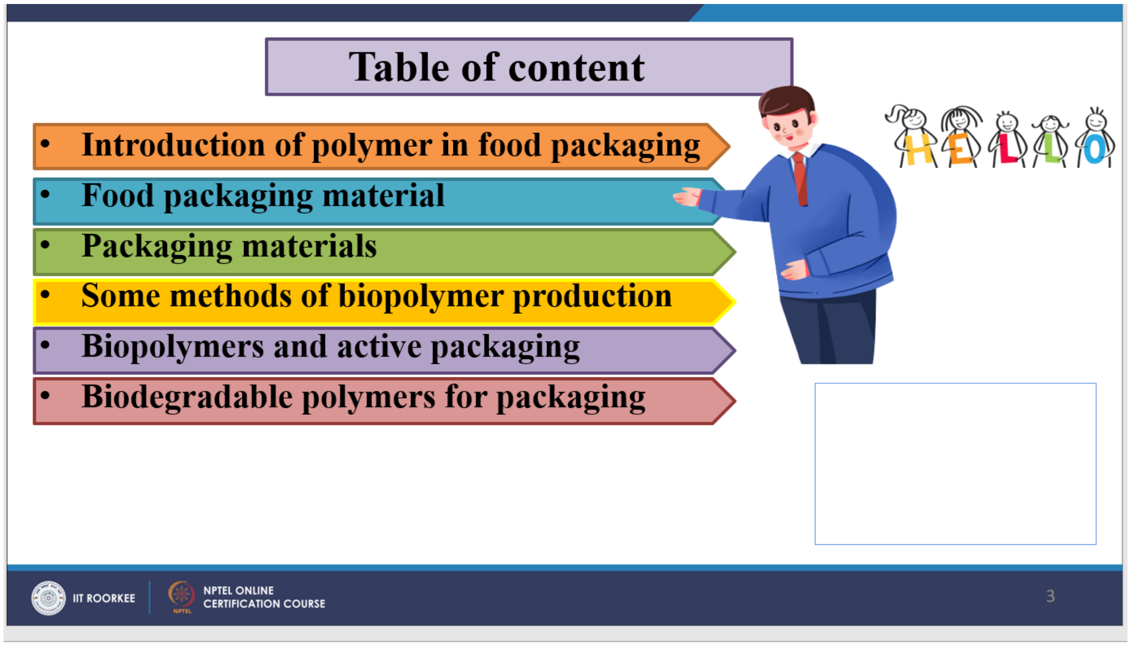
# Lecture 60: Polymer applications in different fields: Polymer and food packaging

In the previous lecture we covered the polymers application in cosmetics. We discussed about the polymer surfactant interaction, then we discussed about the polysaccharide based polymers, then how we are using the polymers in different type of cosmetic industries. Then we discussed the protein modification schemes in cosmetics and discussed different examples related to cosmetics.

In the context of food packaging, we explore different types of food packaging materials, methods of biopolymer production, and the use of biopolymers in active and biodegradable packaging. When it comes to packaging, whether for food items or other products, the material used creates a barrier between the atmosphere and the enclosed product. This barrier must possess specific properties, ensuring non-interaction with the product and non-reactivity with the environment. Therefore, the development and affinity of these packaging materials play a crucial role, especially considering the diverse array of products requiring packaging.



