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Cellulose and Starch as the Source of Bioplastic

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Abstract: Over last several years, need of the polymers has increased. Polymers are a broad class of materials that can be natural in origin or synthetic. Very small variations in the chemical structure of polymer could lead to large change in their biodegradability.
A vast number of biodegradable polymers (example: chitin, starch, polyhydroxyalkanoate, polylactide, polycaprolactone including polypeptides) has been synthesized or is formed in natural environment during the growth cycles of different organism. Microorganisms and enzymes capable of degrading such polymers have been identified.
The use of additives like sorbitol, glycerol and poly ethylene glycol will enhance strength and thermal stability of polymers during processing.
Already existing biopolymers are facing the issues in meeting market demand, cost of manufacturing, being non recyclable, release of carbon dioxide during manufacturing and release of methane gas during degradation. These issues can be overcome by novel starch and cellulose based bioplastic produced from biomass. Bioplastic will meet the market demand and degrade in the soil at high temperature.
Keywords: Bioplastic, Starch, Cellulose, Plasticizer, Biodegradable

I. INTRODUCTION

Bioplastics can be defined as plastics that are made from natural source such as corn and sugarcane bagasse. By producing these kind of plastic demand of fossil fuels can reduced, reducing CO_2 emission and reduce accumulation of the non biodegradable plastic wastes get reduced. Conventional plastics not only take many decades to decompose, but also produce toxins during degradation. Hence, there is need to produce plastics from materials that can be readily degradable to form an environment that is "eco-friendly" [1].

Starch is a polysaccharide commonly found in plant sources. It consists of helical structures of amylose (amorphous and crystalline phases) and a branching structure of amylopectin (amorphous phase). The ratio of amylose and amylopectin influences the properties of starch [2].

Currently，the main opportunities for bioplastics are in film making but in future bioplastics will be used more in higher value products such as electronics and vehicle parts [3].

Many researchers used plant cellulose fiber, such as by products of cotton, waste straw from rice, wheat, rye, barley and cornhusk, wood fiber for the synthesis of cellulose.

The raw materials have a high impact on the cost of bio-based plastic production as in the case of cellulose the cost is highly reduced [4]. According to statistics, by 2025, atleast 55% of municipal waste must be recycled. By 2030 the target will rise to 60% and by 2035 it will be 65%.

Recycling of packing materials should be 65% by 2025, and 70% by 2030. Increase in the population the target to reduce the plastic usage is also increased [5]. The bioplastics does not degrade at room temperatures that should need humidity and microorganisms to degrade [6].

II. BIOPLASTIC AND ITS SOURCE

Bioplastics are that which are produced from renewable resources and are biodegradable in nature. These biopolymers undergo decomposition into CO_2, H_2O and inorganic compounds or biomass under natural conditions through the enzymatic action of microorganisms [7].

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Classification Of Bioplastic & Its Source [Source: Reference 8]

