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Review Article

Development and sustainability of bioplastics: A review

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ABSTRACT

The expansion and development of bioplastics and their products would increase environmental sustainability and reduce greenhouse gas emissions. A game-changer and a critical component of a long-term plastic pollution solution, bioplastics would be a game-changer. However, extensive public awareness is required to achieve long-term change in the fight against plastic pollution. This response could aid in addressing environmental threats. Plastic particles and waste and biodegradable plastics, make up a small part of the worldwide plastics industry, needing further research and development. This work provides a comprehensive analysis of the advances in biodegradable plastics through the challenges of the plastic industry and the vast market potential for biodegradable plastics. Government policy, and the socioeconomic and environmental consequences of plastics. Physio-chemical characteristics, standards, certifications, and analytical methods are discussed. It was found that bioplastics outperform petroleum-based plastics in terms of energy consumption, petroleum use, and carbon dioxide emissions. However, they fall short in terms of cost and application. Pollution and safety differ from one plastic to the next; although, bioplastics are generally safer. Hence, bioplastics are believed to be unviable in their existing state for the wide-scale application.

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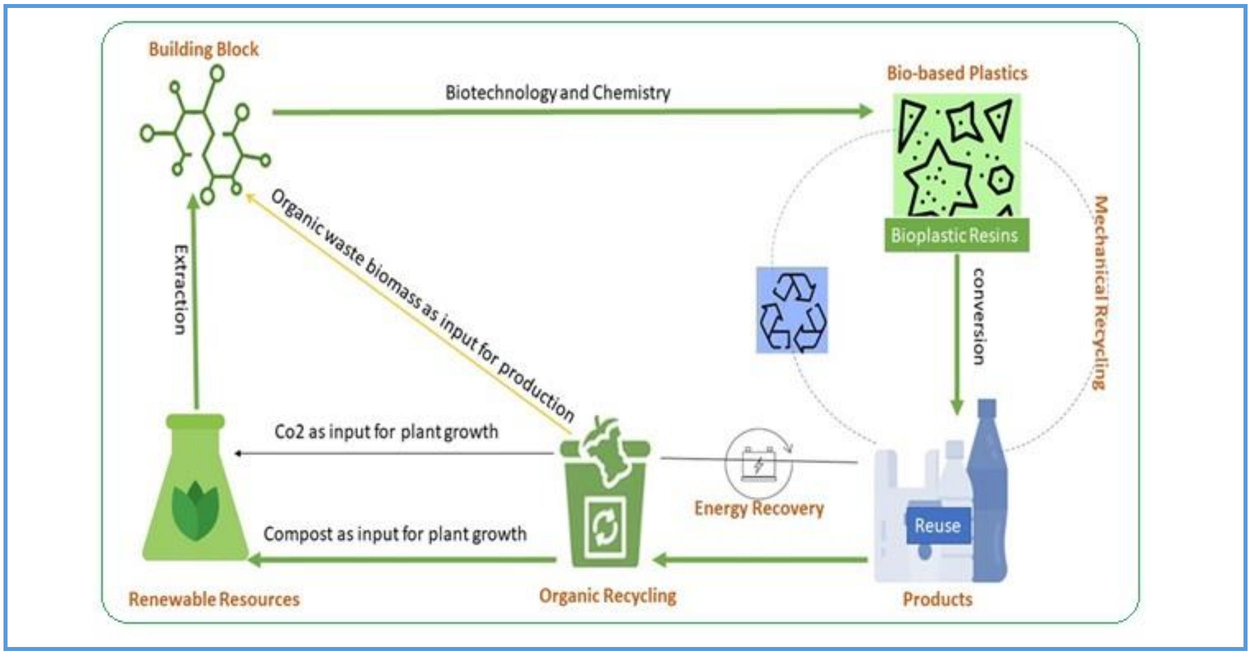
Graphical Abstract



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Introduction

Plastics are a broad group of polymers derived mostly from fossil fuels and have a wide range of qualities and characteristics. Plastics originating from fossil feedstock account for roughly 90% of total production. Every year, humans produce about 34 million tonnes of plastic garbage, with just 7% of it being recycled. The remaining 93% is disposed of in landfills or dumped into bodies of water. Plastic manufacturing currently accounts for 4–8% of world oil use. However, this percentage is anticipated to rise to 20% by 2050. In its early phases, the plastic industry appeared to benefit humanity. However, as its usage has become more widespread throughout time, it has harmed society. Plastic's success and expansion can be ascribed to its low pricing, durability, strength-to-weight ratios, and contributions to everyday convenience. Plastic products, which are common in our daily lives, are increasingly causing severe environmental issues. Millions of tonnes of these non-biodegradable polymers end up environment every year. Persistent plastic trash is causing considerable worry around the globe as current garbage management solutions are insufficient. The "landfill problem" is the first environmental issue caused by excessive plastic. In many places of the world, increasing levels of plastic garbage have become a crisis due to dwindling landfill capacity and rising landfill costs worldwide. The "accumulation of plastics in water bodies" is one of the major environmental issues. For example, long-term investigations in the North Atlantic found 580,000 particles of plastic per square kilometer in one saltwater sample. The burning of plastic produces carbon dioxide and methane [1]. These greenhouse gases (GHGs) play a significant role in global warming. The other major issue is "durability" (i.e., non-biodegradability). Plastic is non-recyclable and will linger for hundreds of years in the environment. "Competition for crude oil and energy security" is the economic issue. The adverse environmental effects of petrochemical-derived plastic polymers are becoming more widely recognized by the public, and hence, these problems can be overcome.

