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# Review on Recent Developments and Future Scope in using Biodegradable Materials for Food Packaging

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***Abstract*- The plastic consumption in our day to day life has increased so rapidly due to which their manufacturing and production have also multiplied drastically. These materials are not degradable and get accumulated in the environment causing severe effects on our ecosystem. Moreover burning these plastic materials produce toxic gases which are very much injurious to both flora and fauna. Scrutinizing these facts, there has to be a replacement for these petroleum based products. These rising issues have led to the development of materials which are eco friendly or the so called green materials. Through this paper the use of biodegradable packaging materials, their advantages over the conventional petroleum based products, their limitations and future scope have been highlighted. The bioplastic can be derived from agricultural resources and biomass feedstock which are renewable, eco friendly and sustainable. Food industry is a major consumer of plastic as a packing material for the food items. Instead of using these typical plastic materials biodegradable materials can be more effectively used to protect the food iems and also prevent the degradation of our environment.**

***Keywords: Plastic, Bioplastic, Biodegradable, Food packaging***

## I.INTRODUCTION

Packaging industries are flourishing in the world due to their extensive applications. The purpose of packaging is to protect the products from damage. The packaging industries play a vital role in providing value to the manufacturing sectors. The packaging of a product is also a marketing strategy to attract the customers to buy that particular product. So packing the product in attractive designs of suitable material also adds up the value to the product. The growth in lifestyle has also increased the demand for safe packaging. The unfortunate fact is that these industries most commonly use plastic as their raw material.

It was estimated that the total productivity of plastic in world was about 280 million tones in 2016 (Plastic Europe market research group), and from which 31.1% of plastic were recycled successfully. In the same year 2016, 16.7 million tones of plastic packaging were collected and of which only 40.9% of plastic were recycled (conversion market and strategy GMBH).

From the above data, we can thus conclude that the use and production of plastics in the world is being multiplied. The plastic which remained after recycling get accumulated in the land as landfills and cause a major threat to the environment.

Food packaging industry is a major consumer of plastics. The main aim of the food packaging industries is to protect food from microbial activities, increase the shelf life and preserve the quality of food. However, the packaging material should, not only protect the food items but also include the properties to not to cause any harm to our eco system. The food packaging involves packaging of food items in bottles, cans, sachets etc. These commodities are generally made of plastic, metals and glass. According to a report published by FICCI, in India around 49% of packaging materials make use of plastic as the raw material. And the best way to reduce the plastic consumption is to use a material which provides the same properties as that of plastic. This has eventually led to the development of biodegradable packaging.

Basically biodegradable means anything that is degenerated and compostable under suitable conditions of temperature, moisture and oxygen and produce no toxic residues. Biodegradable materials can be beneficially used in the food packaging where the key feature of biodegradability is highlighted. The biodegradable polymers can be obtained from renewable resources like agricultural products and biomass feedstock. Many vendors are also introducing biodegradable and sustainable packaging materials due to increasing demand for eco friendly packaging products. The Coco Cola company has introduced plant bottles which are partially made of bioplastic.

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## II.TYPES OF BIODEGRADABLE PACKAGING

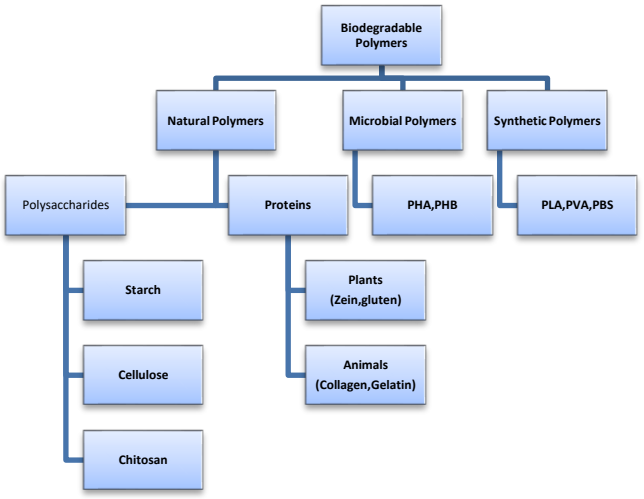


Figure 1 Classification of biodegradable polymers

The biodegradable packaging materials are classified as;-

- ❖ Natural polymers
- ❖ Microbial polymers
- ❖ Synthetic polymers

*A. Natural Polymers*

Natural Polymers are those polymers which are derived from biomass or renewable resources like animals, plants and agricultural resources. These includes polysaccharides and proteins. Starch, chitosan, gums come under polysaccharides while proteins can be extracted from both plants and animals.