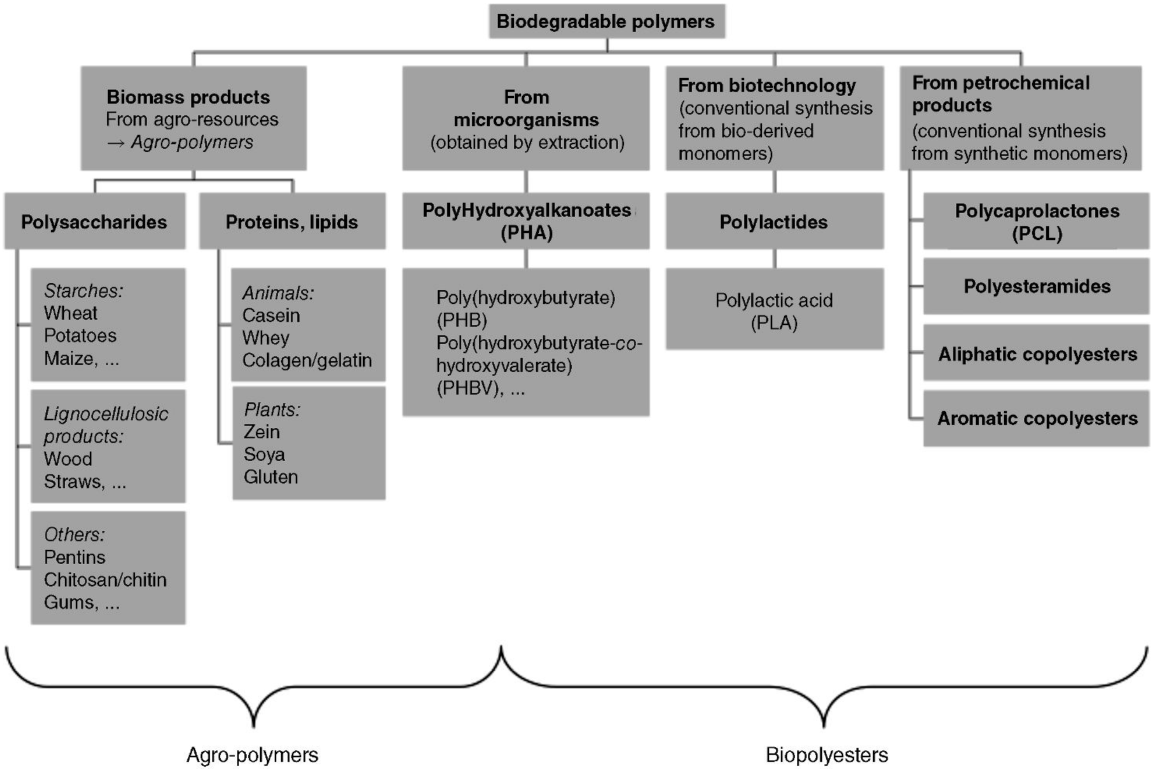

TABLE I
Bioplastic From Different Source

MATERIAL	SOURCE MATERIAL	REFERENCE
Starch	Corn starch	[09]
	Potato peels	[10]
	Banana peels	[11,12,13]
	Cassava	[14]
	Giant squid (Dosidicus gigas)	[15]
	Newspaper pulp	[16]
Cellulose	Rice straw	[17]
	Oil Palm fruit bunch	[18]
	Citrus waste	[19]
	Corn leaf biomass	[20]
Protein	Sorghum and Millet	[21]
	Rapeseed Oil	[22]
	Oil palm mesocarp fibre	[23]
Poly-Lactic Acid	Lactic acid	[24]
	Waste paper	[25]
	Cornstarch/eggshell	[26]
	Prosopis juliflora	[27]
Polyhydroxybutyrate	Water hyacinth	[28]
	Ralstonia solanacearum	[29]
	Burkholderia sacchari	[30]
Starch and cellulose	Apple pomace	[31]

Polyhydroxyalkanoates	Apple pulp waste	[32]
	Ralstonia eutropha 511	[33]
	Cyanobacteria	[34]
	Waste frying oil- Cupriavidus necator Macroalgae -	[35, 36]
	Haloferax mediterranei	[37]
	Pseudomonas putida	[38, 39]
	Bacillus sp (F15)	[40]
Whey protein	Residual dairy streams	[41]
Myofibrillar proteins	Gilded catfish (Brachyplatystoma rousseauxii) waste	[42]
Chitin	Carp fish (cyprinus carpio L.)	[43]
	Giant squid (dosidicus gigas)	[44]
Wheat gluten	Wheat	[45]

III. STARCH AS A BIOPLOYMER

Starch is the second largest biomass produced on earth. Starch is a white, granular, organic chemical that is produced by all green plants. Starch may be a soft, white, tasteless powder that is insoluble in cold water, alcohol or other solvents. The basic formula of the starch molecule is $(C_6H_{10}O_5)_n$. Starch is the polysaccharide comprising of glucose monomers joined by α 1,4 linkages. The simplest form of starch is the linear polymer viz, amylose and amylopectin is the branched form [46].

Starch and its derivatives are produced commercially from a range of biomass and raw materials such as banana peel, corn, wheat, pea, potato and cassava roots. Starch has a wide range of applications beyond the food industry, in the paper and board sector (in the production of recycled paper and surface coating), in the pharmaceuticals sector as binding agent, in the textile industry, in the industrial binder sector as gypsum boards and adhesives [47]. Decrease in tensile mechanical properties was noted at high starch concentrations. Transparency was also seen to decrease with increasing starch concentration [48].

Corn starch consists around 25% amylose and 75% amylopectin molecules. The amylose molecules loose water due to which the biodegradation tendency increases and by amylopectin molecules plasticizer properties increase, i.e. rapid gel formation, good absorption capacity and good flexural strength [49].

Potato peel bioplastic have higher water absorption capacity than commercial bioplastic. Therefore, Potato peel bioplastic may not be used in the food service industry but can be used as packing material bioplastics produced from potato peels completely biodegraded within 28 days [50].

