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Akhilesh Kumar

School of Biosciences, Swami
Rama Himalayan University
Dehradun, Uttarakhand, India

Vijay Kumar

School of Biosciences, Swami
Rama Himalayan University
Dehradun, Uttarakhand, India

Vivek Kumar

School of Biosciences, Swami
Rama Himalayan University
Dehradun, Uttarakhand, India

Rahul Kumar

Forest Ecology and Climate
change Division, Forest
Research Institute, Dehradun,
Uttarakhand, India

Darshita Rawat

Division of Genetics and Tree
Improvement, Forest Research
Institute, Dehradun,
Uttarakhand, India

Production of Bioplastics from Biological Materials

**Akhilesh Kumar, Vijay Kumar, Vivek Kumar, Rahul Kumar and
Darshita Rawat**

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Abstract

Bioplastics are plastics derived from renewable biomass sources like plants, microorganisms, and other biological materials. They offer a sustainable alternative to conventional petroleum-based plastics due to their biodegradability and production from renewable resources. In this paper, we have reviewed the different sources of Bioplastics, like microorganisms, plants, agricultural waste, seaweed and algae, protein, milk, chicken feathers, and waste newspapers. This review article helps to summarize different biological and biological materials that are responsible for the production of biodegradable plastics.

Keywords: Biodegradable plastics, agricultural waste, seaweed and algae, milk and plants

Introduction

Plastic is an important part of our present society. They are found in applications such as in, building, packaging material, electrical industries, automobile, furniture, agriculture and household items. Their durability is the topic of concern about their end of life. The important end of life cycle for non renewable plastic is recycling, because their microbial decomposition is indestructible. The accurate time which is needed for biodegradation is not known & can produce carbon dioxide, methane etc. burning, which is highly pollutant thus causing environmental issues (Goswami *et al.* 2015) ^[6]. Plastic are non renewable resources. The plastic that is used and produced in increasing amount will degrade very slowly, which cause the product to remain in the environment for many of the years. Plastic pollution can severely effect land, waterways and oceans, and also cause disturbance in bio functions of the living organisms. Due to the excessive use of chemical during plastic production, plastic is seem to be more harmful (Yaradoddi *et al.* 2016) ^[28]. Therefore, scientists are looking for alternative to the traditional plastic derived from petrochemical sources.

Plastic waste is increasing day by day. The excessive use of this plastic has created various of the problems. Hence there is need to produce plastic that can be easily degraded or eliminated from our biosphere in an ecofriendly manner (Goswami *et al.*, 2015) ^[6]. Nowadays, it is essential to have a better renewable based plastic material that can reduce the use of conventional plastics. The bio plastics obtained from natural sources will be environmental friendly, trendy, user friendly and decomposable (Yaradoddi *et al.* 2016) ^[28]. Bioplastics are degrade through enzymatic action of microorganisms.

Sources of Bioplastics

There are various sources of bioplastic like animal, plants, microbial and other sources given below (Figure 1).

Corresponding Author:

Akhilesh Kumar

School of Biosciences, Swami
Rama Himalayan University
Dehradun, Uttarakhand, India

