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A sustainable replacement for conventional petrochemical-based packaging materials as bio-based food packaging

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Abstract

Our health and the environment are under serious threat from the fast rise in global plastic manufacture. Due to its irreversible characteristics, the increased production of plastic made from petroleum is posing environmental problems. Researchers are being prompted by these problems to work on bio plastic research to develop environmentally friendly natural materials, as an alternative. The current review paper focuses towards the various types of biopolymer sources that are available in nature which are able to reduce the risk of environment damage through the use of alternative of plastic as a packaging material. The composition of the polymer and external factors like light, temperature, and humidity might have an impact on the biodegradation process. This review intends to highlight the various packing materials, including natural biopolymers (polysaccharides and proteins), synthetic biopolymers (aliphatic polyesters), and bio nanocomposites. It goes into detail on the origins of different biopolymers, how they are created, and how they can be applied to different types of food packaging. Some of the biodegradable polymer examples are also carefully examined in this review.

Keywords: Food packaging, active packaging, biodegradable biopolymers, bioplastic packaging, biobased additives, composability

Abbreviations: PHA, polyhydroxyalkanoates, PLA, polylactic acid, PHB, polyhydroxybutyrate, PHBV, 3-hydroxybutyrate co 3-hydroxyvalerate, BioPE, bio-poly- ethylene, CMC, carboxymethylcellulose, PUR, polyurethane, PF, phenol formaldehyde, LDPE, low-density polyethylene, TPS, thermoplastic starch; ASTM, American society for testing and materials, PVA, polyvinyl alcohol, PCL, polycaprolactone, PET, polyethylene terephthalate.

Introduction

In particular, for packaging purposes, plastics are regarded to be the material that utilized most frequently. According to (Paletta *et al*., 2019) [76], the world produces roughly 320 million tonnes of plastic annually, reflecting its vast range of applications in several industries. Due to the dependence of the plastic industry on fossil fuels, rising natural gas and petroleum oil costs may have an impact on the plastic sector's economic health (www.european-bioplastics.org). According to (Luzi *et al*., 2019) [60]; (Martez-Abad, *et al*., 2012) [63], polyvinylchloride (PVC), polyethylene terephthalate (PET), polypropylene (PP), polyethylene (PE), polyamide (PA), polystyrene (PS), and ethylene vinyl alcohol (EVOH) are often used polymers for this purpose. (Park *et al*., 2017) [77]. However, the disposal of synthetic plastics results in the release of greenhouse gases such as carbon dioxide and methane, which have serious negative effects on the environment (Jain & Tiwari, 2015) [46]. Due to their non-recyclability or lack of biodegradability, the usage of fossil-based plastics is therefore restricted. Therefore, it is crucial to switch to alternative raw materials for making plastic (Ahmed *et al*., 2018) [2]. This concept advocates for creating and using the creation and use of adequate, plentiful, and sustainable resources.

Bioresources are used for the creation of ecologically sustainable substitutes for conventional resources (Bilal & Iqbal, 2018) [13]. For polymer resources, compostability is essential since recycling consumes energy (Al Hosni *et al*., 2019; Asgher *et al*., 2020a) [3, 5]. In general, compostability refers to a set of procedures that take use of organic matter's biodegradability to convert it into a specific end product known as "compost." Soil components can be degraded by composting by creating carbon dioxide, water, and other inorganic chemicals (Al Hosni *et al*., 2019) [3]. Plastics made from renewable resources are not always compostable or biodegradable. The second, biodegradable polymers, is not necessarily based on renewable resources since biodegradation is more strongly associated with the chemical structure of the molecule than with its origin. The duration of biodegradation is specifically determined by the kind of chemical bonding that exists in molecules (Lambert & Wagner, 2017) [54].

Biodegradable or compostable polymers that naturally contain carbon include gelatin, cellulose, starch, lignin, starch, and keratin. In addition, biopolymer-based bioplastics may no longer be biodegradable following chemical modification such as polymerization. For example, Nylon 9 was produced by polymerizing oleic acid, which was created by polymerizing castor oil monomers (Cotarca *et al*., 2001) [21]. From the standpoint of origin and biodegradability, 1 describes the many forms of plastic. Plastics are created by combining polymers that that are created by combining polymers with a variety of additional chemicals, such as colourants, stabilisers, processing aids, etc. Up to now, the weight of renewable resources in bio-plastic has exceeded 50%.

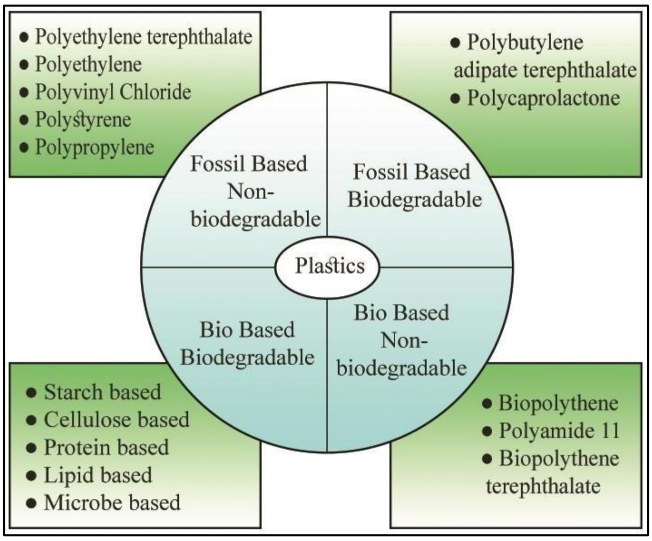

Fig 1: Different types of plastics available in the market from origin and degradability point of view.