Cassava contains a large amount of starch than the other kind of biomass. Resistance to degradation of bioplastics made from cassava was strongly influenced by the quantity of glycerol used as the plasticizer. The greater the amount of glycerol used, faster the degradation process (the complete degradation occurred on the 9th day) [51]

The bioplastic produced from banana peels that can be used as packaging material. Sodium metabisulphite act as the anti microbial agent, glycerol is added to increases its flexibility. The degradation of bioplastic starts after 3 to 4 months from the date of production [52].

IV. CELLULOSE AS A BIOPLOYMERS

Cellulose is an organic chemical compound with the molecular formula $(C_6H_{10}O_5)_n$. It is a polysaccharide consisting of a linear chain of several hundred to over ten thousand β(1→4) linked D-glucose units. Cellulose is the structural component that is found in the primary cell wall of green plants, algae and oomycetes [53]. Plant-derived cellulose is usually found with the mixture of lignin, hemicellulose, pectin and other substances. Cellulose is derived from fiber. Fibers are insoluble in water, it should be treated with sodium chlorite and with concentrated acids at high temperature to get pure cellulose.

Cellulose is taken out from waste newspapers by decomposing them. Then cellulose is decomposed into starch/glucose by process called Cellulolysis which is done with the help of enzymes derived from organisms *(Trichoderma reesei* and *Aspergillus terreus)*. Finally, bioplastic is prepared [54].

Cellulose acetate was synthesized from cellulose which was separated from teak wood (*Tectona grandis*) biowaste. The separation process used an separation method using sodium sulfite, nitric acid, sodium hydroxide and bleached with calcium hypochlorite. Cellulose acetate were synthesized with acetic anhydride, toluene as a solvent and sulphuric acid as a catalyst [55].

Cellulose pulp was taken from elephant grass leaves. Bioplastic is synthesis with various concentarion of chitosan to cellulose pulp ratio 3:10, 4:10, 5:10 (w/w), combined 3 mL of glycerol 2 g of cellulose pulp produced by using inversion phase method. The results have shown that cellulose from elephant grass leaves could form bioplastic with good tensile strength of 7.2 MPa at the ratio of chitosan to cellulose pulp 4:10 [56]. Cellulose - based bioplastic made corn stalks are made possible. However, their mechanical property is weaker when compared to commercial cellophane [57].

Cellulose nanocrystals (CNS) were isolated from rice straw as reinforcing filler of starch-based bioplastics. Tensile strength and modulus of elasticity significantly increased with increasing CNC load. Elongation at break is decreased. The moisture resistance of the starch-based bioplastics was also be enhanced by CNC addition, which was related to the rigid network of crystalline cellulose that hinders the absorption of water [58].

V. DIFFERENT KINDS OF PLASTICIZERS USED IN BIOPLASTIC PRODUCTION

Plasticizers are small, organic molecules, relatively non-volatile that are added to polymers to impart flexibility, reduce brittleness, reducing crystallinity, improve toughness, processability, durability, lowering glass transition and melting temperatures [59]. Plasticization reduces the relative number of polymer–polymer contacts thereby reduce the rigidity of the 3D structure thereby allowing deformation without rupture. Plasticizers that impart additional functions of electric conductivity, optical quality, flame retardancy, thermoxidative stability, chemical and temperature (high and low) resistance in demanding environments, improvement of gas and moisture impermeability, provide or improve biodegradability [60].

Two types of plasticizers are defined in polymer science namely internal and external. Internal plasticizers are a part of the polymer molecules, co-polymerized into the polymer structure, grafted or reacted with the original polymer thereby making the polymer chains more harder to fit and compact with each other closely reducing the elastic modulus[61]. External plasticizers, on the other hand, are low volatile molecules added to interact with polymers and produce swelling without chemical reaction. Internal molecular forces between plasticizer molecules and between a plasticizer and a polymer like dispersion forces, induction forces, dipole– dipole interaction, hydrogen bonds are important in external plasticization [62]

Different kinds of plasticizers in the literature include polyols such as glycerol, maltitol, glycol, sorbitol, xylitol, butanediol, ethylene glycol, propylene glycol, fructose, sucrose, mannose, fatty acids such as myristate or palmitate. Among these glycerol is the classical plasticizer of starch and perhaps the most widely studied and used polyol plasticizer of thermoplastic starch. This is because of its low cost, nontoxicity (for food and biomedical application) and high boiling point (292º C). Glycerol is known to leach out during aging and humidity exposure, a major limitation for large scale applications [63].