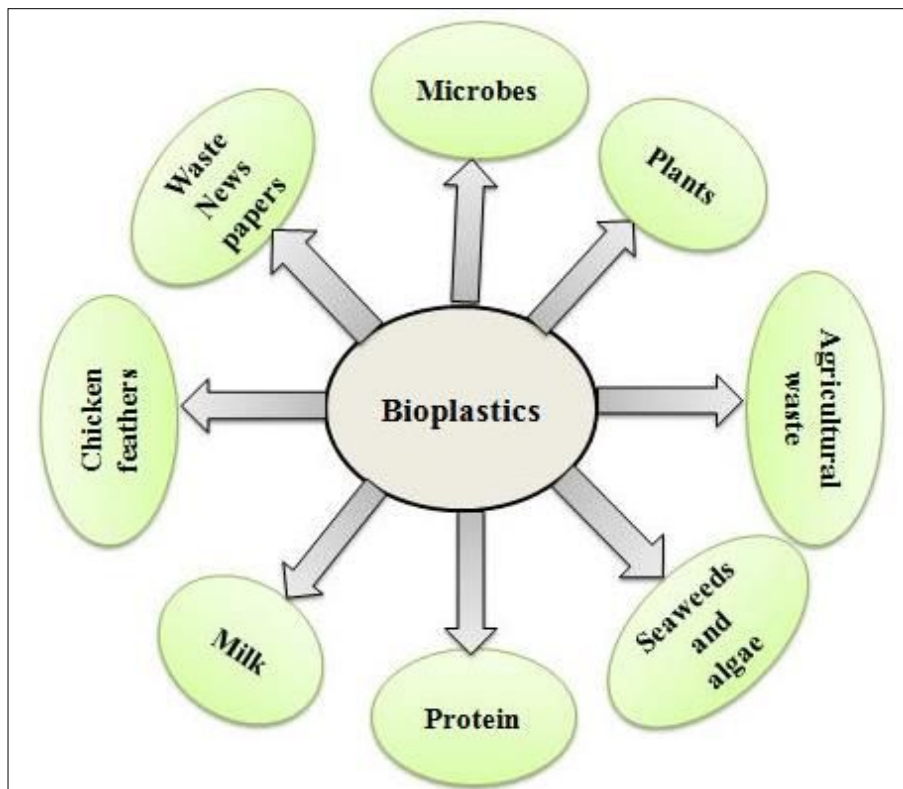


Fig 1: Different Sources of Bio-degradable plastics

1. Bioplastics from Microorganisms

Luengo *et al.* (2003) ^[14] produced bioplastic from microorganisms. Bioplastic are polyester created by a scope of microorganisms, refined under different supplement and natural condition. Organisms having a place with in excess of 90 genera including aerobic, anaerobic, photosynthetic micro organisms, archae microorganisms and lower eukaryotes can amass and catabolise these polyesters. Bioplastic contain, as monomers, diverse beta oxidation intermediates which are enzymatically polymerized by the buildup of the carboxy work, present in a monomeric Co-Athioester with the 3-hydroxy gathering of the following one. Other bioplastic containing exceptional monomers which are integrated through various pathways, proposing that biosynthetic chemicals are broadly conveyed, and that the creation of a specific kind of polyester is strain explicit occasion. Hereditary and metabolic designing has a great deal of generation of bioplastic blend by a wide range of recombinant living being (microscopic organisms, yeasts or transgenic plants). Kumaravel *et al.* (2010) ^[13] produced polyhydroxy butyrate (bioplastic) and its biodegradation by “*Pseudomonas Lemoignei* and *Aspergillus Nigar*”. The production of PHB occurs from an industrial effluent (sugarcane) and the degradation of PHB done by microorganisms on soil. Fungus has high capacity of utilizing PHB as growth substrate than bacteria isolates. All these isolates were tested for the degradation of above polymer in assay agar medium and also in liquid medium. PHB degrading bacteria secrete PHB de polymerases which hydrolyze the polymer into a “monomeric or Oligomeric ester”. The hydrolytic products are taken up by the cells and metabolize. Olayide *et al.* (2007) ^[18] developed biodegradable plastics from starch. Starch is a natural based polymer which is made up of amylose and amylopectin. Amylose is a single chain polymer while amylopectin is branched polymer and has been used in two forms namely

granular (native) form and thermoplastic (plasticized) form. The advantage of starch for plastic production is having a good biodegradable property because it possesses satisfactorily thermal stability and cause minimum restrictions with melt flow of most material used in plastic industry. Lots of developments occur from starch because of its property like bio degradability, oxygen barriers capacity is good in the dry state and have low cost. Ali *et al.* (2017) ^[1] produced bioplastic by bacteria isolated from local soil and organic wastes. The ability of bacteria is to produce bioplastic (PHB) which is isolated from soil and organic wastes by Sodium hypochlorite-Chloroform method. Resulting of screening to produce PHB by Sudan black staining method. Polyhydroxybutyrate (PHB) is biodegradable, ecofriendly, bio compatible and microbial thermoplastic. It is thermoplastic biopolymer which has good mechanical property and that become an alternative for petrochemical derived plastic. The bacteria from the organic waste produce more PHB.

