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Advancing Eco-Friendly Solution: The Rise Of Bioplastics From Agro-Food Waste Byproducts In Mitigating Environmental Pollution.

Aashish Verma[1*] and Dharam Chand Jain[2]

Department of Chemical Sciences, SAGE University Indore (M.P), India

Abstract:

The increasing dependency of human beings on plastics is leading the accumulation of plastic wastes in different environments has become a topic of major concern over the past decades; therefore, technologies and strategies aimed at mitigating the environmental disastrous effects of petroleum products have gained worldwide relevance. In this scenario, the production of a suitable environmental-friendly substitute like bioplastics/biodegradable plastics mainly from polysaccharides such as starch and cellulose are a growing strategy is the need time and a field of intense research. The research and development in this field of Bio-based and biodegradable bioplastics can have similar features as conventional plastics while providing extra returns because of their low carbon footprint in medical, packaging, structural and automotive engineering, as long as additional features in waste management, like composting. Interest in competitive biodegradable materials is growing to limit environmental pollution and waste management problems. The current paper is a review of the progress of research in ecofriendly, recyclable, readily degradable bioplastic obtained from the processing of by Products of Agro-Food Wastes.

Key Words: Bioplastics, Biodegradable, ***Starch, Cellulose,*** Environmental-friendly

Introduction:

Environmental pollution is one of the serious problems faced on humanity and other life forms on our planet today. Environmental pollution, especially pollution caused by plastic waste, is globally becoming more and more serious in both developed and developing countries. **(Sikorska and Vikhareva *et., al.*, 2021).** Plastic industry is considered as one of the most important industries which manufactures polymer materials commonly called as plastic. It is the major threat of the environment **(Needhidasan, 2014) and (Derraik, 2002)** as it remains on the ground, generates heat, and proves to be detrimental to the environment. The usage of plastic is wide enough in all our daily use such as food packaging, school, office, automotive, communication, transportation, pharmaceuticals, household materials, lamination, packing of materials and many other fields due to its advantage of being flexible, transparent, low weight, cost efficient, thermal and chemical stability, solar radiant, insulating properties and resistant to microbial degradation **(Sofiah *et al.*, 2019).** Regarding plastic wastes, they represent approximately 12% of the composition of the world's solid waste **(Kaza *et al.*, 2018)** and their annual production has been increasing since 1950 and exceeded 6 billion tons of waste generated between 1950–2015 **(Geyer *et al.*, 2017).** Today most of the available plastic is synthetically produced from basic raw materials, crude oil and natural gas and several other chemicals serve as starting materials for manufacture of various plastics **(Kalia *et al.*, 2000).** Petroleum-derived plastics pollute the soil, water, and air. They could also destroy the habitats of many species, reduce biodiversity, cause many direct impacts on humans, and hence, is likely to result in the unsustainability of global development. Hence, there is need to produce plastics from materials that can be readily degradable to form an environment that is"eco-friendly" **(Saharan & Ankita, 2012).**

Ecofriendly polymers have gained great attention in the last few decades due to environmental concerns. Hence this review focuses on the different possibilities of bioplastics production from starch and cellulose fibers, -by products of Agro-food wastes, as a substitute for the conventional plastic and to prove that these could be used in the production of the biodegradable plastic

Bioplastics:

European Bioplastics (EUBP)—the association representing the bio-plastics industry's defined "bio-plastic" as the biodegradable plastic materials and plastics produced from renewable resources. IUPAC defined bioplastic as a derivative of "biomass or monomers with plant origin, at some point of processing can be designed" **(Vert *et al.*, 2012; Plastics Europe 2021).** Bioplastics market share is around 1% of the 370 million tons of total global plastic produced. But their annual growth rates hover around 30% until 2025. In terms of renewability and production, some of the most widely known biobased plastics nowadays are polylactic acid (PLA), starch-based plastics, protein-based plastics, cellulose esters, polyhydroxyalkanoates (PHAs) **(Mekonnen *et al.*, 2013)** and plant fibers **(Ramesh & Reddy, 2017 and Ramesh & Rajeshkuma, 2021).** Bioplastics, manufactured from biomass, with or without modifications, such as starch, protein, and cellulose, are biodegradable and therefore gaining more and more attention.

Nowadays, bioplastics produced from eco-friendly and natural biopolymers like cellulose, starch, proteins, lactic acid, hydroxy alkenoates or other materials derived from plant or microorganisms have become a topic of great interest among the researchers worldwide **(Mostafa *et al.*, 2018**). The biodegradation ability of the bioplastics makes them to decompose into inorganic compounds or biomass through enzymatic degradation by variety of microorganisms **(Mouafo Tamnou *et al.*, 2021).** The production and use of bioplastics instead of synthetic plastics (non-biodegradable and oil-based ones) reduce emissions of polluting gases. Regarding environmental problems such as the greenhouse effect (the emission of greenhouse gases is a growing global concern), according to the

