation of plastic. Thus the rate of degradation of plastic by fungi varies with season. pH determines the growth of fungi and rate of degradation of plastic. In general the growth of fungi is higher in acidic and basic pH compared to neutral pH. *Aspergillus* showed maximum growth at acidic pH while *penicillium* showed higher growth at basic pH [26]. Chemical and physical property of plastic greatly influences the degradation process. Polymers having low molecular weight are easily degraded. Melting point also influences the degradation ability. Degradation of polymer decreases with an increase in melting point. Degradation rate is also affected by the size of polymer.

Fungal Enzymes and Biodegradation

Enzymes are biological catalyst that has applications in various industries. Microorganism synthesizes various enzymes to perform their metabolic activities. Enzymes also play a major role in biodegradation by microorganisms. Microbial degradation of a solid polymer like polyethylene requires the formation of a biofilm on the polymer surface, to enable the microbes to efficiently utilize the non-soluble substrate by enzymatic activities. The enzymatic degradation of certain natural polymers follows the unzipping or chain degradation that happens by two mechanism biological hydrolysis and biological oxidation. Large enzymes cannot penetrate through the polymer hence degradation occurs mainly on the surface. The degradation of polymers in solution requires the solubility of polymer in organic solvent. The enzyme activity on biodegradation of polymers is mainly dependent on the solvent properties and the enzyme activity increases with polarity and decreases with viscosity of the solvent. From biodegradation of aliphatic polycarbonate the end products obtained are CO2 and acids [27]

Fungi are reported to produce amylase, cellulase, protease, lipase, and laccase that are known to degrade many polymers. Arthrobotrys oligospora synthesize serine protease that degrade polylactic acid. For polyurthene degradation protease are more effective than esterase. Mixture of protease and esterase was also found to be very effective on polyurethane [28]. *Aspergillus*, *Penicillium*, *Rhizopus*, *Mucor*, *Humicola*, *Thermoascus*, *Thermomyces* have been reported to produce acid protease [29]. *Aspergillus fumigatus* synthesize dehydrogenase and oxidase. The backbone of polymer is cleaved by dehydrogenase and oxidase [30]. Fusarium solani synthesize PHB depolymerases that degrade poly-β-hydroxybutyrate [31]. Polyhydroxybutyrate depolymerase has high substrate specificity, increases adsorption of enzyme since it has two substrate binding domain [32]. Fungus strain Rhizopus delemar known to synthesize lipase that degrades polylactic acid. Comamonas acidovorans produce polyurethane esterase that degrades polyurethane and low and high molecular weight polylactic acid [33]. Lipase and esterase also degrade polycaprolactone polymer[34]. Phanerochaete chrysosporium, Trametes versicolor produces lignin peroxidase, and manganese peroxidase enzymes that are reported to degrade polythene [35]. *Trametes versicolor, Pleurotus ostreatus, Streptomyces,* fungi like *P. ostreatus* and *T. pubescens* produce laccase that degrade polyethylene [36]. *Aspergillus oryzae, Fusarium solani produce cutinase enzyme that is involved in the degradation of* polycaprolactone [37].

Hydrolysis of Polyethylene terephthalate, Polybutylene terephthalate with lipase from *Rhizopus delemar*, polyethylene hydrolysis from pseudomonas sp., *Chromobacterium viscosum* by lipase has been reported [38]. Enzymatic hydrolysis of cellulose can be a multi-component system called cellulase produced by bacteria and fungi. This degradation is highly specific and no byproducts are formed [39]. Laccases are mostly present in lignin- biodegrading fungi, can degrade non-aromatic substrates [40]. Proteolytic enzymes papain and urease found to degrade medical polyester polyurethane. Polymer degraded by papain was due to the hydrolysis of urethane and urea linkages producing free amine and hydroxyl groups. *Pestalotiopsis microspore* produces polyurethane dehydrogenase that degrades polyurethane [41]. Polyurethene degradation occurs by hydrolysis of polyurethane by endopolyurethenases at random locations and exopolyurethenases that remove successive monomer and dimers from the chain ends [42].

Proteases can either break specific peptide bonds (*limited proteolysis*), depending on the amino acid sequence of a protein, or break down a complete peptide to amino acids (*unlimited proteolysis*) [43]. Several enzyme activities namely esterase, protease and urease, from fungi are reported to degrade ester-type polyurethane. Esterase, derived from *Xepiculopsis graminea*, and *Penicillium griseofulvum* reported to degrade polyurethane by two step reaction: i) hydrophobic adsorption onto the polyurethane surface followed by hydrolysis of the ester bonds of polyurethane [44]. Lipases, Candida Rugosa, Hog pancreas, Lipolase and Novozyme are reported to degrade poly bisphenol-Acarbonate [45].

Conclusion

Plastics are widely used in our day to day lives and our modern civilization would look diverse without plastic. Accumulation of plastic in the environment causes hazards to humans and other living organisms. Hence easy and cheap methodologies are needed to develop for clearing the dumped plastics. Biodegradation is the effective way to remove the plastics from the environment. Fungi are major organisms that can be exploited for their ability to degrade plastics. Enzymes from fungi have the ability to convert the polymers into monomers and oligomers, thereby degrading plastics.

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