2. Bioplastics from Plant sources

Coles *et al.* (2011) ^[4] derived bioplastic from renewable raw material. The plants produced material such as starch used for production of bioplastic, carbon cycle play an important role in it. The carbon emission and amount of fossil fuel used by the current technique of production through seed transportation, seed planting, fertiliser/ pesticide produce and method of application, transport of processing facilities and production processes. Classification of bioplastic occurs in many ways such as on the basis of origin, chemical composition, synthesis method and application. PLA is one of the most available bioplastic made from starch/sugar rich crop. The production of bioplastic may use less amount of energy in substrate production and conversion as compared to petroleum based plastic. Hermansyah *et al.* (2014) ^[7] produced food grade bioplastic based on “corn starch with

banana pseudostem fiber or bacterial cellulose hybrid filler". This type of plastic has good mechanical and water barrier properties than synthetic plastic. In this paper, cellulose is added to create hybrid filler with banana pseudostem fiber in glycerol plasticized corn starch matrix for improving mechanical and water barrier properties of plant cellulose filled bioplastic bacteria. The addition of bacteria cellulose was proven to give a best effect to water barrier or resistant properties. These properties were confirmed with SEM and XRD analysis. Chumee *et al.* (2014) ^[3] observed that green bioplastic can be produced by carboxy methyl cellulose from pineapple peel. By etherification the Pineapple peel cellulose can be converted to carboxy methyl cellulose (CMC). The pineapple peel has cellulose which can be extracted by refluxing with acid and alkali solution like 0.5 M HCl and 1M NaOH. Then in end step, the activated cellulose react with chloro acetic acid or sodium hypochlorite. CMC is a natural biopolymer, the solubility depend on reduction of a carboxy methyl group instead of cellular structure. Therefore the CMC is used as a source for fabrication of natural plastic with non toxic, friendly environment. Mulyono *et al.* (2015) ^[17] developed bioplastic from cassava flour and its starch derivative for food packaging. Bioplastic form from the starch and nano particles which are derivative of cassava flour. Tapioca starch was extracted from cassava flour and further processed into its nanoparticle by ethanol precipitation. These all are used to produce renewable plastic with the presence of glycerol as plasticizer. This plastic is used in food packaging because these result in bioplastics absorbed UV-A so the product inside could be protected from photo oxidative degradation. Goswami *et al.* (2015) ^[6] prepared bioplastic from potato peel left after preparing potato chips. Bioplastic is formed from these peels after extracting starch from them, thus resolving problem of their disposal after the chips have been made and thus usable material is made out of it. Bioplastic from potato peel is viable and more ecofriendly. It can degrade at the same rate as paper. Biodegradable plastics means plastics which have short life span and can be convert into carbon dioxide, water and biomass and a compostable substance which breakdown easily and return the nutrients back into the nature. Bioplastic created from organic waste materials (potato peel) which reduce the dependency on petroleum based plastic. Yaradoddi *et al.* (2016) ^[28] used fruit waste material for the production of biodegradable plastic, and its sustainable use for green application. Bioplastic prepared from a best raw material fruit waste, a renewable resources. The plastic is produce from banana peel, mango seed and corn kernals blended with the glycerol, use of proper concentrations (0.1 NaOH & 0.1 HCl) assist in the production of plastic having property of flexibility, user friendliness and good strength. Bioplastic manufactured from this method could be substantial and have a biodegradable property in a developing bioplastic material. Gaonkar *et al.* (2017) ^[5] prepared bioplastics from banana peels that can be used as packaging materials or as a carrying bag. Glycerol is added as a plasticizer that increases the flexibility. To prevent growth of bacteria and fungi sodium metabisulphite is used. Banana peels are used as a raw material to produce a good quality of bioplastic (prepare in lab) which degrade easily. Ashok *et al.* (2017) ^[2] studied the effects of softening agents in the Thermal and Morphological properties of starch based bioplastics.