Like other fossil-based plastics, bioplastics have a variety of uses, including collecting bags, horticulture, agricultural foils, toys, nursery items, and textile fifibers (Marjadi *et al*., 2010; Tortajada *et al*., 2013) [62, 95]. Bioplastics are predicted to preserve food quality and provide environment food packaging. Controlling goes without saying that controlling and changing these material's mechanical and barrier qualities, which depend on the chemical makeup of the packaging material, is essential to carrying out these duties. The features of bioplastics can alter over time when they come into contact with food (Jabeen *et al*., 2015; Jariyasakoolroj *et al*., 2018) [45, 47], therefore this is another crucial factor. Only a few biopolymers are used for food packaging applications, according to a literature review. Contrary to the typical labels, films, wraps, and laminates made from fossil fuels, the use of biodegradable plastic material demonstrates a correct step in the direction of protecting the environment from dangerous chemicals. As identified as a potential source of loss in food quality (Asgher *et al*., 2020b; Biscarat *et al*., 2015) [6, 17], it is crucial to comprehend not only the mechanical and physical properties of such compounds but also their compatibility with food material. We have compiled the most recent information on biopolymers-based coatings and films for food packaging applications in this review, covering the main sources, production processes, incorporation of active anti-oxidant/antimicrobial reinforcements, and perspectives on their biodegradability and compostability.

Biobased polymer resources

Polymers which are synthesized by the living body such as plants and microorganisms through metabolic engineering processes are called bio/natural polymers. Fig. 2 represents the general classification of biopolymers depending upon their origin (Iqbal, 2015) [43].

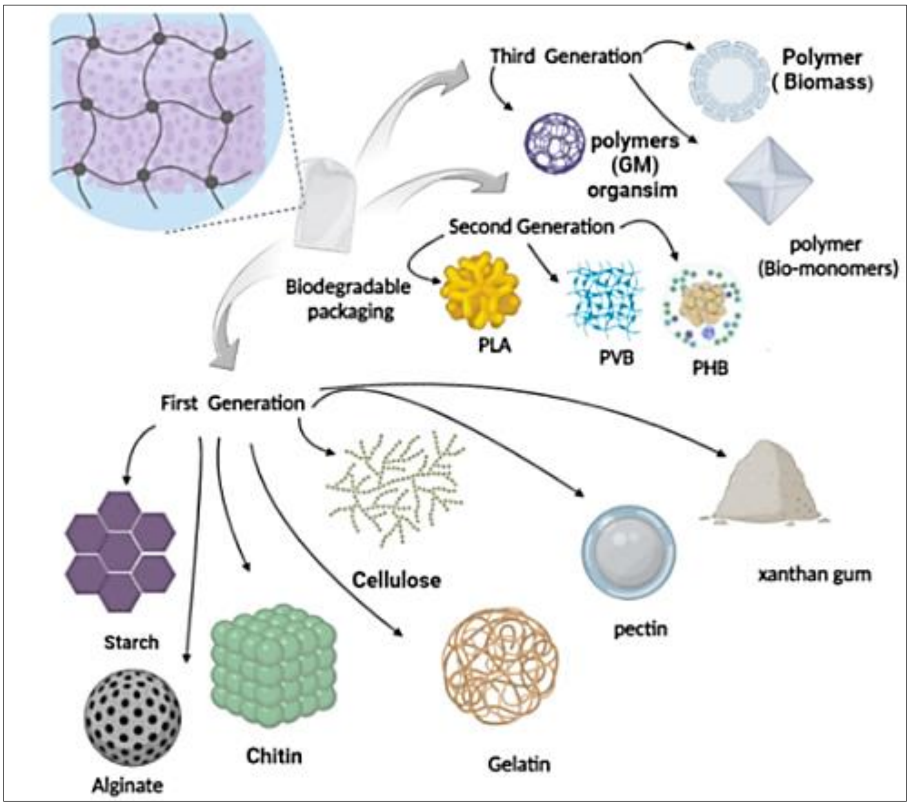

Fig 2: General Classifications of biopolymers

Carbohydrate polymers e.g. starch, chitosan, cellulose or lignin proteins e.g. keratin, collagen or gelatin and polyhydroxyalkanoates e.g., polyhydroxybutyrate (PHB) and its copolymer 3-hydroxybutyrate co 3-hydroxyvalerate (PHBV) (Iqbal & Keshavarz 2016) [44]. Rasheed, Lignocellulosic wood fibers contain high amount of cellulose and hemicelluloses. Their resulting films hold good toughness, tensile strength, high surface gloss and good transparency. Mostly, the cellulose is chemically altered during the procedure of dissolution to facilitate the breakage of polymer chains. Cellulose derivatives that are obtained after chains disintegration can be regenerate as coatings.

