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Review

Bioplastics from Kitchen Wastes: A Developing Green Technology

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Abstract

Plastic waste has become one of the biggest problems due to their excessive use. Decomposition of bioplastics is very difficult as a result its causes lot of negative impact to landfill and water pollution. The most possible solution to overcome this problem is to substitute synthetic polymeric materials with biodegradable materials such as bioplastics. Food wastes can be transformed into environment friendly bioplastics, which will not only reduce environmental pollution due to natural fermentation of these wastes, but also generate National revenue besides generating employment potentials. These polymers can be degraded environmentally by microorganisms and water in compost piles. Application of bioplastics has several advantages over conventional plastics such as lower carbon footprint and greenhouse gases (GHG) emissions, lower energy cost in manufacturing, reduction of permanent litter, and much safer to the environment. In food Industries, the need for high-standard storage features and the urge for packaging with high economic, low ecological impact, ease of customization, and low encumbrance can be answered by compostable or degradable bioplastics where kitchen waste may take essential role. Advancements in biomedical applications of bioplastics lead to the development of drug delivery systems and therapeutic devices for tissue engineering. Nanocellulose and its composites, which may be obtained from the processing of kitchen wastes, may result in potential and economical sources for green plastic studies about the fabrication of medical implants, either in dental, orthopedic, or biomedical fields.

Keywords: Bioplastics, Kitchen waste, Environment, Renewable.

Introduction

Since its widespread adoption, plastic garbage has been a major contributor to environmental issues such as landfill and water contamination [1]. Nearly half of the plastic garbage in 2015 was produced by items with single-use, or "single-stream" purposes, such as plastic packaging and one-time-use items [2]. The proliferation of plastic waste is mostly attributable to the widespread use of plastics, which has exacerbated a number of serious environmental issues. Flame retardants, bisphenol A (BPA), phthalates, and heavy metals like lead and cadmium may all leak and bioaccumulate from plastic wastes dumped in landfills. Therefore, human consumption of marine species may contribute to the development of cardiovascular disease, reproductive problems, and obesity [3]. Only 9 % of plastic waste is recycled (15 % is collected for recycling, but 40 % of that is disposed of as residues). Another 19 % is incinerated, 50 % ends up in landfill and 22 %

evades waste management systems and goes into uncontrolled dumpsites, is burned in open pits or ends up in terrestrial or aquatic environments, especially in under developed countries [4].

The best option is to replace synthetic polymeric materials with biodegradable ones [1]. Microorganisms will break down after use, reducing any potential negative effects on the environment. With the advent of biodegradable polymers, scientists have found a potential answer to the waste disposal issues that come with using conventional plastics made from petroleum. Regarding biodegradable polymers, the main difficulty for scientists is identifying uses that would consume enough of these materials to drive price reduction and make them commercially competitive [5]. Polymers generated from biological sources, such as food waste, may be used to create bioplastic. It includes things like sludge debris, cassava peel, banana peel, pineapple peel, durian seed, jackfruit seed, avocado seed, and chicken feathers from the food processing sector or from people's homes [6]. Climate change is a more systemic environmental problem. One of the primary motivators for the comeback of industrial biotechnology in general and the hunt for bio-based plastics is the need to rapidly and deeply reduce GHG emissions. Biodegradability is not required for all bio-based materials despite the common misconception that the term "bio-based" always refers to polymers made from renewable resources. If reducing greenhouse gas emissions is the top priority, and energy can be recovered during incineration or recycling, then plastics' long lifespan becomes a strength once again. True biodegradable plastics are giving way to bio-based plastics in terms of manufacture, and this trend is expected to continue [7].

What is Bioplastic?

Bioplastics are plastics produced in whole or in part from polymers obtained from biological sources, including sugarcane, potato starch, or the cellulose of trees, straw, and cotton. The term "bioplastic" refers to a group of terms for a wide variety of materials with a wide range of uses and qualities. According to European Bioplastics, plastic must meet one of the two criteria to be considered as "bioplastic": either it must be made from renewable resources or it should be biodegradable [7]. Renewable biomass sources, such as sugarcane and maize, or microbes, like yeast, are used in the production of bioplastics. It is possible to compost some bioplastics once they have degraded. Bioplastics are polymers created from renewable materials that may be recycled naturally via biological processes, reducing the need for fossil fuels and helping the environment in the process. As a result, bioplastics are environmentally friendly, readily biodegradable, and safe for use in the body [8].