Many studies have been undertaken to develop eco-friendly alternatives for managing plastic waste. Bioplastics are an ecologically sustainable alternative that can be discarded in the environment, which microorganisms would easily decompose. Bioplastics are cutting-edge materials for the twenty-first century that will significantly impact the materials industry. Bioplastic manufacturing and usage are likely to increase globally shortly. Therefore, these materials must be carefully assessed for long-term viability and waste management. As a result, this review evaluated the current state of bioplastic materials, concentrating on their advantages and their shortcomings. It also includes a summary of bioplastics standards.

Bioplastic

Bioplastics are biodegradable or bio-based plastics made from plants or microorganisms rather than fossil fuels. Bioplastics are like commercial plastics in appearance and can also be used in various ways. The only exception is that biodegradable or bio-based bioplastics use the term "bio," but they are not the same. All bio-based plastics are biodegradable, but not all biodegradable plastics are bio-based. [2] Biodegradable polymers lose their biophysical properties when exposed to bacteria and disintegrate, converting into CO_2 in aerobic conditions and methane in anaerobic conditions within a given time limit. The amount of time it takes for a substance to degrade depends entirely on the material, temperature, and other environmental conditions such as humidity and the decomposition location. Biodegradable plastics are plastic that microorganisms may break down into humus, which is abundant in nutrients and free of hazardous metals. The biodegradable polymers should adhere to the established guidelines. During this time, particles must also be digested into residues with a dimension of less than 1 mm, so not all biodegradable plastics are compostable.

Bio-based plastics are another form of bioplastic made from a variety of plant-based essential components that are not always biodegradable. Bioplastics are created from organic polymeric components that can be present in bacteria, plants, and animals. Bioplastics are made from biological precursors such as starch, cellulose, and lactic acid produced by living organisms such as microbes, plants, and animals or from biological raw materials such as starch cellulose, and lactic acid that are chemically manufactured [3]. Bioplastics could help with the conservation of exhaustible fossil fuel resources and help overcome the difficulties that come with them if they are produced and used on a massive scale. Chemical and organic recycling would also provide advantages, such as reduced carbon emissions and more waste disposal choices. Biodegradability would solve the world's plastic pollution problems. As bioplastics are compostable, they can be applied to the soil without causing harm since they would simply decay and decompose. However, certain bioplastics may leave harmful residues in the form of soil fragments; for example, some bioplastics may only degrade in a specialized composter at high temperatures since the maritime environment does not provide a suitable habitat for the decomposition of biodegradable plastics. However, effective collection, sorting, and recycling processes would increase bio-plastic recycling resource recovery. Furthermore, products made of bioplastic have superior mechanical strength and thermal stability compared to conventional virgin plastic. Totes, super-absorbent for diapers, sewage control, a wide variety of packaging applications, health and prosthetics, catering and sanitation supplies, and agricultural composting are just a few of the applications for bioplastics [4]. Bioplastics are more expensive than normal plastics. Bioplastics' usefulness and availability have increased because of rising interest in sustainable development, a desire to minimize dependency on fossil fuels, and changing waste management policies and attitudes.

Advantages and disadvantages of bioplastics

Advantages

Biodegradable plastics have great potential in the future. Some of the advantages of bioplastics are as follows:

It is possible to dramatically reduce one's carbon footprint. However, it is vital to remember that a bio plastic's carbon footprint is greatly influenced by whether the carbon taken from the air or by the growing plant is permanently stored in the plastic. The CO_2collected by the plant during photosynthesis is sequestered by plastic manufactured from a biological source. Hence, this sequestration is reversed when bioplastic degrades into CO_2 and water. However, a permanent bioplastic that looks like polyethylene or other ordinary polymers can store CO_2 indefinitely. Even if the plastic is recycled several times, the CO_2 extracted from the atmosphere is still contained. Bioplastics can be created from renewable resources rather than fossil fuels. Renewable resources have a lower carbon footprint, which helps to minimize greenhouse gas emissions. Bioplastics production emits roughly 80% less carbon dioxide than petrochemical plastics manufacturing. In addition, bioplastics require 65 percent less energy to manufacture than petrochemical plastics. Some other benefits include a reduced carbon footprint, energy efficiency, and environmental safety. For example, bioplastics are more marketable and could increase a product's value-add through a green marketing campaign. Bioplastics are a persuasive argument for marketers, given that "80% of European buyers want to buy items with a low environmental impact."