Intergovernmental Panel on Climate Change (IPCC)), a 50% reduction in GHG emissions by 2050 is required for avoiding a 2 ◦C increase in the global temperature. Biomaterials such as bioplastics and biofuels are considered one of the mitigating measures in relation to global warming **(Lackner, 2015; Paula & Contiero, 2018; Naik *et al.*, 2010; Neuling & Kaltschmitt, 2017). (Martins *et al.*, 2013)** revealed that the bioplastic film from combination of organic waste has potential to become alternative resources in plastic making industries, to reduce the amount of discarded organic wastes and to contribute to waste to-wealth industry development in Malaysia. **Reddy *et al.*, 2013** also studied biopolymers for bioplastic formation and suggested several sources for bioplastic production including PLA and PHA and addition of glycerol to improvise bioplastic characteristics and biopolymers serving as renewable, eco-friendly and effective alternative to conventional plastics.

Starch-Based Bioplastics

Starch is a biodegradable, biobased polysaccharide consisting of amylose and amylopectin and is synthesized by most plants via photosynthesis **(Nafchi *et al.*, 2013)** Starch is an abundantly available, renewable, and cheap biopolymer, widely used for packaging in the food industry. Starch-based polymers represented 21.3% of global production capacities of bioplastic **(European Bioplastics, 2019.)** Depending on the starch source, there are disparities in chemical composition and structure which affect the crystallinity and texture of these polymeric materials **(Sudesh & Doi, 2000)** However, the higher rate of crystallinity, strong intermolecular forces like hydrogen bonding, and the presence of disordered granules reduce the mechanical properties and reduce the processability of starch as a thermoplastic polymer **(Cornejo-Ramirez *et al.*, 2018).** In order to overcome these issues, starch is further processed by mixing with plasticizers such as glycerol, **(Teixeira *et al.*, 2007; Viguie *et al.*, 2007; Valerio *et al.*, 2015)**, sorbitol **(Ballesteros *et al.*, 2020 and Hazrol *et al.*, 2021)**, formamide **(Ma & Yu, 2004 and Baran *et al.*, 2020)**, urea **(Wang *et al.*, 2014)**, citric acid (Shi ***et al.*, 2007; Jiugao, & Ning, 2005)**, glycerine **(Liu and Feng, 2001),** polyethylene glycol**(Kahvand & Fasihi, 2019)** amino acids **(Orts, 2007)** and water in the presence of elevated temperatures and shear forces, to facilitate the improvement in plasticity and thermoplastic characteristics of the polymer, yielding the thermoplastic polymer, thermoplastic starch (TPS) **(Khan *et al.*, 2017)**. Plasticization of starch disrupts the crystallinity of starch material and promotes the processability of starch in the development of thermoplastic polymer **(Offiong & Ayodele, 2016). Sothornvit & Krochta, 2005** studied effects of Plasticizers on properties of starch-based films plasticizers are relatively low molecular weight compounds that can be co-polymerized with the polymer or added to it in order to reduce the intermolecular force and increase the mobility of the polymeric chains.

Starch-based materials have shown great potential, especially when an increasing number of countries adopted regulations for banning disposable conventional plastics **(Madhumitha *et al.*,2018)** For example, in Spain, the commercialization of single-use items, such as straws, balloon sticks, and plastic cutlery is banned, as well as the use of microplastics in cosmetics and detergents. In Brazil, the states of Rio de Janeiro and Sao Paulo already established regulations that prohibit the supply or sale of plastic straws in commercial establishments. It is well known that the main benefit of starch-based materials is the biodegradability due to faster degradation and reduced requirement of landfills, as compared to synthetic plastics **(Siemann, 2005).** Besides, the starch source is extensively accessible, being corn, potato, and cassava starches produced on commercial-scale and the most explored starch sources for plastic production **(Ochoa-Yepes *et al.,* 2019).** The formulation of starch-based solutions with plasticizers increases water vapor permeability (WVP), elongation, and reduces tensile strength. **Daudt *et al.,* 2016** reported the elasticity modulus and tensile strength in bioplastics of rice flour decreased with increasing glycerol concentrations, besides increased permeability to water vapor. The hydrophilic character of glycerol facilitates both adsorption and desorption of water molecules, thus increasing WVP. **Lourdin *et al.,*1995*)*** found that for unplasticized starch films, an increase in amylose concentration increased the elongation and tensile strength of the films. Furthermore, (**Forssell *et al.,* 2002)** analyzed the effect of relative humidity on the oxygen permeability of amylose and amylopectin films prepared by the solution casting technique. The prepared film showed an oxygen barrier similar to that of commercial ethylene-vinyl alcohol (EVOH) film at ambient humidity, and on increasing the humidity above 70% RH, amylose had a better oxygen barrier than amylopectin. **Rodriguez *et al.,* 2004** found that the optimum concentration of glycerol as plasticizer is 20 wt% of starch content, and further increase in plasticizer leads to phase separation and leaching out from the film. The study conducted by (**Ma & Yu, 2004)** found that the use of amide-based plasticizers like urea, formamide, and ethanolamine could suppress the retrogradation process and enhance the mechanical properties of PS. Recently, **Kahvand & Fasihi, 2019** investigated the effect of citric acid as co-plasticizer for starch and found that the addition of citric acid as co-plasticizer led to the development of stronger and stable hydrogen bonds with starch, and was confirmed by SEM, FTIR and XRD analysis