Starch is the most commonly used material for manufacturing biodegradable packets to store the food items. Starch consists of two components namely amylose (20-30%) and amylopectin (70-80%). (Kumar., et al , Starch is mainly extracted from cereals like corn.)2014 wheat, etc. and also from potatoes, tapioca etc. The starch based material gives good strength when incorporated with plasticizers. The main advantage is that these materials are economic and easily available. The plasticizers which are , generally imparted with starch are glycerol, urea, etc(Majid Thakur, & Nanda, 2018). They are hydrophilic in nature and offer good gas barrier properties. Starch based films also exhibit similar properties of conventional plastic films like they are odourless, colourless, non-toxic, semi-permeable to carbon dioxide and highly resistant to oxygen.(Rydz, Musioł, Zawidlak-w, & Sikorska, 2018) )Keziah, Gayathri, & Priya, 2018(

Cellulose is the most abundant natural polymer, Cellulose derivatives are composed of β (1-4) glucosidic units with methyl, carboxylic or hydroxypropyl substituents.(Kumar et al., 2014) Cellulose in its raw form posses poor mechanical properties. But when treated with chemicals like $H_2SO_4$, or NaOH they form cellophane which has good . strength. Cellulose is used for making paper and cardboards ., It is hydrophilic in nature.(Agustin et al., 2014) (Meena et al )2017

Chitin is the second most abundant agro polymer. Chitin is a waste produced in the fishing industry. Chitosan is obtained from chitin by deacetylation in presence of alkali. They have excellent gas barrier properties and even provide good resistance to anti microbial activities. Chitosan films are highly viscous. Chitosan can also form high transparent films. The functionality of chitosan films can be improved by inclusion of inert materials or compounds in the polymer matrix. (Shivam, 2016)

Proteins as such can be derived from both plants and animals. They are made up of amino acids. They also posses good gas barrier properties and are also hydrophilic in nature. They are blended with suitable plasticizers to improve their mechanical strength. Zein is the major storage protein of corn Zein have high content of non polar amino acids which make them hydrophobic and have poor mechanical properties. While casein, collagen and gelatin are proteins extracted from animals. Collagen is the protein obtained from connective tissues of animals and they are composed of different polypeptides.(Kumar, et al., 2014)(Lazic, Hromiš, Popovic )Suput, & Bulut, 2018

*B. Microbial Polymers*

These polymers are synthesized by microbial fermentation of polysaccharides. Polymers like PHA (polyhydroxy alkonates), PHB (polyhydroxy butonates) are obtained by fermentation. The PHA is synthesized from sugars or lipids using bacterial fermentation. These polymers are generally hydrophobic in nature so they havr good moisture barrier capacities. They are poor gas barriers. The microbial polymers are finding more industrial applications due to their unique properties and cost effective production.(Basnett & Roy, 2010) They also exhibit thermoplastic properties. Use of these materials also reduce the direct addition of preservatives into the food products. Poly(3-hydroxybutyrate) (PHB) is one of the well known biodegradable (PHA). Alcaligenes eutrophus is the most widely used organism for the production of PHB because it is easy to grow, it accumulates large amounts of PHB.(Mona Popa, 2011)