Microbially-originated polymers

PolyhydroXyalkanoates, exopolysaccharides, and polylactic acid are the three main fermentation-based biopolymers. (Alshehrei, 2017; Asgher *et al*., 2020a; Chen, 2010) [4, 5, 18]. It is possible to produce the monomers needed to create PHA, PLA, and BioPE from recycled biomaterials. Sugarcane and corn wastes are advantageous because their monomers only slightly polymerize, making it simple to extract them from plant sources.

Poly lactic acid (PLA)

The fermentation of sugars (often maize starch) produces bio-based lactide and lactic acid. After hydrolysis, lignocellulosic biomass appears to be an incredible route for producing lactides and lactic acid. According to de (de Kort *et al*., 2019), PLA is processed at a lower temperature than conventional thermoplastics. In order to purify PLA, several processes must be used, including reverse osmosis, adsorption, solvent extraction, and distillation (Huang & Ramaswamy, 2013) [41]. A higher raw material input can lower the cost of conversion operations, but higher enzyme hydrolysis and fermentation costs will result (Nampoothiri *et al*., 2010) [68]. Existing proteins are removed by filtration procedures after fermentation. Lactate is biologically converted to sodium hydroxide and lactic acid by bipolar electrodialysis.

To obtain desirable mechanical, chemical, and biological properties similar to petroleum-based polymers, a number of PLA-based technologies have recently been created. In the past few years, physical and/or chemical modifications of PLA were required to give it the desired consumer applications (Moustafa *et al*., 2017; Nazrin *et al*., 2020; Niu *et al*., 2018) [67, 70, 71]. A growing field of study involves creating ecologically friendly or "green" materials by combining them with other fibres and polymers, such as natural fibre reinforced polymer composites. In addition, the formation of PLA-based nanocomposites by variety of different nanostructures for biomedical and industrial biotechnological applications is a valuable approach not only towards induction of desired functionality but also help in the reduction of experimental cost (Bilal *et al*., 2020a) [14]; (Nazrin *et al*., 2020) [70].

Polyhydroxyalkanoates

PHAs, or polyhydroxyalkanoates, are a large class of biobased polymers. PHAs are also capable of being thermally converted into PLA and are produced from renewable raw materials (such as fatty acids, maltose, and glucose) using a variety of microorganisms (Kawaguchi *et al*., 2016) [50]. Polymers with different building blocks and their various qualities can be produced depending on the choice of microbe, carbon source, additives, and circumstances offered (Keenan *et al*., 2006) [51]. PHAs of various sorts, such as polyhydro Xybutyrate and its copolymer 3-hydroXybutyrate co-3-hydroXyvalerate, have been developed. Their applications span the textile and medical implant industries as well as the packaging industry. PHAs have not been widely used as bioplastics, and their expensive production and recovery processes may be the reason why. For the manufacturing of PHA, researchers are looking for an alternative with affordable feedstocks. As an illustration, hemicellulose-containing raw materials derived from wood that may be employed for the production of bacterial PHAs (Asgher *et al*., 2020a, 2020b; Silva *et al*., 2007) [5, 6, 90] are used.

Exopolysaccharides

Exopolysaccharides (EPS) are complex biopolymers that are primarily composed of carbohydrates and produced by a variety of microbial species, including bacteria (both gram-positive and gram-negative), fungi, and blue-green algae. They are secreted outside the cell wall. EPS comes in a variety of forms, including alginate, glucans, dextrin, Xanthan, Levan, and others. Kefiran is an advantageous kind of EPS compared to other kinds since it is water soluble and biodegradable (Piermaria *et al*., 2009) [80]. Additionally, its uses as an emulsifier, stabiliser, and gelling agent in the food industry are extensively researched (Piermaria *et al*., 2008) [79]. Due to their novel properties, such as biocompatibility, biodegradability, safety, emulsifying and stabilising effects, and excellent water vapour permeability and mechanical characteristics, kefiran-based films are attracting a lot of scientific attention (Junior *et al*., 2020); (Moradi & Kalanpour, 2019) [65]. Additionally, edible plasticizers, such as glycerol, can be effectively synthesised to create kefiran-based films bioplastics, which have excellent visual qualities (Ghasemlou *et al*., 2011) [33]; (Hassan *et al*., 2019) [38]. So, the creation of kefiran-based films may result in useful, eco-friendly coatings and packaging materials with enhanced properties.

Protein-based polymers

Collagen and gelatin

Animal sources are used to make both collagen and gelatin. The protein that is most prevalent in nature is collagen (Fratzl, 2008) [31]. About 20-25% of an animal's total body mass is made up of it. While gelatin is a denatured collagen derivative made up of numerous polypeptides and proteins, its structure is made up of three cross-linked-chains. Collagen-based bioplastics are created by the extrusion process and have a variety of uses (Oechsle *et al*., 2017) [73], whereas gelatin films must be produced through a wet process including the creation of a film-forming solution. Hydrolyzed collagen films have been found to exhibit exceptional tensile strength (Fadini *et al*., 2013) [26], one of the mechanical features of collagen-based bioplastic films. The poor mechanical and barrier qualities of gelatin films, however, demonstrate their hydrophilic nature (Ciannamea *et al*., 2018) [19].