PLA and PHB, two starch-based bioplastics, are non-toxic and pose no health risk. Since they do not impart any flavor to food and do not absorb toxins (such as BPAs) like certain oil-based plastics, they are great for food packing. Plastics selection is aided by several instruments, one of which is the "plastic spectrum" (Figure 1). Bio-based bioplastics are the most common in this category as they are at the right of the pyramid and are made from natural materials that can be replenished.

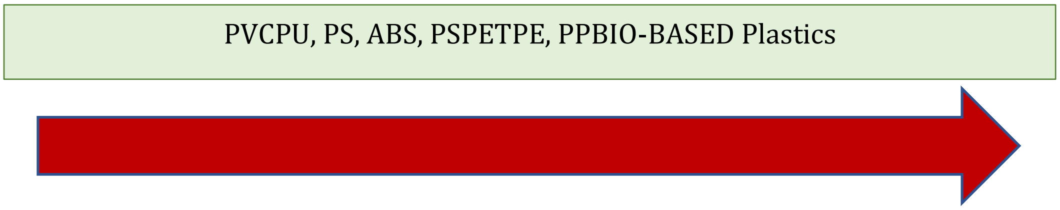

Figure 1. Plastic spectrum based on the different plastic

Plastic spectrum

PVC stands for polyvinyl chloride; PU stands for polyurethane; PS stands for polystyrene, and ABS stands for acrylonitrile butadiene styrene. PC stands for polycarbonate; PET stands for polyethylene terephthalate; PE stands for polyethylene, and PP stands for polypropylene.

Biodegradable bioplastics have been discovered to have applications in numerous fields. Medication and drugs are identified as one the pioneer usages.

Disadvantages

Bioplastics have numerous substantial advantages over petrochemical plastics, which is an obvious fact. Nevertheless, they also have certain drawbacks that must be addressed and considered. Some of them are discussed below:

Bioplastics are seen to be two times more expensive than ordinary plastics. Cost-cutting measures will have to be implemented as the number of major bio-plastic manufacturing plants will increase. Uncontrolled and incorrect disposal of bioplastic waste contributes to littering and soil and water pollution. If bioplastics are not separated from ordinary plastics, they may contaminate the recycling process. Bioplastics, for example, cannot be separated using infrared rays in a trash separation system. Bioplastic waste littering, like regular plastic, poses significant detrimental effects to wildlife. Bioplastic waste disposed of in landfills may contribute to greenhouse gas emissions.

Some bioplastics have a shorter lifetime than oil-based polymers due to mechanical properties such as higher water vapor permeability than typical plastic, easy to shred like tissue paper, or being extremely brittle [5]. For example, certain algae-based bioplastics break down in the ocean in hours, making them both biodegradable and fragile. Crop-based bioplastics are weather-dependent and necessitate fertile land, water, and fertilizer. Natural disasters, such as drought, could put the availability of raw materials for bioplastics in danger.

When bioplastic is described as compostable, it is possible to get confused due to a misunderstanding of terminologies. Bioplastics, like organic food waste, cannot be composted at home and must be treated in an industrial composting facility, which isn't always available. Other manufacturers are also misusing the terms "bioplastics" and "similar terminology" to make their products appear more enticing on the market. Manufacturers use buzzwords like "environmentally friendly," "non-toxic," and "biodegradable" to deceive the uninformed and overburdened consumer. There is no legislation governing the manufacture of bioplastics. Bioplastics production has expanded to more than 6.7 million tonnes by 2019. However, many countries have yet to enact rules governing the creation, use, or disposal of trash.

Types of bioplastics

Bioplastics come in various shapes and sizes that differ in terms of their qualities and applications, as well as the raw materials and production procedures used to create them. Bioplastics are currently classified into the following groups:

Bioplastic based on starch

The first bioplastics made from maize starch-substituted plastics were EverCornTM and Nature Works. Combining petrochemical plastic polymer with biodegradable starch polymeric components yielded these plastics. Potatoes, corn, wheat, and tapioca are now used to make starch-based polymers [6].

Bacteria attack the starch molecules in the polymer during the degradation of these bioplastics, causing the plastic polymer to disintegrate. The physical and chemical features of these starch-substituted bioplastics, on the other hand, make them unsuitable for commercial use. Furthermore, the aggregation of non-biodegradable plastic waste in water and soil can potentially disrupt the environment. Additionally, these bioplastics are made from starch via microbial fermentation processes.

For example, microbial fermentation of starch produces bioplastics like polylactic acid (PLA) and polyhydroxyalkanoates (PHA). In addition, starch and other carbohydrates are used as starting materials in the production of bioplastics like bio-based polyolefin like polyethylene (PE) and polyvinyl chloride (PVC), as well as partially biobased polyethylene terephthalate (PET) [7].