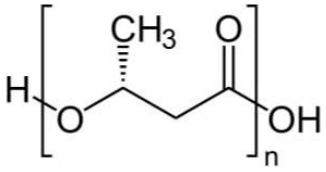


Figure 2 Polyhydroxy alkonates PHA

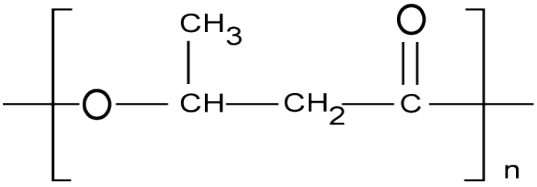


*Figure 3 Poly(3-hydroxybutyrate) (PHB)*

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*C. Synthetic Polymers*

PLA (polylactic acid) is a major polymer under the category of synthetic polymers. PLA can be easily produced from carbohydrates based feedstock and these include agricultural crops like wheat, maize etc. From the agricultural resources lactic acid is formed by fermentation. Then on condensation lactide is produced. Lactide on polymerization produce PLA. They have high molecular weight and good gas and moisture barrier properties. PLA is also a thermoplastic and the PLA films are obtained by various mechanical processes like injection molding, blow molding, thermoforming and extrusion. They can be used as a packing material for food products with low shelf life.(Kumar, Kaur, & Bhatia, 2017)

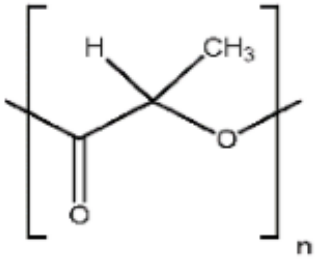


*Figure 4 Polylactic acid PLA*

PCL (polycaprolactone) is a thermoplastic which is completely biodegradable synthesized from crude oil. It cannot be used as a food packaging material but can be used as trash bags. It is easy to process and has low degradation time. It even has good chemical resistance to oil,and water. PVA (polyvinyl alcohol) is another synthetic biodegradable polymer which can be obtained from partial or complete hydrolysis of polyvinyl acetate. PVA is soluble in water. They have very low permeability to gases like oxygen. PBS (polybutylene succinate) is derived from the condensation reaction of glycols like ethylene glycol and 1,4- butanediol with aliphatic dicarboxylic acids like succinic acid and adipic acid. PBS has high tensile strength. PBS is biodegradable via ester linkages.(Majid et al., 2018) (Ck, Dave U, Sukrutha S, Bayineni K, & Rk, 2016)

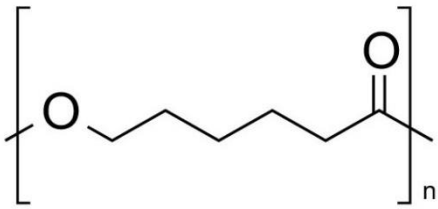


*Figure 5 Polycaprolactone PCL*

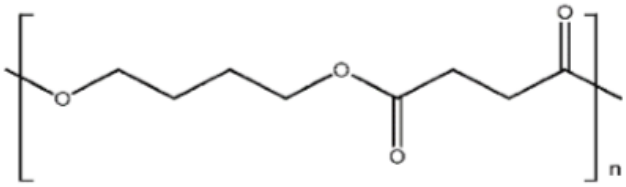


*Figure 6 Polybutylene succunate PBS*

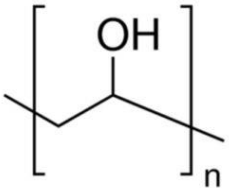


*Figure 7 Polyvinyl alcohol PVA*

## III. ADVANTAGES

- First and foremost these materials are biodegradable and compostable. No toxic residues are produced.
- Biopolymers are obtained from renewable resources mainly from agricultural resorces and other feedstock.
- They are light in weight.
- They are transparent and due to which the food item packed in it can be easily identified.
- They have good gas barrier properties which improve the shelf life of the food item.
- They do not react with the food items stored.
- They can easily be manufactured from the renewable resources and the raw materials used are cheap.
- The mechanical properties are improved when blended with plasticizers.
- They can easily be molded into any desired or complex designs.
- Films formed from various ingredients can be easily laminated together.
- They can be successfully used for microencapsulation to preserve the aroma of food.
- They are also resistant to UV radiations.
- Antimicrobial agents can be integrated effectively with these polymers.(Gontard & Guilbert, 2011), ( Ck et al., 2016)

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## IV. LIMITATIONS

- It is found that these materials have poor moisture barrier properties when compared to the existing packaging materials.
- These materials are generally hydrophilic in nature due to which the moist food products have limited shelf life.
- Some categories of biopolymers are not cost effective in terms of production.

