Perspectives Of Bioplastics- A Review

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Abstract—Polyhydroxybutyrate (PHB) is a thermoplastic easily degradable by the action of microorganisms. A large amount of non-degradable plastics wastages are causing Environmental biggest problems. These plastics are the availability of in some markets and it's very dangerous to the environment. The non-degradable plastics are solid wastes, greenhouse gas, carbon dioxide, different air contaminations, dangerous dioxins, and polycyclic aromatic hydrocarbon are discharged to the environment it causes extreme damage and harmful to the occupants. The finding of alternate for the problem causing non-biodegradable plastics is needed to protect our environment. Therefore, the easily degradable bioplastics gained attention in the environmental research community. Biodegradable bioplastics are generally publicized in the public and the demand for a package is quickly expanding among the retails and food industry at large scales. This review highlights every one point are regarding the applications, types, production, sustainability, challenges, and fermentation process advancement and uses of modest substrates for the production of bioplastics. Microbial production of bioplastics with assorted structures is entering another developing phase. It views the author that is bio-degradable plastic materials are generally adept for single uses of disposable applications are post utilization wastes can be privately treated the soil.

Index Terms— bioplastics, Microorganisms, Polyhydroxyalkanoate, Polyhydroxybutyrate, biodegradability,

1 INTRODUCTION

Polyhydroxyalkanoates is a Polyhydroxybutyrate, a polymer with a polyesters class that is an interesting area bio-derived subsequently biodegradable bioplastics [1]. Petroleum oil-derived plastics are (traditional plastics are made from mineral oil) qualities for having highly versatile such as robustness, lightness, and resistant to degradation. These have become important materials for everyday life and over the years have successfully replaced Many other substances which have a wide variety of domestic applications. Industrial and medical fields in this form of a disposable gear, machinery frames, furniture, packaging, and Accessories to improve the comfort and quality in life [2]. A new sort of plastic is now being made, called Bioplastic. Bioplastics are naturally biodegradable that they are either made from biomass or fossils. Biodegradation is the capacity of various microorganisms to utilize synthetic polymers as a source of carbon Polymers being utilized for the bioplastic productions are include Polyhydroxybutyrate. A few microorganisms utilize this polymer as a carbon source and energy. Microbes also secrete the polyhydroxyalkanoate enzyme de polymerases that help to degradation of plastics. [3]. Biodegradable plastics provide the best option for protecting the environment from hazards caused by traditional petroleum-based plastics because they are in nature 'eco-friendly.' There are several types of biodegradable bioplastics with various degrees of biodegradability. between them is the polyhydroxybutyrate are only 100 percent biodegradable ones. PHBs are bacterially synthesized macromolecules and have accumulated as reserve materials the bacterial grow under various stress conditions [4]. Polyhydroxybutyrate (PHB) and its copolymers, P(3HB- co- HV) poly(3- hydroxybutyrate-co-hydroxy valerate) are the most thoroughly and widespread characterized polyhydroxyalkanoates. Various microorganisms are *Pseudomonas spp, Alcaligenes spp*. various filamentous genera are having the capacity to produce bioplastics [5]. Despite the difficulty in handling this wastes, it may serve as a low-cost source of carbon for the commercial synthesis of biodegradable polymers are such as Polyhydroxybutyrates (PHBs) due to the presence of high sugar concentration in the waste. PHAs is a thermoplastic material that is synthesized by various bacteria (30–80 percentage of dry cell weight) as carbon storage material and intracellular energy under stress conditions resulting from limitations of certain nutrients such as carbon (*Hyphomicrobacterium spp, Spirillum spp*) Phosphates (*Caulobacter crescents, Rhodobacter rubrum*) and nitrogen (*Ralstonia eutropha, Pseudomonas oleovoran, Alcaligenes latus*) [6]. Various prokaryotic species that can be produced PHBs, the most commonly studied being *Cupriavidus necator* are (formerly referred to as *Waustersia eutrophus, Rasstonia eutropha, and Alcaligenes eutropha*) *Cupriavidus necator* is capable of autotrophically rising and accumulating PHB using CO_2 the primary source of carbon and as hydrogen energy sources [7,8]. To date, Over 250 various natural PHB producers have been identifying, but only a few people have made it for commercial biosynthesis are including *Pseudomonas oleovorans, Bacillus megaterium, Alcaligenes latus,* and *Cupriavidus necator*. as the easily usable and inexpensive raw materials can be used as carbon sources. *Cupriavidus necator* was the most widely studied and often used bacterium for the development of PHA. Earlier mutant which used glucose. C. necator was used to generate PHA industrially and marketed as BiopolTM [9]. Numerous microorganisms are including *Bacillus megaterium, Rhodospirillum rubrum, Azotobacter chroococcum, Pseudomonas oleovorans, Zoogloea ramigera,* and *Alcaligenes eutrophus*, synthesize and accumulate PHBs as an reserve energy materials when nitrogen supplies are reduced as nutrients [10, 11]. H16 *Ralstonia eutropha* is a Gram-neg litho autotrophic bacterium which belongs to the Proteobacteria b-subclass. It is an omnipresent inhabitant of freshwater and soil biotopes and is well suited to life in environments under transient anoxia [12]. Even though more than 300 different micro-organisms are synthesizing PHA, only several of these, such as *Ralstoniaeutropha* (formerly known as *Alcaligeneseutrophus*), *Alcaligenes latus, Azotobactervinelandii*, several strains of Methylotrophs and recombinant *Escherichia coli* are suitable for the production of PHA to a high concentration with high productivity [13, 14].