Bioplastics based on cellulose

Cellulose is a glucose polymer that has 1,4-glucosidic connections that connect the glucose units. Cellulose is found in the cell walls of all significant plants and green algae and in the membranes of most fungi. Cellulosic polymers are created by extracting or chemically modifying natural cellulose. The most prevalent sources of cellulosic plastic are cotton fibers and wood pulp. Organic cellulose esters and regenerated cellulose are the two types of cellulosic polymers. About 20% of the world's total chemical-grade pulp is used for organic cellulose esters. Organic cellulose esters are formed when cellulose is esterified with organic acids. Cellulose acetate (CA), cellulose acetate propionate (CAP), and cellulose acetate butyrate (CAB) are the most extensively used in the industry [8]. Packaging film, cigarette filters, textile fibers, medications, and specific other specialized industrial applications all use organic cellulose esters. Cellulose regeneration is made from cellulose that has been dissolved by chemicals and subsequently rebuilt into fibers or films. Currently, cellulose regenerates account for over 60% of all chemical-grade pulp produced globally. Viscose, viscose silk, lyocell, and rayon are some examples of regenerated cellulose.

Bioplastics based on polylactic acid

The major bioplastics on the market today are polylactic acid (PLA) and polylactide polymers. LA is a lactic acid-based product mainly derived from maize, cassava, potato, sugarcane, and sugar beet starch fermented by bacteria. These PLA bioplastics can solve the difficulties that have been found in starch replaced bioplastics.

Plant starch is converted to lactic acid as a monomer by bacteria, which is then chemically processed to link the molecules into long polymeric chains. This PLA material is biodegradable and has the appearance of conventional petrochemical plastics. PLA plastics offer a high rigidity, durability, transparency, thermoplasticity, and enhanced efficiency with contemporary plastics manufacturing equipment [9]. PLA plastics, which contain characteristics like polyethylene and polypropylene, are extensively used in packaging materials. Furthermore, PLA plastic saves two-thirds of the resources required to produce fossil-fuel-based polymers. PLA plastics release roughly 70% fewer greenhouse gas emissions during landfill breakdown than traditional plastics. PLA and PLA-blends in the granulated form are currently available in various grades for use in film, moulded parts, beverage containers, cups, bottles, and other common things. PLA-based plastics are increasingly used in various fields, including pharmaceuticals, textiles, cosmetics, and household items. Furthermore, dashboards, door tread plates, and other parts are made from PLA-based plastics in the automotive sector.

Bioplastics based on polyhydroxyalkanoates

Microbial fermentation produces polyhydroxyalkanoates (PHA)-based polymers from plant-based starch. The physiochemical properties of these PHA-based polymers are quite similar to those of polyesters, polyethylene, and polypropylene. Numerous biological bacteria manufacture PHA particles intercellularly in the presence of plentiful carbon sources. Polyhydroxy butyric acid (PHB), polyhydroxy butyrate, polyhydroxy valerate (PHV), and poly-3-hydroxybutyrate-valerate are the most common polyhydroxyalkanoates used in the production of plastics (PHBV). Bippolo and Bonello are two well-known PHA-based polymers used on a large scale. Bonello is a chemical compound of PHA-based biodegradable plastic, while Bippolo is a poly 3-hydroxybutyrate-co-valerate (PHBV) copolymer of polyhydroxy butyrate (PHB). PHA can be produced intracellularly by more than 100 genera of prokaryotes and archaea. Bacteria such as Alcaligenes spp., Pseudomonas spp., and several filamentous taxa such as Nocardia spp. The phase gene is involved in PHA formation and accumulation in bacteria. Due to innovative transgenic carbohydrate fermentation, some bacteria may store up to 80% of their body weight as PHA polymer granules in the cytoplasm cells under constrained nutritional circumstances [10]. Purification of the PHA polymer is accomplished by fracturing the cell wall and then extracting it using organic solvents in an aqueous-based extraction procedure. The PHA biopolymer is then refined and turned into lattices for use in plastic manufacture. Many genetically altered plants that manufacture PHA from the phase gene have been created by scientists using genetic engineering.

Panicum virgatum, or switchgrass, has been used as a genetically engineered host to produce PHA. Scientists then produced genetically modified maize to produce PHA, and the plants were successfully grown as a plastic crop. Metabolic, a European bioscience engineering firm, reported the successful start of a biobased PHA synthesis program in switchgrass, camelina, and sugarcane using multi-gene expression techniques. In recent years, biopolymers such as polyhydroxyalkanoates and alginates have been produced from anaerobic digesters and aerobic wastewater treatment sludge. The utilization of low-cost waste sludge in the synthesis of biopolymers from sludge offers various benefits, including a low cost of production. PHA-based plastics are truly biodegradable, with many different microbes completely decomposing them in less than a year in both aerobic and anaerobic conditions, producing CO_2 and water in aerobic conditions. It is utilized in different aspects, including food packaging, agriculture, and medication, because it is a natural and non-toxic polymer.