Cellulose -Based Bioplastics

Cellulose is one of the promising organic chemical compounds to be investigated for use as bioplastics, owing to its abundance and excellent properties. Cellulose is one of the natural polymers extracted from various plants **(Klemm *et al.,* 1998).** Its polysaccharide consists of β(1–4)-linked D-anhydroglucopyranose units, forming a long linear chain packed densely due to the formation of intra- and intermolecular hydrogen bonds, which generates outstanding mechanical properties **(Zugenmaier, 2008 and Wustenberg, 2015).** In addition, the structure of cellulose has the ability to be modified for advanced applications **(Zanchetta *et al.,* 2021).** Cellulosic polymeric materials are mostly available as bacterial cellulose, microcrystalline cellulose, cellulose nanocrystals or nano whiskers **(Charreau & Foresti, 2013 and Mohanty *et al.,* 2018)** They have good film-forming characteristics, as they are non-toxic and transparent film materials with exceptional mechanical, thermal and barrier properties, specifically for oxygen and oil barriers (**Noshirvani *et al.,* 2017; Vartiainen *et al.,* 2017)**. Modified cellulose and different cellulose derivatives such as cellulose acetate and cellulose esters are predominant materials used in industry for molding, extrusion and film applications (**Babu & Connor, 2013).** However, their poor solubility and indigestibility have hampered their commercialization in the field of edible films and coatings **(Amin *et al.,* 2021).**

The preparation of cellulose bioplastics has been extensively developed in recent years. The cellulose was obtained from various resources such as oregano waste (**Tran *et al.*, 2020),** cotton and sugarcane bagasse **(Aguilar *et al.*, 2019),** rice straw (**Bilo *et al.*, 2018)** and many others. However, cellulose was merely used as filler or modified as a cellulose derivative in the preparation of bioplastics. The most commonly used cellulose derivative is cellulose acetate, which has excellent mechanical and thermal properties. However, it requires a complicated and complex process (**Tran *et al.*, 2020 and Nigam & Das, 2021).** As a filler, cellulose has been added to various matrices such as amylose **(Xu *et al.*, 2021*)*** carrageenan **(Othman and Adam, 2020)** and starch **(Syafri *et al.*, 2019)**. The results showed that cellulose improved the properties of bioplastics. Nevertheless, the utilization of cellulose as the main component of bioplastics has not been widely studied.

Ryu *et al.*, 2002 found that cellulose was converted into starch with help of group of enzymes such as cellobio-hydrolase, β-glucosidase, endo- β-1,4- glucanase. Hydrolysis of cellulose in which breakage of β-1,4glycosidic bond occurs. is used in formation of Bioplastic. **Nourbakhsh, (2008)** studied the effect of different concentrations of cellulose fibers in a woodplastic composite. It was found that the addition of 30% and 40% of reinforcement fibers to the plastic matrix resulted in higher modulus and strength. **Hansen *et al.*, 2012 and Saxena and Ragauskas 2009** showed that nanocellulose addition improves the properties of xylan-based bioplastic. Due to its high crystallinity (higher than 60%) and dense network of polymeric bonds formed by hydrogen bonds, whisker-type nanocellulose produces a tortuous path in bioplastics, since it works as a barrier structure, thus hampering the transport of water molecules through the material. **Stevanic *et al.*, 2012** demonstrated the addition of adequate amounts of nanocellulose to xylan based bioplastics increased the bioplastics' mechanical properties and hydrophobicity. The authors obtained higher values than those achieved by **Goksu *et al.*, 2007** who used the only xylan in the formulation of the bioplastic matrix and reported lignin is necessary for the obtaining of continuous xylan-based bioplastics. **Bayer *et al.*, 2014** showed that trifluoroacetic acid (TFA), a natural organic acid with low toxicity that can be biodegraded by microbial action, is capable of extracting cellulose bioplastic. Green solvents, such as the organic salts known as ionic liquids (ILs), have received attention as promising solvents for lignocellulose pretreatment or fractionation

Conclusion:

The present review discusses the use of starch, cellulose fiber, and plasticizers for the synthesis of bioplastics. bioplastics are a promising alternative to traditional petrochemical-based plastics as they are eco-friendly and 100% biodegradable in soil . Starch and cellulose are two of the most commonly used materials for the synthesis of bioplastics Starch-based bioplastics are the most extensively synthesized bioplastics, representing about 50% of the total bioplastics in the market . Cellulose is abundant in nature and holds immense potential for manufacturing eco-friendly plastics due to its physical and mechanical properties. Bioplastics are biodegradable making them an eco-friendly option and will be great solution for the most serious urgent global environment problem. However, it is important to note that we cannot stop the usage of plastic altogether. Instead, we can alternate using eco-friendly bioplastics.

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