Importance of Bioplastic

These polymers can be degraded environmentally by microorganisms and water in compost piles [9]. Bioplastics can be categorized as petroleum-based biodegradable polymers (fossil-based), bioplastics from mixed source (bio-petroleum), and renewable resource-based polymers (naturally from plants and animals), etc. [10]. Bioplastic has several environmental benefits, including reduced carbon footprint and greenhouse gas emissions, decreased energy cost during production, less accumulation of trash, and a more safer environment [11]. Bioplastics also have advantages in the characteristics of the material, such as much greater water vapor permeability than standard plastic, less oily feel, good printability, softer, and more tactile. The method of bioplastic making may differ for each material used, the bioplastic characteristics produced, and various product configurations [12]. One of the most well-known benefits of biodegradable bioplastics is its ability to reduce trash. Disposable plastic bags account up a significant proportion of the trash floating around in our seas. Many municipalities and nations are prohibiting single-use plastic bags in an effort to reduce trash [7]. Most bioplastics are biodegradable, meaning they may be broken down by microorganisms in the environment. The byproducts of this process include carbon dioxide (CO_2) and water in an aerobic setting and methane (CH_4) in an anaerobic one, such as a landfill. There are so many advantages and disadvantages of bioplastics which is summarized in Table 1 [13].

Table 1. **Pros and cons of bioplastics [13].**

Pros of Bioplastics	The Cons of Bioplastics
Bioplastics are made from plant raw materials	Bioplastics are generally NOT cost-competitive compared to their oil-based counterparts.
Plant raw materials are renewable and sustainable	There is a concern that bioplastics based on terrestrial crops could harm food supplies
The carbon footprint of manufacturing bioplastics is very low	Some bioplastics have a shorter lifetime than oil-based plastics
Bioplastics are non-toxic and won't leach chemicals into food or soil.	Being compostable and biodegradable sounds great, but many bioplastics must follow a specific disposal procedure and require industrial composting in order to avoid being incinerated or going to landfill.
Bioplastics are biodegradable and compostable.	Crop-based bioplastics require fertile land, water, fertilizers, and are reliant on weather conditions. This means that the supply of raw materials for bioplastics are at risk of natural phenomena, such as drought.
There are a variety of zero waste end of life options for bioplastics.	Bioplastics are not the answer to marine litter.

Bioplastic Composition

Carbon and hydrogen make up the polymers. In addition to carbon, hydrogen, oxygen, nitrogen, and phosphorus, plastics may include sulphur, silicon, chloride, fluorine, and phosphorus. Plastic is a versatile material that can take on numerous shapes and sizes throughout manufacturing [14]. During the process of making bioplastics, the monomers are taken from biomass compounds, like the sugars in plants, or made from scratch. The monomers are then polymerized to make either a straight replacement for an existing plastic, like polyethylene (PE), or new polymers, like polyhydroxyalkanoates (PHAs). Extraction of biomass can also produce natural polymers that are not made in a lab, such as starch, natural rubber, and proteins [15].

Bioplastics are synthetic polymers that may either be broken down naturally or produced from renewable sources. As the carbon dioxide released during manufacturing, use, and recycling of plastics is offset by the carbon dioxide taken in throughout the plant's development cycle, the overall carbon dioxide balance is significantly reduced. Bacterial microorganisms and typically nanometer-sized particles, most notably carbohydrate chains, may be used to produce bioplastics as well (polysaccharides). In order to make bioplastics long-lasting and to improve their qualities, research is often conducted into the manufacture of additives, such as polymer and composite combinations, to increase biodegradability [16]. The polysaccharides in the algae can be used to produce biodegradable plastic [17].

Importance of Kitchen Waste

Those of us who are stuck at home because of the Movement Control Order (MCO) will probably cook more meals at home to avoid the risks of going out, which isn't always a bad thing. It is an opportunity to spruce up those tried-and-true dishes or try something new, and it may even mean better nutrition. "Kitchen waste" refers to any leftover food, drink, or other organic materials from kitchens in public or private establishments. Every day, tons of food waste is created in densely populated places. Due to their high moisture content, kitchen wastes that make their way into the mixed-municipal waste system present unique processing challenges, such as incineration.

In most cases, garbage from kitchens is dumped in landfills, composted, or fermented. European Union rules once recommended using food scraps as animal feed, however this practice was outlawed due to health and safety fears. Most studies focused on bioplastic manufacturing procedures, operational conditions, and novel bacterial/archaeal species employed in the fermentation process, proving that food waste (FW) can be simultaneously converted into energy and bioplastics [18].