Wheat gluten films

By intensively extruding plasticized wheat gluten, followed by compression and moulding, bioplastic films may be created (Zubelda *et al*., 2015) [102]. The synthesis of hydrophobic, hydrogen, and disulfide contacts occurs during film formation. Sulfhydryl groups help disulfide bonds stay stable (Sharma *et al*., 2017) [89]. Heat causes the polymer to denaturize and the inherent hydrophobic and disulfide groups to break down. By again oxidising gluten, additional disulfide bonds are created during drying.

Soy protein films

In order to create bioplastic sheets for packaging purposes, soy proteins are also used in this process. Soy protein-based films are more transparent, flexible, smooth, and affordable than other protein-based bioplastics (Otoni *et al*., 2016) [75]. Additionally, they demonstrate effective oxygen barrier properties at low moisture levels (Denavi *et al*., 2009) [23]. The main drawbacks of employing these films over low density polyethylene (LDPE) are their lower mechanical strength, lack of heat stability, and allergenicity. On stainless steel plates at a high temperature, soy protein isolate aqueous solution also has the ability to produce films. Other protein-based raw materials, such as pea protein, canola protein, pumpkin oil cake, pistachio globulin protein, etc., have also been reported to form films by a number of scientists (Acquah *et al*., 2020; Popovi *et al*., 2012; Umaraw & Verma, 2017; Zhang *et al*., 2018) [1, 82, 96, 103].

Films made of whey protein

Whey protein has remarkable film-forming and functional properties. Essential oils and lipids have been demonstrated to enhance the water barrier and other functional aspects of whey-based films (Bahram *et al*., 2014; Seydim & Sarikus, 2006) [10, 88]. To create packaging material with the correct properties and usefulness, it is vital to determine how different biopolymers interact throughout the coatings development process (Perez-Gago & Krochta, 2001) [78]. Whey protein isolate was used to create edible films that were then plasticized using glycerol.

Biobased packaging materials processing

A multistep process is used to create biobased packaging materials, such as (i) breaking down intermolecular links, (ii) creating new molecular arrangements, and (iii) using the newly created linkages to create 3D polymeric networks (Galic *et al*., 2011) [32]. According on processing conditions and the geometry of the polymer (i.e., length, breadth, and ratio), new molecular linkages can be formed (Ballesteros *et al*., 2018; Galic *et al*., 2011) [32]. Hydrophobic, electrostatic, covalent, and H-bonding interactions stabilize freshly created films (Liu *et al*., 2019; Zubair & Ullah, 2020) [58, 101]. For the creation of biobased plastic materials, two main processing approaches, namely (i) wet processing and (ii) dry processing, have frequently been documented. Wet processing depends on dissolution, the type of solvent used, and the solvent's pH, which can change the polymer's confirmation. Dry processing relies on the thermoplastic properties of polymers, in which thermo-mechanical treatment results in the initiation of the sulfhydryl/disulfide conversion reaction. The procedures utilised to create biobased polymeric products are depicted in Fig. 3.

Wet processing

The creation of biobased plastics from renewable resources, such as lipids, proteins, and carbohydrates, has frequently employed casting, continuous spreading, or wet processing methods (Fig. 3A). Biopolymer dissolving in a suitable solvent is necessary for wet processing. Romero, and Guerrero (2017) [28], a number of substances, such as antibacterial agents, cross-linking agents, micro/nanostructures, antioxidants, plasticizers, and fillers, are employed as additions to bioplastic films. The casting of the film-forming solution and the solvent evaporation can be used to classify this technique. In order to produce a smoother and more flexible material, the use of plasticizer is effective (Lin & Krochta, 2003; Sanyang *et al*., 2016) [57, 87]. Wet processing improves the mechanical properties of bioplastic films, which is helpful for the packaging industry (Farris *et al*., 2009) [27].

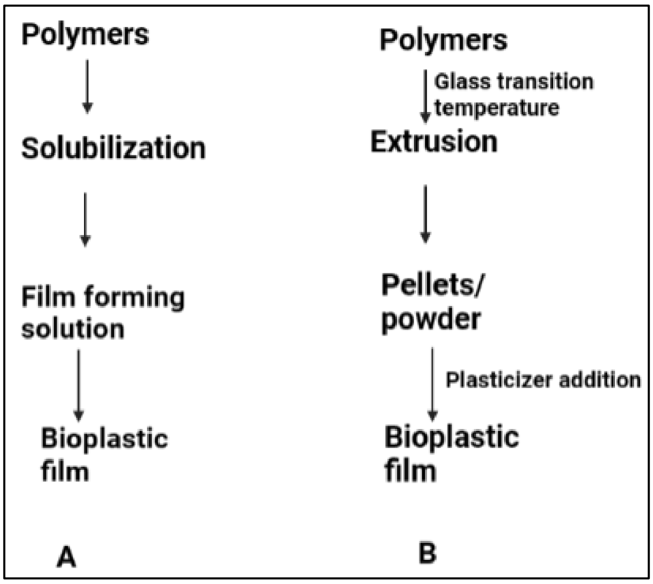

Fig 3: (A) Wet processing (B) dry processing for the development of bioplastic films