The generation of PHB by bacteria and their pathways of PHB biosynthesis has been extensively studied for the last decades. However, knowledge on the diversity of bacteria producing PHB in Antarctic regions, These PHB properties, and enzymes are involving in their biosynthesis. finally, to date, this produced PHB only one *Pseudomonas species* from

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the Antarctic origin. Was described [15, 16]. This work aimed to characterize the polymers obtained through the transformation of *Pseudomonas Mediterranea* 9.1 mediated glycerol and its major physicochemical properties. Its unique capacity to create a very filmable polymer, the instead of usual sticky MCL- PHB, it's the possible application in polymeric mixes for Medical device and packaging [17]. The research focused on the development of granules polyhydroxybutyrate (PHB) by strains isolated from various soil samples. Ther were Isolation, Screening, and optimization techniques that are done for the microbes by using different techniques. The production of PHB granules was tested using different C: N sources, C: N ratios, C&N concentrations used, and incubation times, and effect of pH, different temperatures, and different fermentation media. It was noticed the PHB granules maximum density from clay soil samples was recorded [18]. Polyhydroxybutyrates is used in productions following; Food containers; Shampoo bottles; effective use of dishwasher due to strong material impact and temperature resistance; Disposable utensils; Composite glial growth factors; PHB coated papers; Disposable razors; Fishing nets; Drug carriers; Golf tees, etc.. [19].

Types of bioplastics

Various types of bioplastics are being attempted to be manufactured on a large scale. Some of those are mentioned below.

Starch-based bioplastic

Thermoplastic starch is the most commonly used bioplastic, making up about 50 % of the bioplastics in the market. Simple bioplastic starch can be developed at home[20]. starch is cheap, renewable, and abundant, the origin of this raw material due to [21]. complex blends of starch-based plastics are starch of compostable plastics like Polubutylene adipate terephthalate, Polycorpolactone, Polylactic acid, Polyhydroxybutyrates, and Polybutylene Succinate. These complex mixtures improve both water resistance and mechanical properties and processing. [21, 22]. Starch can absorb moisture which makes it an appropriate candidate for the production of drug capsules. Starch can also be handled thermo-plastically, with the addition of sorbitol and glycerin to starch. Starch-based bioplastics are sometimes combined with biodegradable polyesters are produce polycaprolactone. These compounds are biodegradable [23].