Bioplastics Reprocess of Kitchen Waste

Fruits and vegetables are full of nutrients, and not just in the parts that we eat. Bioactive phytochemicals are chemical substances generated by plants, and they are commonly found in the peel, pulp, and leaves of fruits and vegetables that are otherwise thrown away. These extracts have potential use in nutritional supplements, medicines, and food preservation products, all of which have the potential to reduce food waste. High-end cosmetics may also benefit from extracts and oils generated from food scraps. Researchers have discovered that potato husks may be recycled into health supplements and bioplastics, which are polymers made from renewable sources and have several applications, including packaging, coatings, and adhesives. Bioplastics rely on carbohydrates, lipids, and cellulose fibre, which may be salvaged from leftovers via processes like freeze-drying and hydrodynamic shockwave separation. Creating bioplastics from food scraps has the potential to reduce both food and plastic waste, as well as emissions from plastic manufacturing. Liquid biofuels like biodiesel and bioethanol may also be made from compounds derived from food waste. Biofuels are utilised mostly in Australia to power vehicles because of their reduced emissions compared to conventional gasoline or diesel. They may also be used for other purposes [19].

The creation of bioplastics like PHA is a fantastic option for getting rid of FW. When FW is dumped in landfills, it has unintended consequences, including GHG emissions and water pollution. Making bioplastics out of FW is eco-friendly since it uses carbon-neutral resources to create the final product. Under commercial composting and biodegradation conditions, certain bioplastics may be used [20].

For the most part, plant-based materials, including starch, cellulose, and chitosan are used as polysaccharides in bioplastics. The most valuable bioplastic polysaccharide, starch, is found mostly in foods like cassava, rice, and soybeans that are often thrown away. Plant fibre waste may be used to develop polymeric composites or used as bioplastics. The fibres may be classified as coming from the bark, fibres, seeds, core, or the reed of the vegetable. Bioplastics have the potential to replace non-biodegradable materials in package production, making their thorough characterization essential inbio package research elucidates crucial factors [21]. How Bioplastics can produce from kitchen waste is shown in schematic diagram Fig. 1.

Foam, coatings, adhesives, sealants, and elastomers are just some of the many everyday uses for polyurethane (PU) components. Conventionally, polyols and isocyanates react to create PU. Vegetable oil, cashew nutshell liquid, cellulose, lignin, and protein are only some of the renewable resources that may be used to create bio-based polyols alongside petroleum-based polyol [22]. Polyols can have different traits depending on the biomass and how they are processed. The melted result is a mix of polyols that can be used right away to make foams, glues, and films [23].

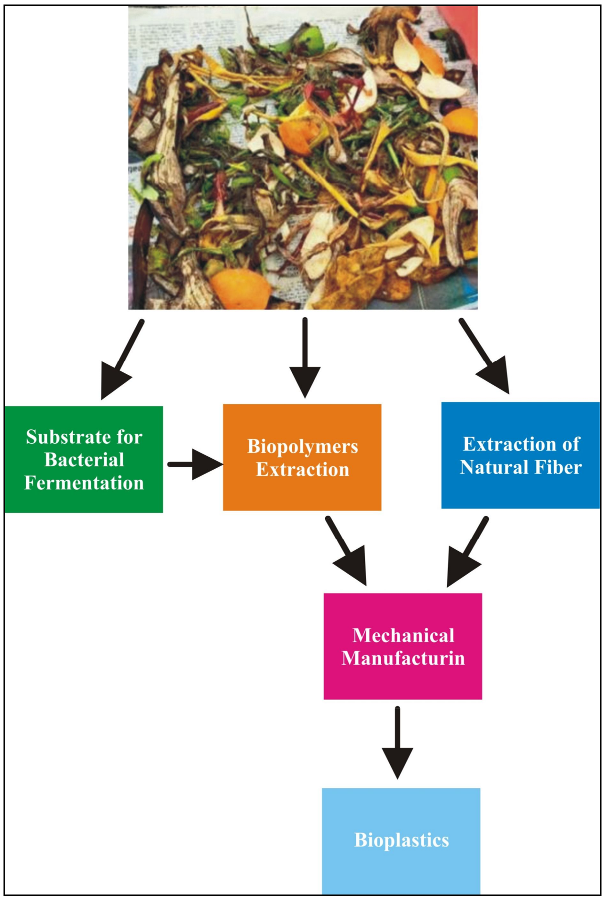

Figure 1. **Process of bioplastic from kitchen waste**

Chandarana et al. and Maura et al. have found that banana peel bioplastic is versatile and may be used for both packaging and bags. The addition of glycerol, a plasticizer, makes it more malleable [24,25]. Besides that, many researchers found that bioplastics can make from Cassava peel, Pineapple peel, Durian seed, Jackfruit seed, and Avocado seed [26-30].