Plasticization of starch with 1, 2, 3 -trihydroxy-propane (Glycerol) as a softening agent (Plasticizer) offers good stability, improved physiochemical and functional property of starch. These agents replace the starch -starch bond to starch -massive glycerol bonds. Hydrogen bonds between starch intermolecular chains are destroyed due to the formation of starch plasticizer complexes & this destruction is responsible for the plasticizing concentration. As the glycerol content decreased, the transition temperature also decreased and the sample with less glycerol content shows narrow fusion and melting curve. Syafri *et al.* (2017) ^[25] observed the effect of precipitate calcium carbonate on, mechanical, physical and thermal characteristics of cassava starch bioplastic composite. Cassava starch mixed with glycerol as a plasticizer and 0-10% by weight of PCC is used to make bioplastic composites. The material was then pelt down into a mould and dried in oven. When PCC is added into a starch matrix it increase the tensile strength of resulting bioplastic or PCC composite with the most favorable value by adding 4% of PCC. Then all characteristics of bioplastic or PCC composites are estimated using tensile strength measurement, XRD, SEM, etc. An increase in crystallinity of the bioplastic/PCC composite are shown in the results of XRD with increase in PCC content but moisture absorption get decreased and the SEM images indicate that the PCC filler content was absorbed into the matrix. Analysis of TGA graph shows that thermal stability of the composite is improved by the addition of PCC. Isroi *et al.* (2017) ^[8] produced bioplastic from cellulose of oil palm empty fruit bunch (EFB). EFB is found in Indonesia as side product of COP (crude oil palm). It consist of cellulose, hemicellulose and lignin. Cellulose is a good source of bioplastic production based on EFB. The production of bioplastic from EFB was done by isolation and purification of cellulose, then cellulose modification and then synthesis of bioplastic. Cellulose was isolated by sodium hydroxide method and bleached using sodium hypochlorite and use glycerol as a plasticizer in bioplastic synthesis. Kasmuri *et al.* (2018) ^[11] used chitosan and eggshells on potato starch for increasing bioplastic production. The aim of this research is to overcome the inherent drawbacks of bioplastic by using eggshells and fillers in potato starch. The eggshell or chitosan in Potato starch based plastic enhance the tensile strength, reduce water absorbtion and reduce the weight in biodegradability that improves the bioplastic property. Wade *et al.* (2018) ^[27] used waste vegetables to manufacture bioplastic. Bioplastic are composed of starch, cellulose, biopolymers and different material for which waste vegetable as a raw material is used. Corn starch is used to form bioplastic where glycerin is used as a plasticizer and a small quantity of glycerine is easy to make thin film and a uniform film of bioplastic and vinegar is also used which contain ethanoic acid that form atomic no. 1 is an acetate ion creating bioplastic film from starch. Maulida *et al.* (2018) ^[15] used starch of mango seed in production of bioplastic, reinforced by microparticle clay using glycerol as plasticizer. The starch of mango seed contain good amount of amylose and amylopectin and the addition of micro particles has improve the properties of bioplastic. The starch of mango seeds having clay increased tensile strength and decreased extension at break in bioplastic was observed. The improvement in bioplastics with strengthen particles provide the strong hydrogen bond

between hydroxyl groups of the interface of both clay filler and starch matrix.

3. Bioplastics from Seaweeds and algae

Rajendran *et al.* (2012) ^[21] observed that a new source of bioplastic is seaweeds. Bioplastic are biodegradable. There are various sources of bioplastic like animal, plants, and microbial sources, they have some of the problem such as no-availability of high biomass and cultivation difficulties. In some cases seaweeds can be alternatives for the production of bioplastic because their biomass is high. These are not costly. Their impact on the food chain is low and are not dependent on chemical. Bioplastics from seaweeds are observed to be more resistant to radiation, less brittle and durable nature. Sreenikethanam *et al.* (2021) ^[23] used algae in production of renewable bioplastic. Algae is a powerful alternative than other microbial sources, because an algae has high biomass growth rate and ease of culture in natural environment. Consequently, bioplastic based on algae are a feasible alternative. They are not based on fossil resources and can be degraded easily and also they are biocompatible. Use of algae is renewable, biodegradable, non toxic and environment friendly in bioplastic production for a sustainable environment.

4. Bioplastics from Milk: In year 2013 Jayakumar *et al.* ^[9] used milk as a raw material for the production of bio degradable plastics because milk contains high level of casein protein, it is a natural bio polymer and have good film making properties. Casein from milk builds up the basic units of the biodegradable materials. The term biodegradable represent a process where the micro organisms that are found in the surrounding convert casein from milk into products like water, carbon dioxide and compost. Reddy *et al.* (2013) ^[22] proposed that bioplastic is green and sustainable alternative to plastic. The common type of bioplastic is derived from starch, cellulose, poly lactic acid, poly hydroxybutyrate. Bioplastic are 100 percent biodegradable, produce from natural renewable sources, which are capable to be reused, recycled, composted or incinerate without producing any harmful byproduct, which makes it a better product. Biopolymers releases low amount of carbon dioxide during production and degrade easily by microorganisms after disposal. These renewable plastic has two third less harmful green house gases emission as compared to toxin producing plastic during the production. It is cheaper, beneficial to rural economy, reduce toxic substances, reduce carbon footprint, and also reduce carbon dioxide emission. Pathak *et al.* (2014) ^[24] discussed timeline of bioplastic based on its scenario and challenges. Plastic waste management not occur properly that lead to dwindling nature of petroleum resources, increased green house gases into the atmosphere and disruption of aquatic life. Bioplastic introduced as sustainable alternative of bad plastic use in order to reduce the petroleum dependency. The idea of bio based plastic change the source of producing plastic i.e., the conventional plastic are replaced with the more renewable, economical, accessible, abundant, and decomposable source. The future trends are expansion of effectual and economical practices for PHA production, purification, isolation, and increase of PHA material.