Dry processing

While dry processing relies on the thermoplastic properties of polymers, which play a key role in the creation of packing material. The hypothesis of the glass transition, which states that a glassy substance transforms into a semi-solid state at a specific temperature, can be connected to this process. This transitional (semi-solid) state fundamentally changes the mechanical and physicochemical properties of polymers by causing molecular mobility and disorderness. Intermolecular connections between proteins molecules break, leading to denaturation, and new linkages and bonds develop, leading to changes in material characteristics (Khwaldia *et al*., 2004) [52]. Different methods, such as (i) extrusion and (ii) thermal processing, can be used to create polymer-based packaging (Fig. 3B). Extrusion is used for making small adjustments and mixing, while heat processing is utilized to create the finished product. Both procedures can be employed separately or together.

Strengthening bioplastic films

Antioxidant-capable bioactive reinforcements

The need for safe and healthier meals among consumers has prompted scientists to create new preservation techniques. A number of methods have been used to reduce lipid oxidation, such as directly incorporating antioxidants into food or packaging (Domnguez *et al.*, 2018; Kusznierewicz *et al.*, 2020) [25, 53]. Without oxygen, food items like fresh red meat or fish goods cannot be packaged. Directly adding antioxidant material to food has drawbacks since the protection ceases when the active chemicals are chemically absorbed and the food starts to degrade at an accelerated pace (Navikaite-Snipaitiene *et al.*, 2018) [69]. Antioxidant packaging is currently being developed to increase the stability of foods that are oxidation-sensitive. This packaging is based on the addition of antioxidant to the packaging material. Natural antioxidants, especially plant essential oils, have been extensively researched for this purpose (Table 1). Excellent antioxidant and antibacterial capabilities are present in essential oils (Deng *et al.*, 2020; Heredia-Guerrero *et al.*, 2018) [24, 39]. However, due to their stronger flavour, essential oils cannot be used as food preservatives (Zeng *et al*., 2015) [99]. To solve this issue, bioactive compounds are used to create edible films with the appropriate functionality (Vilela *et al*., 2018) [97].

Table 1: Raw materials for bioplastic/biocomposite films development with their origin, active reinforcements, advantages and disadvantages.

Raw Material	Origin	Active Reinforcements	Advantages	Disadvantages	References
Starch-based	Corn, wheat, potatoes	Natural fibers	Renewability, biodegradability, compostability	Brittleness, poor moisture resistance	(Onyeaka *et al*., 2022) [74]; (Ben *et al*., 2022) [11]
Cellulose-based	Wood, cotton, hemp	Natural fibers, nano-particles	Renewability, biodegradability	Expensive, chemical treatments may be required	(Yuvraj *et al*., 2021) [98].
Polyhydroxyalkanoates (PHA)	Bacterial fermentation of plant oils, sugars	Natural fibers, nano-particles	Biodegradability, renewability	Expensive, specialized equipment may be required	(Liu *et al*., 2021) [59]; (Obruca *et al*., 2020) [72]
Polylactic acid (PLA)	Corn starch, sugar cane	Natural fibers, nano-particles	Renewability, biodegradability, compostability	Brittleness, poor moisture resistance	(Yuvraj *et al*., 2021) [98]; (Li *et al*., 2020) [56]
Soy protein-based	Soy protein	Natural fibers	Renewability, biodegradability	Expensive, poor moisture resistance	(Otoni *et al*., 2016) [75]; (Denavi *et al*., 2009) [23]

Essential oils have received a lot of press in recent years for their amazing strengthening of bio-based and biodegradable coatings and films. Because of their lipid composition, they are projected to help in the lowering of water uptake qualities. Additionally, by offering antimicrobial and antioxidant properties, they aid in the improvement of mechanical properties of polymeric films, such as optical structure and tensile strength (Iamareet *et al*., 2018; Moradi *et al*., 2016) [42, 66]. The phenolic content of biopolymeric films is investigated using the Foline-Ciocalteau (F.C assay) method. The 2,2-diphenyl-1-picrylhydrazyl (DPPH) radical is a traditional synthetic radical used to measure the activity of phenolic antioxidants. By using a spectrophotometer at 515 nm, the disappearance of the DPPH radical caused by the antioxidant is measured until constant absorbance is reached. Radicals can interact with other radicals, such as alkyl, and the estimate curve is not linear, showing a range of DPPH/antioxidant ratios, which limits the utility of the DPPH activity assay (Frankel & Meyer, 2000) [30]. As the concentration of green tea extract was increased, the antioxidant capacity of polymeric films also increased. Green tea extract has been incorporated into chitosan films, which demonstrated good antioxidant capacity (Siripatrawan & Noipha, 2012) [91]. Several researchers have described the ferric cyanide reducing assay (Huang *et al*., 2011) [40]. According to results, the higher the absorbance, the higher the reducing power will be for ascorbic acid in bio-plastic. The addition of thyme oil has enhanced the reduction strength of hake protein-based films (Pires *et al.*, 2011) [104]. Another study investigated the capacity of several essential oils to reduce the amount of protein in hake and discovered that coriander oil was the most effective of all (Pires *et al.*, 2013) [81]. The use of Zataria multiflora oil in the chitosan-based films was favorably connected with antioxidant action (Moradi *et al.* (2016) [66]. The ability of antioxidants to convert Fe+3 into Fe+2 at an acidic pH is directly correlated with their ferric-reducing antioxidant power (FRAP). By combining olive leaf extract and -tocopherol with polystyrene, antioxidant-capable bioplastic films have also been created (Marcos *et al*., 2014) [61]. With the use of red grape extract achieved by compression moulding as opposed to casting, soy protein films demonstrated increased antioxidant capacity (Ciannamea *et al*., 2016) [20]. This demonstrates the significant impact of the film's acquisition method on the matrix release attributes and, ultimately, the film's activity. After being dissolved in an appropriate solvent, the film extract is employed by solidification, crushing, and mixing. The abundance of phenolic compounds often correlates with the bioplastic films' ability to resist oxidation.