FW is a good starting material for making bioplastics, but it must first be treated to change or improve its physical, chemical, and biological qualities. Also, it's important to increase the amount of food trash that gets recycled, especially from complicated municipality waste food (MWF). Collecting and sorting trash at its source can cut down on the cost of the steps that come after. This is a smart way to increase yield and profit, lessen the impact on the environment, and make it easier to recover materials. FW can be put into three groups based on where it comes from: industry, farming, and home. The total amount of FW from factories and farms is big, but it is mostly made up of easy things. On the other hand, home FW is comprised of many different things [31].

Application of Bioplastics Produced by Kitchen Waste

Bioplastics may be used for a wide variety of purposes, from food packaging to healthcare.

Food Packaging

Packaging is becoming more important in the food business, to the point that it is now considered a sub-sector in and of itself. Focusing on the development of new biopolymer-based packaging is crucial for the sustainability and quality standards of the entire food industry, resulting in cleaner and more sustainable delivery chains from production facilities and their internal storage systems to transport facilities, to marketplaces, and finally to consumer houses. Compostable or biodegradable bioplastics provide a response to the need for high-quality packaging that is also lightweight, customizable, environmentally friendly, and cost-effective [32].

The environmental issues and scarce resources of petroleum-based polymers have piqued industry interest in bioplastics or biopolymers made from renewable resources. Approximately 65% of 2018's worldwide bioplastic output came from the packaging business. Biodegradable plastics include compostable bioplastics. To conclude, all biodegradable bioplastics are compostable, but not all compostable bioplastics are biodegradable [33].

A differentiation based on food typology is employed to provide a holistic perspective, since various food kinds call for various characteristics. Vegetables and fruits have a high respiration rate, which may hasten their deterioration even under ideal circumstances, and they are also very sensitive to the concentrations of water, carbon dioxide, and ethylene. A package's primary functions are to protect its contents from environmental hazards including light, moisture, and oxygen, as well as to preserve the integrity of the product via sturdy construction and an airtight seal.

The development of spoilage germs and pathogens is facilitated by the raw state of the meat. In order to maintain the fresh meat's vibrant colour, a high oxygen content in the packaging is necessary. Consequently, many people think that vacuum packaging is a suitable option, and adding oxygen-absorbent layers, leading to active packaging, may better preserve cured meat [34].

Protecting dairy products from oxidation and microbiological development requires containers with low oxygen permeability. Moreover, a strong light barrier helps prevent lipids from oxidising. Other key characteristics are resistance to water evaporation and the absence of outside odour absorption. Some polysaccharides, such as pectins, which are often created by extraction from fruit and vegetable sources, might include these characteristics and serve as a safety barrier for food items [35].

Agricultural Applications

There were a total of 6.96 million tons of plastics used in farming in 2017. Bioplastic mulch is quickly replacing PE mulch for a safer way to farm. It helps reduce the carbon footprint because bioplastics break down faster than PE mulch and have less of an effect on the environment. Bisphenol A (BPA), a chemical that can mess with hormones and is often found in traditional plastics, is not in bioplastic. Bioplastic is also less harmful [36]. After the seeds sprout and grow, the seedling trays tend to break down in the soil. This process does not release dangerous chemicals into the soil or cause the plants to take them up [37]. In addition, PHAs have been used as pesticide carriers, crop protection films, fertilizer encapsulants, and seed protectors [38].

The nets, grow bags, and mulch films are valuable agricultural uses of PHA-based bioplastics. Instead of using high-density polyethylene (PE) nets, which reduce the crop's quality and output while still protecting it from birds, insects, and winds, farmers might utilize bioplastics-based nets instead. The low-density PE used to make grow bags, also called planter and seedling bags, is widely available and inexpensive. The grow bags made with PHAs would decompose quickly, be gentle on plants' roots, and not pollute the water supply. To sum up, mulch film bioplastics are crucial to maintain outstanding soil structure, moisture retention, weed control, and pollution prevention in place of fossil-based plastics [39]. So, long-term, sustainable farming development is possible with the support of innovations like bioplastics and sound agricultural methods.