Cellulose-based bioplastic

when extensively modified, cellulose can become a thermoplastic. Cellulose acetate is an example of this, which is costly and therefore rarely seldom used for Packaging. Nevertheless, cellulosic fibers added to the starches can be improving mechanical properties[24]. A group at Shanghai University was able to create a novel, cellulose-based green plastic using a process called hot pressing[25].

Protein-based bioplastic

Bioplastics may be made from a protein from various sources, for example, casein, and wheat gluten exhibit promising properties for various biodegradable polymers as a raw material[26] Due to its water sensitivity and comparatively high cost, there are difficulties soy protein-based plastics are used Production of soy protein mixtures with some already usable biodegradable polyesters, therefore, increases the sensitivity and cost of the water[27].

Polylactic acid (PLA)

Corn and dextrose are used to produce transparent Polylactic acid in nature. It carries similar characteristics as plastics based on petrochemicals and it can be produced using methods of production followed for traditional plastics. PLA is commonly used in films, cups, bottles, and fibers production [28].

Polyhydroxybutyrate (PHB)

Some glucose- and maize starch-producing bacteria can be used to manufacture of poly-3-hydroxybutyrate. It bears the same characteristics as polypropylene plastics. PHB is used in packaging purposes by the South American sugar industry. PHB can also be transformed into transparent films and has a melting point above 130 ° C and is naturally biodegradable [29].

Polyhydroxyalkanoates (PHA)

These are linear polymers formed by fermenting sugars and lipids with bacteria. It is produced by bacteria to store carbon and energy. This polymer is extracted from bacteria at the industrial level and is used in the fermentation of sugar. less elastic, but PHB is more ductile. PHB is biodegradable as well. PHB has its application medical field [30].

Polyamide (PA11)

It is gotten from natural normal oil and is under trade-off name Rilsan B, Arkema by manufactured. Polyamide 11 is not biodegradable and has similar properties to Polyamide12. Polyamide11 finds use in automatic fuel tanks, airbrake pneumatic tubing, gas pipes, and flexible oil. Polyamide 410 is derived from castor oil, produced by DSM, under the trade-off name EcoPaXX. Polyamide 410 has approximately 250° C melting point is hight. has low humidity absorption and is extremely resistant to other chemical substances [31].

Polyhydroxyurethane

Recently the considerably larger focus has been put on the manufacture of isocyanate-free polyurethanes and bio-based. One example, spontaneous reactions are cyclic carbonates, and polyamines are used to produce polyhydroxyurethane [32] Cross-linked polyurethanes are unlike traditional; Cross-linked Polyhydroxyurethanes can be recycled and reprocessed by dynamic transcarbamoylation reactions [33].

Application of Bioplastics

This Application of Polyhydroxybutyrates both in types and quantity has increased over the past 2 to 3 decades in particular. Earlier uses were mainly in packaging areas of (e.g) shampoo bottles and cosmetic containers [34, 35]. It has been found that many microorganisms accumulate Polyhydroxyalkanoates (PHA) intracellularly under unfavorable conditions. Biodegradable thermoplastic polyesters. As for raw material, around 40 percent of the overall cost of production is used in PHB production. To replace this high production cost of PHB a cheaper carbon source is required [36]. Compostable waste bags, carrier bags, and organic waste bags to collect. which can be used also be organic waste bags. They will increase the amount of organic waste collected, therefore landfills reduce and improve the compost quality and composting process. These bags are most of them also sometimes called biobased often regarded to be a primary market for biodegradable plastics concerning the sizeable volume markets and valid arguments for favoring its use [37]. Biodegradable mulch film that can be plowed into the field once used, which can reduce labor which disposal costs. Wide event catering products or packaging operations for sales snack food. They can be quickly composted along with any other food scraps remaining after use. The list of available compostable items includes trays, dishes, cups, bags, and cutlery [37]. Packaging film for foods with a shelf life short that requiring attractive appearance, or to prolong shelf life. Which include compostable, netting, and (foam) trays for fruit and vegetables (organically produced), as well as fresh meat recently. The quick disposal and the fact that the sales period may be extended in part are advantageous to retailers. Spoiled food can be recovered by composting without separation of packaging and sale point material [37]. Rigid packaging, for example, containers and bottles. PLA-made bottles are used in non-sparkling drinks and dairy products. Many other products use their specific features, such as a tire with starch materials added to reduce hysteresis and urns, fuel consumption, diaper soft touch and back sheet, etc.. [37]. These compounds are particularly used for long term dosing of the drug, medicine, hormone, herbicides, and insecticides as biodegradable carriers.They are also used as synthetic osteo materials in promoting bone growth due to their piezoelectric properties, surgical sutures, and replacements of the blood vessels, in bone plates.However, the Pharmaceutical and medical applications in sterile tissues are limited due to slowly biodegradation, and high hydraulic stability [38]. Special biodegradable plastics are uses for some in the area of medical technology as stitching material and decades for implant or screws (extremely high price niche products) [39].