Bio-based materials with antibacterial properties

To prevent microorganisms from growing on food goods, antimicrobial packaging involves incorporating antimicrobial chemicals into the packaging materials (Han, 2003, 2005) [36, 37]. Because pathogenic microbes can't grow, this kind of packaging improves food quality, food safety, and shelf life

(Lavoine *et al*., 2014) [55]. The consumer's preference for food products that are fresh, minimally processed, and additive-free also increased the appeal of the antimicrobial packaging (Moon & Rhee, 2016) [64]. The antimicrobial substances used for preservation are created chemically or obtained from the biomass of animals, plants, and microbes (Table 1). These could consist of chitosan, enzymes, essential oils, and pure plant extracts (Pereira *et al*., 2015; Qamar *et al*., 2020) [105, 83]. The majority of bioactive chemicals, including phenolic compounds, terpenoids, and others, that are typically referred to as antimicrobial agents are found in essential oils that are collected from various plants (Ruiz-Navajas *et al*., 2013) [86]. Essential oils affect microbial cells through a number of different processes, including disruption of enzyme structures, phospholipid bilayer cell membrane damage, and weakened microbe genetic composition. (Kumar *et al*., 2018) Fig. 4 illustrates active packaging material based on bionanocomposites with outstanding preservation effect against UV-irradiation and food borne pathogens.