Medical Applications

Materials made from renewable resources have been employed for quite some time in the healthcare industry. Gelatins capsules, whether derived from animals or plants, are used because they dissolve easily in the stomach and intestines. These may be found in a wide variety of over-the-counter (OTC) drugs. Biodegradable bandages are intended to encourage clotting and proactive skin regeneration, and there are also biodegradable sutures that do not need to be removed manually after healing. For such uses, poly-lactones or polyhydroxyalkanoates provide characteristics similar to those of petroleum-based polymers. However, injection molding is not often used for these kinds of projects [40].

Biomedical uses of biodegradable polymers have advanced to the point where implants and scaffolds are possible as drug delivery systems and therapeutic devices for tissue engineering [41].

There are a wide variety of biomedical and healthcare applications where polymers are necessary. Cellulose may be used as the primary bioplastic in these fields. Since it is biocompatible, does not cause cancer, and does not cause mutations, cellulose has been extensively researched for use in artificial organs, tissues, and brain engineering, and medicines [42].

Because of their biocompatibility and bioresorbable properties, biodegradable biopolymers like Poly Lactic-co-Glycolic Acid (PLGA), poly lactic acid (PLA), and polycaprolactone (PCL) may find use in a wide range of biomedical settings. Additionally, despite the biopolymers' many biological uses, they need a few tweaks to their chemical and physical makeup in order for their mechanical properties to be fully absorbed at an implantation site. Modifying and blending biomaterials to make them more biocompatible and less crystalline is a cost-effective research and development strategy [43]. Applicatins of bioplastics in different fields are shown in Fig. 2.

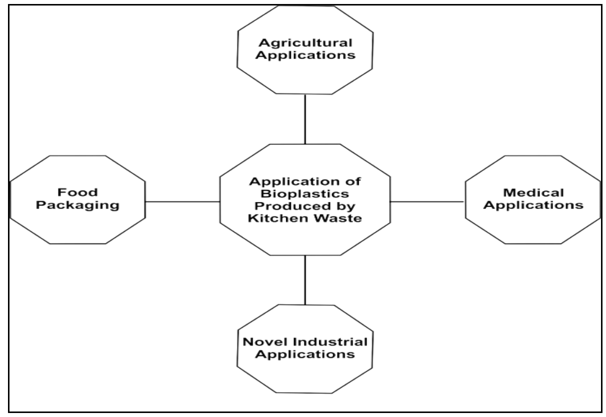

Figure 2. **Importance of kitchen waste bioplastics**

Novel Industrial Applications
Consumer electronics

Bioplastic has many uses today in the electrical and electronic industry (E&E industry). For example, bioplastics conductors, which are now called solid polymeric electrolytes (SPEs), are used to make electrochromic devices, batteries, diodes, fuel cells, and other things [44]. Aside from that, bioplastics are often used to make parts for high-demand market goods, like the cases for computer parts and cell phones, speakers, computer mice, and vacuum cleaners [45].When bioplastics are used in business, their thermal and electrical qualities are very important. Aside from being used as parts for assembly, bioplastics don't have many uses in the industry. This is because the main needs of the industry are electrical and heat resistance. Most traditional plastics are electrical and thermal insulators without any added usefulness or support. Conversely, bioplastics have low electrical and thermal conductivity and low temperature stability, which further limits their use in the E&E business [46].

When bioplastics were strengthened with carbon nanotubes (CNT) and cellulose nanofiber, they had better mechanical, electrical, and thermal qualities than bioplastics that weren't strengthened. This makes them better for use in electronics. Cellulose nanofiber-reinforced bioplastics and CNT-reinforced bioplastics have many uses in industry, such as flexible photovoltaic cells (solar cells), sensors, and advanced electronics. They are also used as surfaces in roll-to-roll production methods [47]. So reinforcing bioplastics with the right elements, bioplastics may take on and improve electrical and thermal conductivity capabilities, expanding its usefulness.

Architecture and construction industry

Plastics have been used in buildings and construction for a few decades now. Plastic is often used in these fields to make pipes, padding, floor covers, wires, and other things. In the building and construction industries, bioplastics are used for things like wall coverings, geotextiles, facade elements, and pipes. Traditional uses of plastic in the industry, like cloth fleece, wires, and floor covers, need to be very strong so they can stand up to different kinds of heavy workloads. Bioplastic materials have a lot of potential uses in the industry, but they are expensive because better quality bioplastics usually cost more to process, and the performance of conventional bioplastic in the industry is not good enough to use it [48]. According to Ivanov and Stabnikov, using biodegradable bioplastics can benefit the industry, including environmental and bio-economic sustainability, a reduction in the cost of construction waste disposal, and transient construction excavation costs [49]. But according to Friedrich, traditional plastics are preferred for use in building since some features of bioplastics cannot be guaranteed, including their mechanical strength, resistance against biodeterioration agents, and lifespan [50]. In addition, conventional plastics, which are stronger and more flexible than bioplastics, are more suited for this application since they are used in the textile fleece business [51].