Properties of Bioplastics

Many microorganisms can degrade PHBs to CO_2 and water at a high rate (3 to 9 months), using their ownly secreted PHB depolymerases[40]. It can be generated using renewables.Naturally Eco-friendly. PHBs extracted from the bacterial cells have similar properties to plastics conventional, such as polypropylene. Hence they are a very good substitute for petrochemical thermoplastics[41]. Therefore, the composition and types of the polymer, the nature of microorganisms and environmental conditions affect the biodegradation of PHBs (various microorganisms develop specific PHB-depolymerase to degrade PHBs)[42]. PHBs and other solvents made from chlorine are soluble in chloroform.Their temperature for various glass transitions from −50 to 4 ° C, the temperature is melting from 40 to 180 ° C[43]. The temperature of Thermo degradation, water vapor, youth module, tensile strength, and transmission of oxygen rate differ depending on this type of polymer and monomeric unit composition. [44].

Classification and Structure

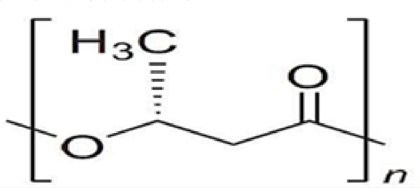


Fig-1 General structure of Polyhydroxyalkanotes [45].

Some 150 different PHA congeners were reported [46]. the general PHBs structure in fig. 1 is shown. if the group is R=CH_3, the resulting polymer is called Polyhydroxybutyric acid or polyhydroxybutyrate, while the polymer is called polyhydroxyoctanoate if R = C_3H_7. PHAs are categorized into three groups of Short-chain length, medium-chain length, and long-chain length (SCL, MCL, and LCL) respectively depending on the number of carbons in the side chains [47].These classifications are based on this number of carbon atoms in this chain of branching polymers ranging from 3 to 14 carbon atoms and the types of heteropolymers or homopolymers monomer units producing [48]. PHAs short chain lengths (PHASCL) is composed of 3 to 5 carbon atoms. For examples of these types are poly(3-hydroxy valerate) P(3HV), poly (3-hydroxybutyrate) P (3HB), and poly (4-hydroxybutyrate) or P(3HB-co-3HV) copolymer. PHAs Medium-chain lengths (PHAMCL) consist of 6 to14 (or) more than fourteen carbon atoms [49].The difference between the two groups is mainly due to this substrates specificity of the PHB syntheses. that can be accepting 3HBs of a certain carbon length range. for example. *Alcaligens eutropha* PHB synthase can polymerase 3HBs consisting of 3 to 5 carbon atoms at the same time PHB synthase of *Pseudomonas oleovorans* can accept only 6 to14 carbon atoms [50]. There are also hybrid polymers consisting of both short and medium-chain length monomeric units, such as poly (3- hydroxy hexanoate -co-3- hydroxybutyrate) [51]. The PHB production homopolymer has resulted from the use of even-numbered n-alkanoates while oddly numbered n-alkanoates produce 3HB and 3-hydroxy valerate (3HV) copolymers. Poly terpolymers (3-hydroxyheptanoate-co-3-hydroxybutyrate-co-3-hydroxy valerate) have been produced by recombinant Alcaligenes eutrophus strains harboring the PHB synthesis gene of Aeromonas caviae from odd carbon number alkanoic acids [52, 53].