VI. CONCLUSION

The present review reports the use of starch, cellulose fiber and plasticizers for the synthesis of bioplastic. Bioplastics are formed well with the high amount of amylopectin present in starch. High amount of amylopectin is present in cassava starch. Cellulose sources are abundant in the environment. Cellulose makes the bioplastic stronger and makes it more rigid by forming network with starch. Plastic are more important for our day to day life. We cannot stop the usage of plastic. But we can alternate using ecofriendly bioplastics. It will not cause any pollution to the environment and it will 100% degrade in soil. Bioplastic will be great solution for the most serious urgent global environment problem.

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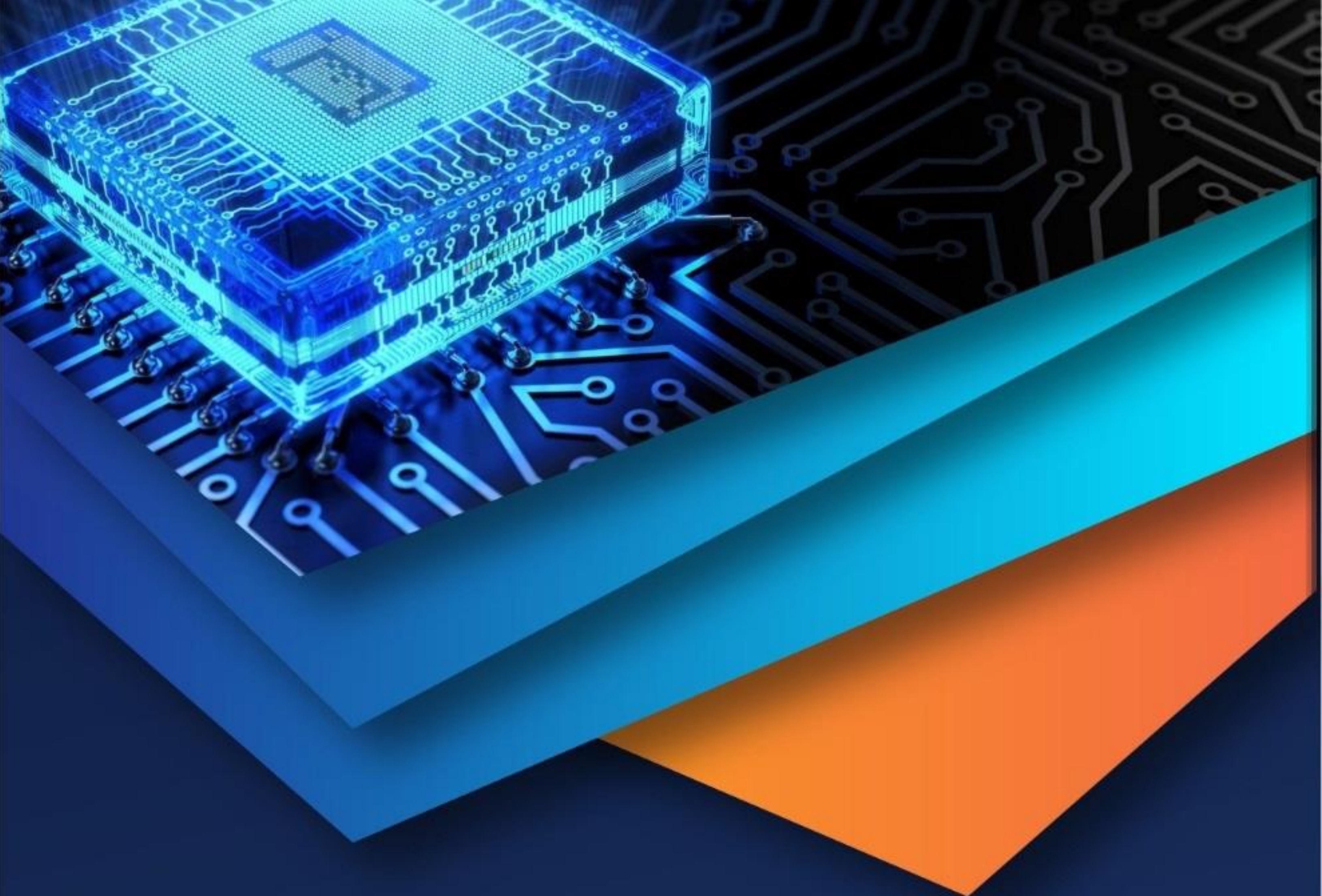

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