According to some researcher suggestion reinforcing materials can be added to bioplastics to make them stronger mechanically. This makes it possible for reinforced bioplastics to be used in industry. Bioplastics that are strengthened with different structure materials have benefits like being water-resistant, lightweight, stable under load, cheap, long-lasting, and easy to work with as building materials [52,53].

Automotive industry

Plastics are an important part of the car industry because they are cheap and easy to work with, but customers are seeing more and more pictures of trash mounds and huge floating islands of plastic. Bioplastics could be part of the answer to some of the problems that come with regular plastic. With custom mixing, bioplastic can be used in a wide range of ways in the car business. The strength and looks of parts made from this material are not limited in any way. Many awards show that it is better than other types of plastic, especially when it comes to being good for the earth [54].

The last two decades have seen a sharp rise in bioplastics usage, specifically in the auto industry. This is largely due to their role in sustainability. The bioplastic industry is expecting to rise in capacity from 2.11 million tons per year in 2018 to 2.6 million tons in 2023 [55]. Due to the excellent compatibility of Polylactid-Acid (PLA)-thermoplastic Polyurethan (TPU) -blends with natural fibers and glass, as well as their good adhesion with decorative elements inside the body, such as Polyurethane foils and wood imitation foils, these PLA-TPU-blends are suitable for use in the manufacture of car interior elements. PLA-TPU-Blends can be effectively manufactured in a single step process that combines compounding and injection molding, thereby enhancing the quality of the final product [56]. With such major advancements, bioplastics have a bright future in the vehicle manufacturing industry.

Houseware and Kitchenware

Bioplastic is a more sustainable material that is being explored by an increasing number of furniture and homeware designers. A plastic-like substance made from vegetable fats and oils, maize or potato starch, algae, shrimp shells, and other biomass is employed in a number of different applications. Biopolymers can be used to make tools and items for the kitchen, clean storage cases and cups, bathroom decorations, toys, hangers, and hooks. Biodegradable plastics are used to make United Colors of Benetton pegs [57].

Tableware and dishes that are only used once can be made from a wide range of materials. These products can come from new or used sources. They can be made by simply molding it into the shape you want (for example, wooden utensils or flatware) or after a simple or complicated process, such as making molded composites of natural fibers (or other fillers) and (bio)plastics or (bio)-plastic items with no natural fibers at all.To stop contamination of the environment, laws and many groups have suggested that single-use goods should be clearly labeled with information about their biodegradability, (bio)plastic content, proper dumping methods, and environmental risks. It will help in getting rid of plastics that don't break down and replacing them with newer materials. Products made of more than one material, like those with layers, should be changed or remade so that the separation of materials could become easier (so they can be recycled better) [58]. Hence, the markets for conventional plastic disposable house ware and kitchen utilities are progressively being replaced by those for biodegradable polymers manufactured from renewable resources. These products includehangers, plastic shelves, plastic toys, plastic pots and pans, biodegradable cups, bioplastic water bottles, etc.

Conclusion

Bioplastics and biodegradable plastics made from renewable resources have been hailed as a big step towards solving the waste management problem. From the above discussion it is clear that bioplastics are very ecofriendly. As they are produced from renewable sources and biodegradable products there is no worry about waste management or pollution. The demand of bioplastics in various industries is increasing day by day.

Due to higher manufacturing costs bioplastics are still not available in open market. Bioplastics' upstream technologies and processes are subject to uncertainty as a result of the field's still-developing upstream technology. Several common misunderstandings about bioplastics lead to an incomplete and incorrect assessment of the industry, which in turn slows down investment decisions.

It can be concluded that bioplastics arethe polymers that are both renewable and inexpensive. Bioplasticsare a viable alternative to fossil-based plastics in most food packaging, agriculture, medical, and other novel industrial applications due to their similarity in properties to fossil-based plastic. This results in a smaller carbon footprint and less environmental impact.

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Conflict of Interest

No conflict of interest.

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