General Polyhydroxybutyrate (PHB) Production Process and Applications (Google sources)

Various microbes involved in bioplastic production

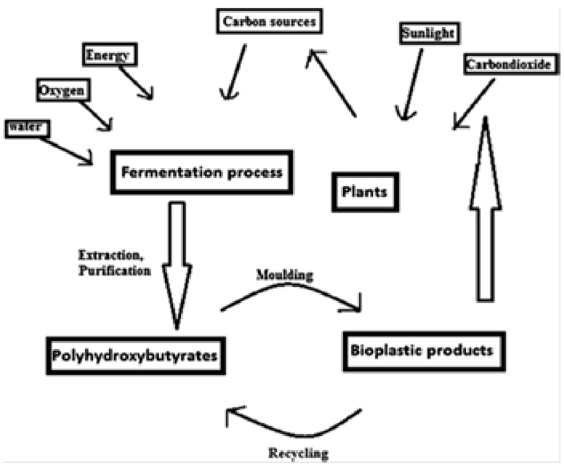
S. No	Strains	Biopolymers	Substrates	Reference
1	*Alcaligenes*	P(3HB)	malt waste,	[54]

	latus		Soya waste	
2	*Bacillus megaterium*	P(3HB)	date syrup, Beet molasses	[45]
3	*Bacillus spp* SV13	P(3HB)	Pineapple and sugarcane	[55]
4	Recombinant *Escherichia coli*	P(3HB)	Soyabean oil, Glycerol	[56]
5	*Pseudomonas aeruginosa*	PHA	Palm oil	[57]
6	*Bacillus sp.*	P(3HB)	Glucose, glycerol, sod. Acetate	[58]
7	*Cuprividus necator*	P(3HB)	Bagasse hydrolysates	[49]
8	*C. necator*DSM 545	PHA	Waste Glycerol	[59]
9	*Pseudomonas guezenneibiovar*	PHA	Coprah oil	[60]
10	*Waustersia eutropha*	PHA	Canola oil	[61]
11	*Pseudomonas pitida*	PHA	Glucose, Octanic acid	[62,63]
12	*Pseudomonas oleovorans*	Medium-chain length-PHA	Octanoic acid	[64, 65]
13	*Escherichia coli mutants*	PHB	Molasses, ethanol, sucrose, glucose, palm oil, glycerol	[66, 67,68]
14	*Bacillus cereus*	PHB	Sugarbeet molasses, glucose	[69, 70, 71]
15	*Pseudomonas aeruginosa*	Medium-chain length-PHA	Technical oleic acid, waste-free frying oil, waste-free fatty acids, glucose	[72, 73]
16	*Rhodopseudomonas Palustris*	PHBV, PHB	Acetate, fumarate, malate, gluconate, glycerol, malonate, butyrate, succinate, propionate	[74]
17	*Waustersia eutropha*	PHB	Palm kernel oil, crude palm oil	[75]
18	*Pseudomonas guezennei*	PHA	Pyruvate, acetate, glucose, hexanoate, octanate, decanoate, heptanoate and oleic acid	[60]
19	*Ralstoniaeutropha H16*	PHB	Glucose	[76, 77]
20	*Ralstoniaeutropha*	P(3HB/3HV)	Glucose + propionic acid	[78]