Drop-in bioplastics

Drop-ins are a type of bioplastic that is partially or entirely made from renewable resources, but they are not biodegradable. Corn, sugarcane, and sugar beets are the most common sources of drop-in polymers. This type of plastic is a hybrid of petrochemical and organic polymers. The sole distinction between drop-ins and traditional plastics is the availability of a whole or partly renewable bio-based input material foundation. The use and manufacture of drop-in bio-based goods are rising right now. These bioplastics include bio-polyethylene (PE), bio-polypropylene (PP), bio-polyethylene terephthalate (PET), and traditional polymers such as polyethylene (PE), polypropylene (PP), and polyvinyl chloride

(PVC), which are made from bioethanol, a renewable resource [11]. Drop-ins are a type of bioplastic made entirely or mainly from renewable resources. However, they are non-biodegradable. Bio-LDPE is employed in bottles and films, while Bio-PET polymers are generally used in the manufacturing process. The most important benefit is that bioplastics are biodegradable and thus have a lower carbon impact because they are generated from a renewable resource. Traditional plastics can be processed, manufactured, and recycled in existing facilities, lowering manufacturing costs.

Bioplastic derived from fossil fuels

Both bio-based and petrochemical raw materials can be used to make biodegradable polymers. For example, petroleum polybutyrate adipate terephthalate (PBAT) is utilized to manufacture bioplastics. Petrochemical polymer PBAT is a new version of a petrochemical polymer. It is still biodegradable and is commonly referred to as polybutyrate. It's frequently combined with starch and other bioplastic components to increase application-specific performance with tensile strength and biodegradability. The evolution of PBAT manufactured from renewable resources has increased in recent years. Polybutylene adipate-co-terephthalate (PBAT), for example, is made from adipic acid, terephthalic acid, and 1, 4-butanediol. It is biodegradable and has high elasticity, fracture resistance, and flexibility, making it a popular choice for bags, wraps, and other packaging materials. It is also used to manufacture rubbish bags and disposable packaging because of its speedy decomposition and is also used in bioplastics to provide stiffness and flexibility [12].

Bioplastic waste management options

Depending upon the product, material used, and the volumes and recovery technologies available, bioplastics waste is recovered and treated the same way as conventional plastic trash.

Prevention and control

The use of production techniques and materials that reduce resource consumption while maximizing product functioning is required at this phase of the waste hierarchy. Plastics have repeatedly demonstrated their use, with goods becoming thinner, lighter, and stronger because of their use. Bioplastics' success is evidenced by many products already on the market and their quick demand.

Recycling options

Reuse

Many plastic goods are available on the market that can be used numerous times. After cleaning, PET bottles and bio-based PET bottles can be recirculated in recycling systems after cleaning. Before the material goes out, bio-based PE, PLA, or starch carrier bags can be repurposed several times. Bioplastics may be used to make a wide variety of reusable items [13].

For the long-term treatment of bioplastics, recycling is the most viable alternative, followed by incineration with energy recovery, which is a more acceptable approach than landfilling. Bioplastics management is compatible with all recycling systems, including material, chemical, and organics recycling. Due to the variations in basic ingredients between bioplastics and conventional plastics, bioplastics that enter municipal waste pose issues in removing plastics because bioplastic trash is biodegradable. It can also be used as a substrate for composting. Therefore, valuable organic ingredients can be recovered as a product [14]. Mechanical recycling firms use washing, density separation, and compounding methods to convert these sorted items into recyclables. Depending on the base ingredients, bioplastics can be recycled alongside traditional plastics with ease. For example, biobased polyethylene (PE) is recycled in the PE stream, whereas biobased polyethylene terephthalate (PET) is recycled in the PET stream. In this approach, bioplastics lead to a better recycling rate. PLA polymer wastes can be mechanically recycled several times without losing their properties. The recycled materials can subsequently be turned into products like plastic lumber, piping, garden furniture, and pallets. Another method for recycling bioplastics is chemical recycling, which involves remitting and degranulating biopolymer wastes to create a new product. In some circumstances, biopolymer wastes are transformed into chemical building components, such as monomers, which can then be utilized to make more biopolymers.

Feedstock recycling is another name for this form of recycling. PLA-based bioplastics can be recycled using this method, which gets recycled into lactic acid and transformed into new PLA-based products in Belgium and the United States of America. The Loopla method, which converts PLA to lactic acid by hydrolysis, is also a chemical recycling process. Composting is a method of recycling biodegradable plastic waste into nutrient-rich soil amendments employed in many regions of the world. Natural bacteria may transform these biodegradable polymer wastes into simpler compounds. They are then degraded into carbon dioxide and water in aerobic settings and methane and carbon dioxide in anaerobic settings. Organic recycling, a kind of material recycling, also known as composting, is also considered a sustainable and environmentally beneficial method for bioplastic waste management. According to ISWA, bioplastics do not emit any hazardous components throughout the composting process. Biodegradable plastic waste compost, like other organic manures, increases soil quality and plant growth indices.

Mechanical recycling

Easy-to-recycle plastic products include big surface films (such as carrier bags), large hollow containers, and construction materials. Plastic product recyclability is governed by the product's design, material composition, and the cost-effectiveness of the recycling process. Products that are not composed of complicated material mixes can be simply divided into recyclable materials to make work easier.