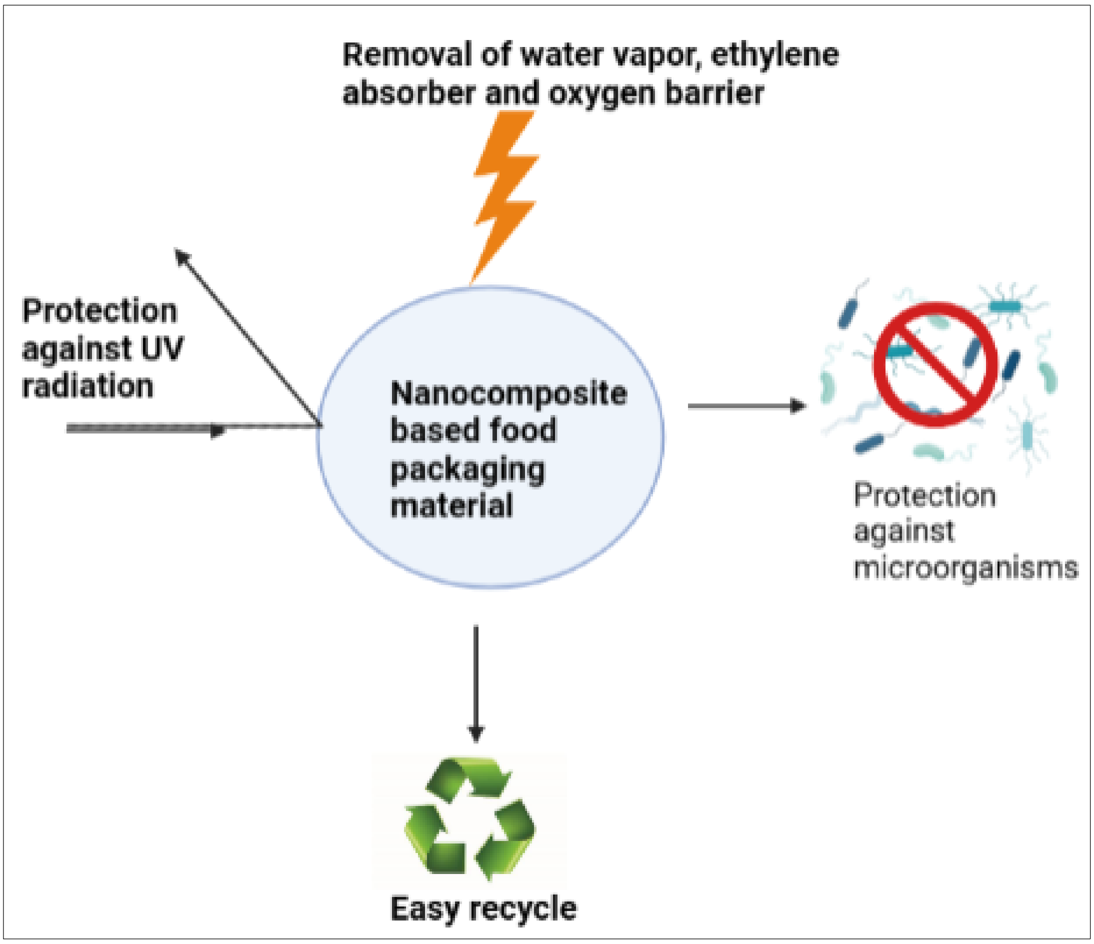

Fig 4: Bio-nanocomposites are the basis for active food packaging that has superior pathogen and UV protection.

The chemical molecule known as azinobis (3-ethylbenzothiazoline-6-sulfonic acid), also known as ABTS, is colourless. With the aid of ethanol, the solution was diluted, the absorbance at 734 nm was determined, and a mixture was created using an antioxidant sample. The calibration curve is used to compare the absorbance decrease after 6 min of incubation. By adding citrus essential oils, the antioxidant capacity of gelatin films has been tested. In addition, it has been determined that lemon possesses outstanding antioxidative qualities (Tongnuanchan *et al*., 2012) [94]. Bioplastic has also been made with other biobased components.

Bioplastic packaging's capacity to be decomposed

According to ASTM-D6400, any material that degrades biologically at a pace similar to other recognised compostable compounds qualifies as a compostable material. Therefore, according to ASTM standards from 2004 only materials that can degrade biologically in a composting environment can be designated as "compostable." Not all materials that degrade by microorganisms can be composted. Only a small percentage of plastic packaging and papers are compostable because they degrade naturally over time. Microbes may use biopolymers including cellulose, lignin, and starch-based polymers directly. Enzymatic degradation causes a reduction in molecular weight in the environment, or outside the microbial cell (Thakur *et al*., 2018) [93]. Small segments are created by enzymatic cleavage, and the segment that is sufficiently small compared to the microbial cell is transferred inside and consumed. Hydrolysis, which causes polymers to randomly break and ultimately lose molecular weight, can speed up the biodegradation of these polymers. According to (Emadian *et al*., 2017) [106], the resultant low molecular weight molecules are more susceptible to enzyme-based breakdown (Fig. 5).