PHB from microbial resources
Microorganisms a source of research for biopolymers (polysaccharides) and bioplastics using agricultural waste as the medium for production. While they are more costly at the moment, bacteria still can produce bioplastics with properties comparable to conventional polymers that can be further altered by altering the bacteria's growing medium and growing conditions. The method of bioplastic production from microbes has been optimized with the arrangement of end products having increased properties. A large number of produced biopolymers have become suitable in food applications and other industrial applications and such microbiologically synthesized plastics, polyhydroxybutyrate are called (PHB), Which are synthesized from different bacterial groups and cheap renewable resources and completely degraded by microorganisms under-stimulated control atmosphere to CO_2 and H_2O aerobically.PHB is produced using certain natural isolates and recombinant bacterial strains on various substrates, along with the measure of PHB accumulated inside of the bacterial cells[79] To maximize the maximum benefits and commercial production of this biopolymer, it is necessary to select a bacterial strain with the highest PHA output which can grow at the same time with efficient fermentation with a simple recovery process[50].
These are the criteria that need to be standardized before the commercial manufacturing of PHB. Under unbalanced growth conditions, polyhydroxybutyrates (PHB) are synthesized by bacteria which regulates the types and amount of PHB in the cell [80]. Some bacteria can produce PHA up to 90 percent (w / w) of dry cell weight by modifying media conditions, such as the depletion of the essential nutrients (phosphorus, nitrogen, or magnesium).PHB an energy storage compound in the microbes also allows them as a drain to minimize equivalents[81].
PHA is insoluble within the bacterial cytoplasm and, due to its aggregation, does not increase the osmotic pressured of bacterial cells, thus allowing them to accumulate more PHB without limiting their growth[9].
After the commercial development of Biopol, it became clear that PHB creates microbes and harbors native machinery for degradation of polymer making it difficult to recover PHB molecules from the bacterial cells [82].
This led to genetic engineering development in the isolation and identifying bacterial strains can produce higher amounts of PHB with a simple extraction procedure. PHB is produced industrial by 2 main processes, Fermentation, and renewable resources [83].

Biodegradation part
In recent years, the need to protecting our environment from plastic contamination, and use to sustainable resources i.e. waste, biomass, etc., to meet our material has needs gained worldwide attention. While biobased and biodegradable bioplastics can bring some technological advances, our environmental and sustainability challenges should not be viewed as a comprehensive technological solution[84,85] PHB reaches international biodegradation levels in anaerobic digestion conditions and industrial composting but demonstrates a very slow degradation rate in water and soil[86]. 5 g samples of the produced Cellulose acetate were dried at a temperature of 45ºC for 24 h, weighed accurately, and then buried in the municipal solid waste mix. They were then looked into for potential biodegradation. The mixture included leaves, cow dung, composting seeds, wood waste, paper waste, food waste, urea, and water [87]. This mixture was 55ºC at kept in an oven, at which the thermophilic microorganisms are maximum growth occurred. the samples are weighted every 3 days to asses the percentage of weight-

loss. The biodegradability is the property that separates PHB from petroleum-based plastics. PHBs become depleted upon compost, soil, and marine sediment exposure. Biodegradation depends on several factors, such as environmental microbial activity, humidity exposed surface area, pH, temperature, and bioplastic molecular weight [88]. Degradation has also been found to influence the structure of the monomer units. Copolymers that contain PHB monomer units were found to degrade faster than either PHB or 3HB-co-3HV copolymers. The biodegradation of PHB results in CO_2 and water under aerobic conditions, while the degradation products are methane and CO_2 under anaerobic conditions. PHBs are compostable over a large range of temperatures; also at a high humidity level of about 60ºC at 55 percent. In seven weeks, about 85 percent of PHB can be degraded [89].



Biodegradation process of Polyhydroxy butyrates [90].

Conclusion

This paper focuses on the value of biodegradable plastics because of the adverse effects of petroleum-based plastic materialism on the environment and raising concern about oil scarcity and petroleum prices. The sustainable nature and biodegradability of PHBs make them ideal tools in many applications for replacing synthetic plastics. Their processing is currently costly but these plastics are still at their 1st stage of commercial growth. Potential applications of PHB are promoting in different industries and the field of, medicine. Nevertheless, PHB's cost of production has a major drawback. As a result, scientists have made tremendous success in discovering new bacterial strains, developing new types of the recombinant strains, and the tailoring various forms of PHB to reduce production costs. It is anticipated that the ongoing marketing activities in several countries will soon make PHB available for this application in different areas

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