PE, PET, and (coming) PP bio-based variations are chemically and physically similar to their fossil-fuel-derived equivalents, allowing them to be recycled in existing systems. Other bioplastics for which there is currently no clear recycling path will be possible once commercial volumes and revenues have grown sufficiently to warrant the necessary investments. New separate streams (for example, with PLA) will be introduced shortly. Numerous research programs and experiments, such as for PLA, are currently underway in Germany, Belgium, and the United States.

Organic recycling/composting

Biodegradable and recyclable plastic objects, such as (biowaste) bags, packaging, and cutlery, can increase the number of waste treatment choices available. Industrial composting (organic recovery/organic recycling) is a viable waste management alternative in addition to energy recovery and mechanical recycling.

When plastic products are mixed with biowaste, neither the plastics nor the biowaste can be mechanically recycled under these conditions. The combined trash is suitable for organic recycling due to biodegradable plastics, allowing for a movement in the waste hierarchy from recovery to recycling (a higher-ranking treatment option). This strategy keeps biowaste out of other recycling streams and landfills, allowing for more straightforward separation and more useful compost.

Products and materials must fulfill the standards of the European standard EN 13432 on industrial compensability to be eligible for organic recycling. After successful certification, certain items and materials can be sold and labelled as "compostable" after successful certification.

Recovering feedstock

Feedstock recovery is indicated when mechanical recycling has technological hurdles or is not cost-effective. This method is less prone to contaminants and is used for various materials. Plastic trash may be recycled and utilized as a substitute material in concrete and steel manufacturing. Plastics, both bio-based and non-bio-based, and municipal waste, can be gasified to produce syngas. The bio-based component of the produced syngas is high, as assessed by the number of bio-based polymers and organic materials waste. Syngas can be used to generate energy, heat, or fuel, and they can also be used to make gasoline (synthetic petroleum) and methanol and ethanol [15]. In the latter scenario, it may be used as a chemical feedstock for the polymerization of polyester, polyethylene, polypropylene, and other polymers such as olefins and acrylates with high bio-based content.

Landfill

Landfilling is an inefficient use of resources. Even while it is still one of the most used disposal alternatives in many European countries, it is gradually being phased out. In 2014, roughly 31% of plastic garbage was disposed of in landfills, declining from 47% in 2012. European bioplastics advocates a European-wide ban on the disposal of plastic products in landfills and other measures to improve plastic waste recycling and recovery.

Energy recuperation

Different techniques, such as anaerobic digestion, pyrolysis, and incineration, are used to create energy from bioplastic wastes. However, it can only be carried out when all recyclable components from bioplastic trash have been recovered. As bioplastics have a high caloric value, they can be used to generate energy in standard plastic waste incineration facilities. Even though some bioplastics, such as natural cellulose fiber and starch, have lower gross calorific values (GCV). They are like wood, making energy recovery from bioplastic wastes via incineration feasible [16].

Large amounts of carbon dioxide will be released during the burning of bioplastic waste, which will be recovered and used to generate new biobased goods. As a result, bioplastic waste incineration will become a sustainable solution. Bioplastic wastes from various garbage collection programs and mechanical treatment of bioplastic wastes are successfully handled using anaerobic digestion. Bioplastic trash decomposes to produce methane under anaerobic conditions and carbon dioxide. Biogas and digestate are produced during anaerobic digestion and can be used as renewable energy sources and organic manures, respectively. According to Song et al., are suitable for anaerobic digestion, which converts waste biopolymers into methane that could be used to create electricity [17].

Bioplastics market demand

For the past two decades, the value of bioplastics has been challenged. On the other hand, bioplastics have just recently emerged as a significant part of our daily lives. Continuous development and research on bioplastics-related activities have increased awareness of environmental protection, which has resulted in a tremendous increase in the use of bioplastics in the general market. Furthermore, strong legislative reforms to limit plastic usage have raised the demand for recycled plastic and bioplastics in several countries. Bioplastics currently provide a minor contribution. Bioplastics currently account for about 1% of the overall plastic market.

The yearly market data update from European Bioplastics was delivered at the 12th European Bioplastics Conference in Berlin on November 29, 2017, reaffirming the worldwide bioplastics industries sustained development. A total of 2.05 million tonnes of bioplastics are produced globally. By 2022, bioplastics will grow at a pace of roughly 20-25 percent per year, while traditional plastics will grow at around 4-9% per year by 2022, to 2.44 million tonnes. According to the European bioplastics market, the worldwide bioplastics market is predicted to grow at a rate of more than 20% per year. The global bioplastics market’s only drawback is that it is more expensive to produce than traditional plastics. Technological advancement, on the other hand, can overcome it. Furthermore, the rising cost of crude oil has benefited the manufacture of bioplastics with a petroleum base over petroleum-based plastics. Developing countries such as India and China are also encouraging the use of bioplastics through incentives and contract manufacturing, which is expected to help the bioplastic market grow in the future [18]. The bioplastics market is now dominated by drop-in bioplastics. Drop-in bio-based materials account for roughly 56% of total bioplastics production. Bioplastics include bio-PET, bio-PA, and bio-PE.