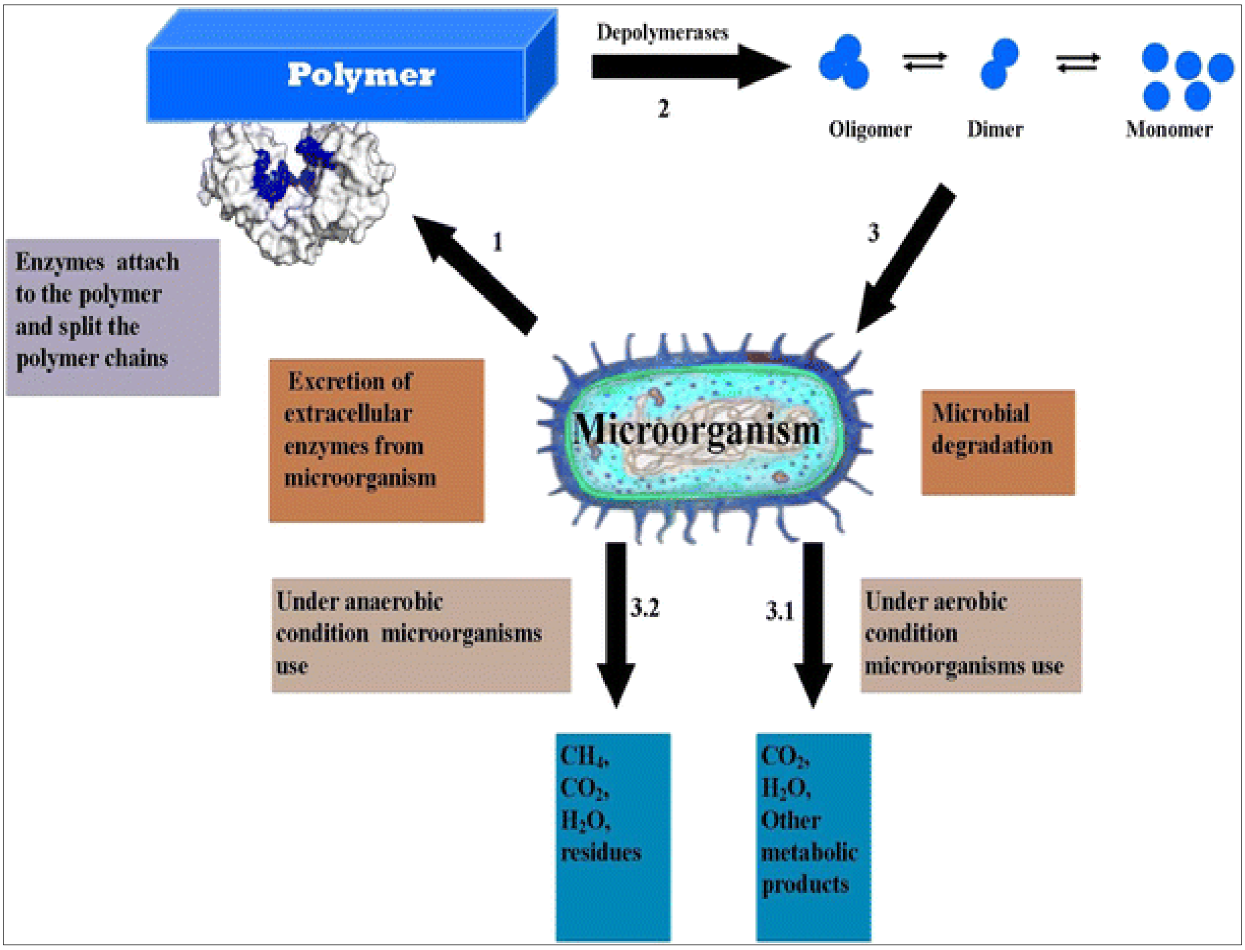

Fig 5: General degradation mechanism of plastic products via micro-organisms.

Another form of polyester that has previously been covered in the preceding section is bacterial polyhydroxyalkanoates. Various bacterial species synthesize these as backup materials when faced with nutrient-limited conditions and an abundance of carbon (Raza *et al*., 2018) [84]. Vinyl polymers with carbon backbones, such as polyethylene, polypropylene, and polyvinylchloride, are often resistant to biodegradation and hydrolysis. One exception is polyvinyl alcohol (PVA), which is biodegradable due to its high hydrolysis power. Enzymatic oxidation of the hydroxyl group produces carbonyl groups, which eventually induce cleavage in the polymer chain and reduce molecular weight (Halima, 2016) [35].

In hetero polymers, the backbone contains elements besides carbon, such nitrogen and oxygen. Because of such atoms, polymers are more prone to hydrolysis, which in turn makes them more prone to biodegradation (Asina *et al*., 2016) [7]. Synthetic hetero polymers like nylons, polyester, and polycarbonate don't degrade much when exposed to the environment. Polycaprolactone (PCL), polyglycolic acid (PGA), and PLA are now well-known hetero polymers. Bacterial polyester, such as PHAs, can be researched within this area as well. Elevated hydrolysis rates create more potential targets for microbe assault, which accelerates the rate of biodegradation. Water diffusion rates in polymeric amorphous zones influence polymeric hydrolysis in part (Rowe *et al*., 2016) [85]. Aliphatic polyesters, including PLA, PHA, and PCL, constitute the majority of biodegradable polymers, with bright futures for packaging applications. Due to their similar qualities to petrochemical-based polymers, which are usually used in packaging applications, it also contains polybutylene succinate (PBS), polybutylene adipate-co-terephthalate (PBAT), polybutylene succinate adipate (PBSA), and a few poly-esteramides.

PLA has similar heat stability and processability to polystyrene, the same flavour barrier and grease/oil resistance qualities as PET, and a lower sealing temperature than polyethylene and polypropylene (Auras *et al*., 2004) [9]. These polymers have at least one hydrolyzable link in the form of an ester, carbonate, ether, or amide in their backbone (Göpferich, 1996) [34]. While C-C bonds increase stability, the presence of hydrolysable groups in the polymer's backbone sharply increases susceptibility to microbial degradation (Kale *et al*., 2007) [49]. This is because it not only increases the susceptibility of the polymer to hydrolysis but also makes it more flexible so that polymer chains can easily be arranged to fit into enzyme active sites. While non-enzymatic breakdown can happen anywhere in the polymer's bulk due to water diffusion through the polymer's amorphous regions, degradation by microorganisms via enzymes occurs at the polymer surface.

Conclusion

The use of bioplastic films in food packaging technologies offers a cutting-edge biodegradable and environmentally friendly replacement for polymers derived from petrochemicals. This can address the issue of waste buildup brought on by petrochemical-based plastics' inability to degrade naturally. The mechanical and barrier qualities described for natural-based biodegradable polymer films differ from those of the majority of petroleum-based polymers used as food industry packaging materials. However, by incorporating additional biopolymers into composites or blends, these poor-quality films are becoming better. The use of biopolymers is greatly influenced by erosion mechanisms. For instance, if a polymeric material is used as a drug delivery system, the active ingredient will release the drug more quickly if the polymer's surface is subjected to surface erosion. On the other hand, if the drug is released more slowly, a polymer that experiences bulk erosion is more appropriate because the active ingredient can release over a longer period of time. The potential use of bioplastic films on meals has generated a lot of discussion. The efficiency of bio-polymeric films depends on the polymers and other materials used as additives to boost functional qualities; hence efforts are concentrated on developing the right mixture of components used. It will need more work to provide bioplastics characteristics similar to those of polymers made from petroleum. Future research will need to go into greater detail in order to fully comprehend, be aware of, and take into account the possibility that bio-based plastic will eventually replace synthetic plastics.

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