5. Bioplastics from Waste News papers: Joshi *et al.* (2014) ^[10] used waste newspaper as a raw material for the

formation of plastic from cellulose. Cellulose is taken out from waste newspaper by decomposing them. The cellulose is decomposed into starch/ glucose with help of enzymes called cellulolysis (prepare plastics in lab by starch/ glucose). For the preparation of bioplastic, extraction of cellulose from pulp and conversion of cellulose into dextrose has to be done and produce PLA plastic.

6. Bioplastics from chicken feathers

Kota *et al.* (2014) ^[12] produced bioplastic from chicken feather waste. The feather is a highly microcrystalline, mechanical and thermal stress resistant, because of the presence of the keratin a protein. It is same as polypropylene. Feather comprises over 90% of protein. The main component is beta keratin. A fibrous containing disulphide bond an insoluble protein. These bond have a property of resistance to digestion by the proteases of animal which are the major problem for degradation, feather waste contain keratinase which is use to degrade feather waste and in the production of animal feed, fertilizer. Bioplastic quality was improved by the addition of EPS which act as plasticizer that trap the water in the crude precipitation containing the keratin unit by making the product less crystalline and reduce surface tension thereby increasing the flexibility and high tensile strength of it. Bioplastic from feather having good flexibility results in the increase in the tensile strength.

7. Bioplastic from agricultural wastes

Mostafa *et al.* (2015) ^[16] produced bio degradable plastics from agriculture waste. The relevant method for the production of the “cellulose acetate biofiber from flax fibers and cotton linters” by using sulphuric acid -catalyzed process. The used process yield 81% and 54% for flax fibers and cotton linters respectively. Flax is a crop in Egypt and cotton linters are valuable cellulose raw material. Bio degradable plastics based on cellulose acetate produce plastics which decompose in soil or water and also recycle or burn without residue. Cellulose acetate has good mechanical strength, impact resistance, transparency, colorability. Trivedi *et al.* (2016) ^[26] studied degradation of synthetic plastic and manufacture of bioplastic by the microbes. Microorganism are used as a source of bioplastic manufacture and also used for degradation of plastic, it will decrease solid waste which cause environmental problems. Polymers like polyethylene are utilized as substrate for microorganism growth when they are degraded and the polymer used for production of bioplastic is polyhydroxybutyrate. Microorganism secrete enzyme polyhydroxyalkanoates depolymerases and decrease the polymer chain size by oxidation which help in plastic degradation.

8. Bioplastic from Protein Sources

Patel *et al.* (2016) ^[19] used protein for the fabrication of bioplastic. Protein and synthetic petroleum based polymer share some vital characteristic such as synthetic polymer consist of identical polymer covalently bonded in a long chain while protein are composed of repeating units of different amino acid. These type of bioplastic are easily degraded by bacteria and fungus. The extraction of protein was obtained from rapeseed defatted cake and this cake is generated from oil seed after extracting oil. The extracted protein was blended with filler, binder, lubricants and

plasticizer and the percentage of calcium carbonate is used to increase the tensile strength and the impact strength of the green plastic sheet. Rapeseed protein based bioplastic seed can be used for making disposable article such as lightweight utensil. Perez-Puyana *et al.* (2017)^[20] developed a pea protein bioplastic with anti microbial property, pea protein as a raw material isolates byproduct of the agro food by adding nisin (polycyclic peptide antibiotic) by thermo chemical process based on mixing then followed by injection, moulding and produce by spray drying. Bioplastic with better anti microbial characteristics, in aricular against gram positive bacteria were obtained by adding nisin to the initial protein or plasticizer mixture. However, by adding nisin more rigid but less deformable bioplastic is produced. Growth inhibition studies against gram negative and gram positive bacteria was used for testing antimicrobial activity of the bioplastic and the addition of nisin makes bioplastic as potential candidate in alternate to conventional plastic.

Conclusion

Bioplastics, derived from biological sources, offer a promising sustainable alternative to conventional plastics by reducing reliance on fossil fuels and promoting biodegradability. While challenges remain in terms of cost and performance, advancements in material science, biotechnology, and manufacturing processes are steadily improving their viability for various applications. Ultimately, responsible use, proper disposal, and recycling are crucial for maximizing the environmental benefits of Bioplastics.

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