## V. FUTURE OF BIODEGRADABLE FOOD PACKAGING

The majority of plastics used nowadays are produced from crude oil and other fossil fuels. The conventional packaging materials as such have many disadvantages as compared to biodegradable packaging. There is a shift towards biodegradable packaging mainly attributed to rise in health awareness and environmental concerns associated with non-biodegradable packaging.

In India the packaging industry is expected to grow from US$32 billion in 2015 to US$73 billion in 2022 at a CAGR of 18% (Source- Economic Times). This shows the growing demand for packaging materials. Therefore the market potential for biodegradable packaging materials is also heightened.

Globally the food packaging market is anticipated to grow at a CAGR of 4.4% till 2019 (Source- Global Food Packaging Market 2015-19, Technavio). According to the report by WiseGuyReports the biodegradable food packaging market is forecasted to increase from US$4.7 billion in 2015 to US$14.3 billion in 2022 at a CAGR of 17.2%. The European Bioplastics Association reported that the global production capacity of biodegradable polymers, reached 428,000 metric tons in 2010.The bioplastic industry is noted to have solid growth in PLA, PHA and plant starch based materials. Bio based polymer production would be tripled from 5.1 million tons in 2013 to 17 million tons in 2020 (Darby,2012).

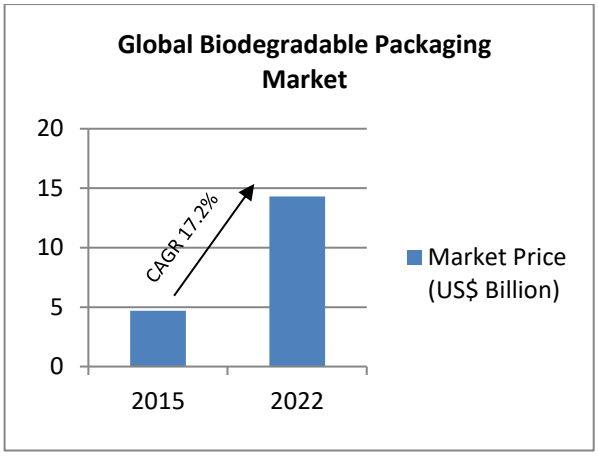


*Figure 8 Global Biodegradable Packaging Market Analysis* [Source- Global Biodegradable Packaging Market Analysis 2016 and Forecast to 2022, WiseGuy Reports]

## VI. CURRENT APPLICATIONS OF BIOPOLYMERS IN FOOD PACKAGING

Table I

| ***Food Products*** | ***Application*** | ***Company*** |
|---|---|---|
| Vegetables | Corn Starch bags | Iper Supermarkets (Italy) |
| Potato Chips | PLA bags | PepsiCo- Frito lay |
| Meat | Corn Starch covers | Plantic |
| Yoghurt | Cups made from PLA | Nature Works |
| Fruits/vegetables | Corn Starch bags | Novamont |
| Sweets | Cellulose based films | Quality street, Thomton |
| Bread | PLA Bags | Delhaize |
| Fruits/vegetables | Plant biomass | Ecoware |

## VII. CONCLUSION

Bioplastics are a revolution for the future generation where the unique factor of biodegradability make them more advantageous than the conventional plastics. The threatening issues like global warming and environmental degradation have increased the demand for sustainable, and ecofriendly products. Bioplastics can be taken as a healthy solution to overcome these issues. They certainly do not cause any kind of pollution in the environment. These compostable products have found a wide variety of applications in the food service and catering sectors as a packaging material. Many commercial institutions have recognized their significance and have also begun the manufacturing of these ecofriendly materials. They are not only ecofriendly but also cause no harm to the food stored in them. Many researchers have studied that these materials do not cause any health issues. Though these materials posses poor mechanical properties they can be blended with other polymers to improve their qualities. Still many researches and developments are going on in this field to improve their quality and economic feasibility so that the people can afford these materials and make use of them more effectively in their day to day lives.

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The biopolymers can be classified based on the origin or source and synthesis as natural, and synthetic polymers. The starch derived biopolymers can easily be manufactured and have similar properties like that of plastic.PLA iis another important material which is also most widely used as biodegradable packaging material. Therefore bioplastics could easily make an impact in our lives by their socioeconomic benefits and a best substitution for the conventional petroleum based products.

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