Compared to other types of bioplastics, such as those made from starch, drop-in biobased PET is the market leader in individual variants. As a result of their improved characteristics and viable end-of-life possibilities, PLA and PHA-based plastic production are expected to grow in the bioplastics industry. Packaging, textile, agriculture, injectable, electronic, medical, building construction molding, and a range of other segments, make up the worldwide biodegradable plastics market. The packaging industry is their most important market, accounting for 60% of global bioplastics production.

In India, the bioplastics industry is still in the early stages of its development. In India, just a few businesses engage in the bioplastics industry. Bioplastics companies in India are benefiting from environmental awareness initiatives, feedstock capabilities, and government backing, but more initiative is required in production, raw resources, and technology development [19]. The first step in achieving this transformation is raising environmental awareness and promoting bio-plastic's long-term advantages. Scientists throughout India are developing bioplastics. The recent development of bioplastics came from IIT-Guwahati, which is in the process of commercialization. Biogreen is India's first biotechnology company for biodegradable products. Bioplastics are already being produced in India by True Green, Pastorage, Eco Life, and Envi Green. There have been numerous technological advancements. India's bioplastics sector is booming. There has been an increase in the industry. It is now up to us to encourage everyone to stop using conventional plastics as much as possible in their daily lives.

Standards and certifications for biodegradable plastics

To the bare eyes, all plastics appear to be the same, regardless of their feedstock or durability. As a result, several standardized examinations, certificates, and badges are available online.

With a range of tests with specific conditions for biodegradability, Standardized tests frequently strike a balance between a high level of accuracy and a low level of difficulty, as well as time-saving testing (shortest 14 days, longest 24 months) and real-world scenarios (in fact, the temperatures are higher than they are in real-world scenarios to reduce testing time) [20].

Companies that develop new polymers must commit significant resources to self-evaluation and certify their products' long-term viability. The overall biodegradability evaluation, including lab space and equipment, is expensive and time-consuming. The OECD issued the initial rules for chemical testing in the 1980s, and they have been revised regularly since then. These recommendations are available for free on the internet and include various techniques. On the other hand, these rules are not universallyrecognized and serve as self-certification.

Standards

Standards are a collection of regulations that a product must follow to receive a specific label. The following are the major standardization bodies and their compostability requirements for bioplastics:

ASTM

The American Society for Testing and Materials (ASTM) is a non-profit organisation dedicated to the advancement of science and technology in the United States of America [21]. ASTM D6400–According to ASTM International (ASTM), compostable plastic is "a plastic that degrades by biological processes during composting to yield carbon dioxide (CO_2), water, inorganic compounds, and biomass at a rate consistent with other known compostable materials and leaves no visible, distinguishable, or toxic residue (That is, biodegradation plus disintegration plus ecotoxicity).

ISO–International Organization for Standardization (global)

The four parameters of compensability are considered in ISO 17088:2012:

a) biodegradation, b) composting disintegration, c) negative impacts on the composting process and facility, and d) severe effects on the quality of the compost produced, such as a high concentration of restricted metals and other dangerous components.

CEN (European Union)–European committee for standardization

According to the EN 13432 composability standard, Chemical test: Discovery of all constituents' threshold values for heavy metals should be observed. Biodegradability in regulated composting conditions (oxygen consumption and CO_2 production): at least 90% of the organic material must be converted to CO_2 within 6 months.

Disintegration: Not more than 10% of the original materials should remain after 3 months of composting and subsequent filtration via a 2.0 mm. A compostability test is to be performed in a semi-industrial (or industrial) composting facility. There must be no detrimental impact on the composting process. Examining the impact of the finished compost on plant growth (ecotoxicity test and agronomic test).

Certifications

In Europe, DIN Certco and Vincotte issue independent certifications for biodegradable polymers. DIN Certco offers compostable plastics and compostable packaging certifications based on EN 14995 (or ISO 17088) and EN 13432 (or ASTM D6400) standards.

Vincotte offers compostable plastics certifications based on EN 13432, as well as certificates for home compostable plastics (OK home composting), soil biodegradable plastics (OK biodegradable SOIL), and water biodegradable plastics (OK biodegradable WATER) (OK biodegradable WATER).

Biodegradable plastics certificates are also available from the Biodegradable Products Institute (BPI) in the United States and the Japan Bioplastics Association (JBPA) in Japan and other less well-known organizations.

Usage of Bioplastics in the Phase of the COVID-19 Pandemic

More shutdowns and stay-at-home orders are being enacted as we acclimatize to the "new normal" brought on by COVID-19. Supply chains have been thrown off, and the new normal is quickly becoming the norm. Industrial biotechnology and corporations are scrambling for new ways to succeed so that labs can continue essential operations to develop new products like biofuel production and hand sanitizer. The silver lining in all of this is the environmental consequences, which have become obvious like an astonishing 60% has reduced air pollution in nearly all of the world's main cities compared to the same three-week period last year, which spanned March and April and included most of the global lockdowns. In New Delhi, the quality fell from 68 percent in 2019 to 17 percent in 2020.In 2020, Los Angeles had the most prolonged period of clean air in the world. Different projected benefits of changing our economic and social behavior are realized on a large scale. This is a significant win for the environment, but air quality concerns must be addressed. All the pollutants will return once the world economy reopens.

According to a recent Harvard study, COVID-19 can kill people because many of the pre-existing conditions that increase the risk of mortality of people with COVID-19 are the same diseases that are affected by long-term air pollution exposure [22]. Harvard researchers investigated whether long-term average exposure to fine particulate matter (PM 2.5) in the United States is linked to an increased risk of COVID-19 death. So, pollutants may be reduced via industrial biotechnology procedures, resulting in a cleaner environment. Bioplastics are being produced, and recycling methods are being practiced, resulting in these processes being sustainable. COVID-19 has given plastics a , more significant role amid a global pandemic, owing to the need to protect ourselves by wearing plastic face shields or working behind plastic shields, ensuring food and personal items are protected under plastic packaging including gloves for everyday use. Plastic is used in various industries, including automotive, aerospace, electronics, and healthcare. Plastic is frequently used in healthcare because of its sterility properties and ability to provide medical equipment such as syringes, insulin pens, pacemakers, and prostheses [23]. However, most of these things are created from fossil fuel feedstock, adding to the global problem of plastic waste. Unfortunately, due to limited bioplastic production quantities, fossil fuel polymers were used for these purposes during the COVID-19 epidemic. Plastics that are recyclable, biodegradable, and compostable are accessible as alternatives to fossil-fuel plastics in the bio-based economy.

Numerous unique bioplastics discoveries and uses have recently emerged, paving the way for mainstream bioplastics acceptance and policy support [24]. For example, in July 2019, Japan switched to plant-derived bioplastic wrappers for all its rice ball items. Since 2015, Germany has promoted the use of bio-based and biodegradable biowaste plastic bags. Even though the bioplastics industry is still tiny and new, there have been several interesting developments recently. For example, high-density bioplastic containers made from rice starch with excellent thermal resistance and mechanical strength, corn-based bioplastic food wrappers made from edible shellfish by-products, etc. Sugarcane-derived bioplastics are currently used in some Lego kits. These innovative inventions may be able to lower costs shortly and reduce our reliance on fossil-fuel-derived plastics. As a result, we may reduce our carbon footprint and pollution, resulting in a cleaner and healthier environment [25].

Conclusions

Bioplastic is a big step forward that could give long-term, environment-friendly solutions to plastic pollution. The best approach is to use them for industrial purposes in an environmentally sustainable manner using the most cost-effective method of bacterial fermentation. Biomass can be converted into biofuel, biogas, or bio-oil. Creating bio-oil in an environmentally sustainable manner using mutagenesis and because of its long-term viability, the market for biopolymers is expected to grow significantly in the future. The biotechnology of microorganisms has given new hope to the manufacturing of bioplastics that has the potential to have a substantial impact on the environment, and to compete with present hurdles, the output must be increased. Bioplastics' use over standard plastics is limited due to their expensive cost, although there are other low-cost methods for efficiently generating bioplastics from biomass feedstock.

The study was disputed, and the results were amazing. During the research, it was determined that expanding the use of biopolymers for the green economy can help control marine pollution. Their carbon footprint is significant, yet they are often less expensive than their oil-based counterparts. For scientists, bioplastic has grown into a cutting-edge field of study throughout the globe. This steady progression has been motivated by a desire to find ecologically beneficial alternatives for materials derived from fossil fuels. Bioplastics have the potential to provide excellent biodegradability, helping the globe in dealing with environmental issues like littering, particularly in seas, rivers, and urban areas. Continued, concentrated study on this subject would allow even more discoveries and advancements. On the other hand, bioplastics are not the only way to address the issue of plastic pollution. The shift in consumer purchasing patterns, consumption, and disposal of plastics and extensive public awareness of bioplastics are all necessary for reducing plastic pollution.

Future perspectives

Bioplastics are environmentally friendly since they disintegrate into carbon dioxide. As a result, the need for bioplastic applications is increasing fast. Since bioplastic products are renewable, biodegradable, compostable, and ecologically beneficial, hence they should be commercialized.

Bioplastics are projected to benefit from research and development initiatives that will help to improve the current situation and overcome barriers to commercialization.

Universities are teaming up to create a cooperative research center dedicated to the creation of biologically derived plastics. The environmental claims made for bioplastic alternatives will be strengthened as a result of this. The ultimate goal is to have precise and detailed information on various alternative materials.

Disclosure Statement

No potential conflict of interest was reported by the authors.

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