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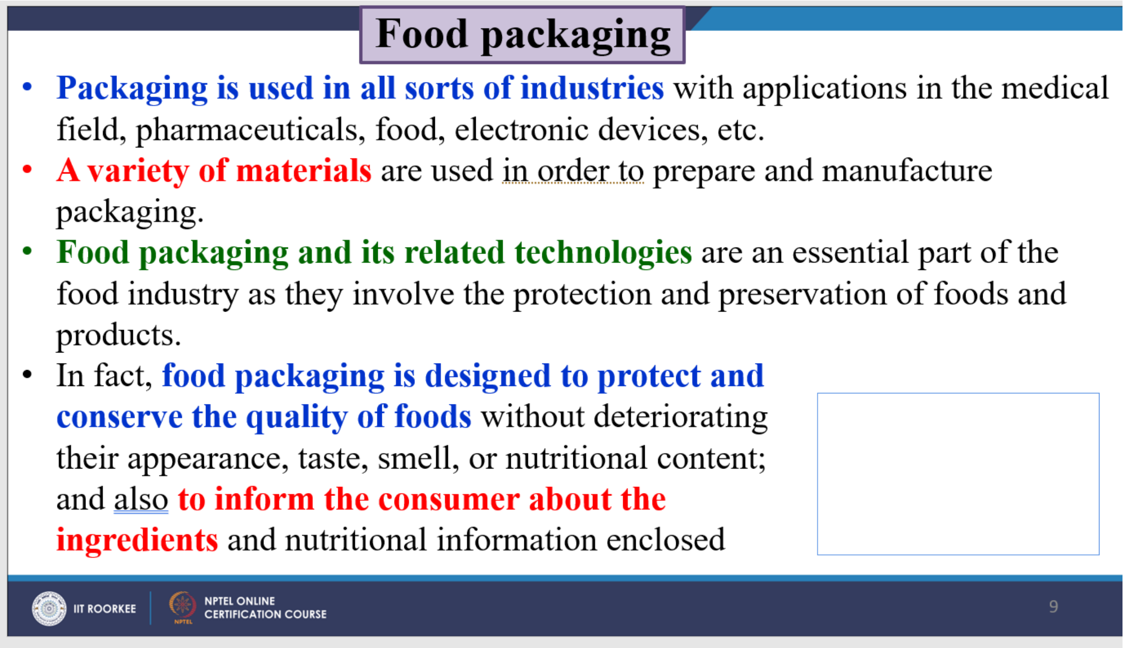
Our exploration will delve into the complexities of designing packaging materials that meet these criteria, ensuring the preservation and safety of various products. The aspect of packaging is crucial across various segments, especially in the realm of food products. In today's context, with a growing emphasis on hygiene and safety, packaging plays a pivotal role. The packaging of food items is particularly critical, as even a slight mistake or deficiency can lead to problems. Therefore, understanding the different strategies for creating effective and efficient food packaging solutions using polymers is essential.

The significance of packaging extends beyond mere protection; it is increasingly becoming a key factor in the marketing value of products. On the shelf, food items compete for attention from potential buyers, and the packaging is a key element in creating a positive consumer experience. Attractive packaging and presentation contribute to a positive attitude from customers. A well-designed package, incorporating graphics and informative labels, enhances the overall customer experience.



## Food packaging

- **Packaging is used in all sorts of industries** with applications in the medical field, pharmaceuticals, food, electronic devices, etc.
- **A variety of materials** are used in order to prepare and manufacture packaging.
- **Food packaging and its related technologies** are an essential part of the food industry as they involve the protection and preservation of foods and products.
- In fact, **food packaging is designed to protect and conserve the quality of foods** without deteriorating their appearance, taste, smell, or nutritional content; and also **to inform the consumer about the ingredients** and nutritional information enclosed

From an engineering perspective, considerations such as the type of dyes used, printability, and material affinity become crucial in achieving the desired packaging design. Interestingly, the design of packaging can sometimes make unhealthy food products more attractive to consumers than healthy ones in poorly designed packages. Therefore, proper design considerations are imperative for all types of packaging materials.

Modern industries view packaging not only as a means to protect and cover products but also as a tool for advertising and conveying their brand to customers. In the food industry, one of the most commonly used materials for packaging is petroleum plastic or synthetic polymers. The choice of packaging material has implications for both product protection and its presentation to consumers, making it a multifaceted aspect of the overall product experience.

In the current market scenario, synthetic polymers, including polyethylene terephthalate, low and high-density polyethylene (LDPE or HDPE), polypropylene, polyvinyl chloride, polystyrene, and polylactic acids, are extensively used for packaging various food items. However, the environmental impact of the disposal of these synthetic polymers has led to increased interest in sustainability from scientists, researchers, and environmentalists.

The sustainability aspect has become a significant concern, especially considering the environmental problems associated with the improper disposal of packaging materials. The focus on sustainability has gained momentum, particularly with the global movement against single-use plastics, which are widely used for packaging various commodities. The non-biodegradable nature of these plastics poses significant environmental challenges.

As a response to these concerns, biodegradable polymers, or biopolymers, have gained attention as an environmentally friendly substitute for synthetic polymers. Biopolymers are designed to be biodegradable, making them a more sustainable choice. They are derived from agro-industrial waste or biomass, utilizing renewable raw materials. The use of biopolymers addresses the issues related to the disposal of packaging materials, contributing to a more environmentally conscious approach in the field of food packaging.

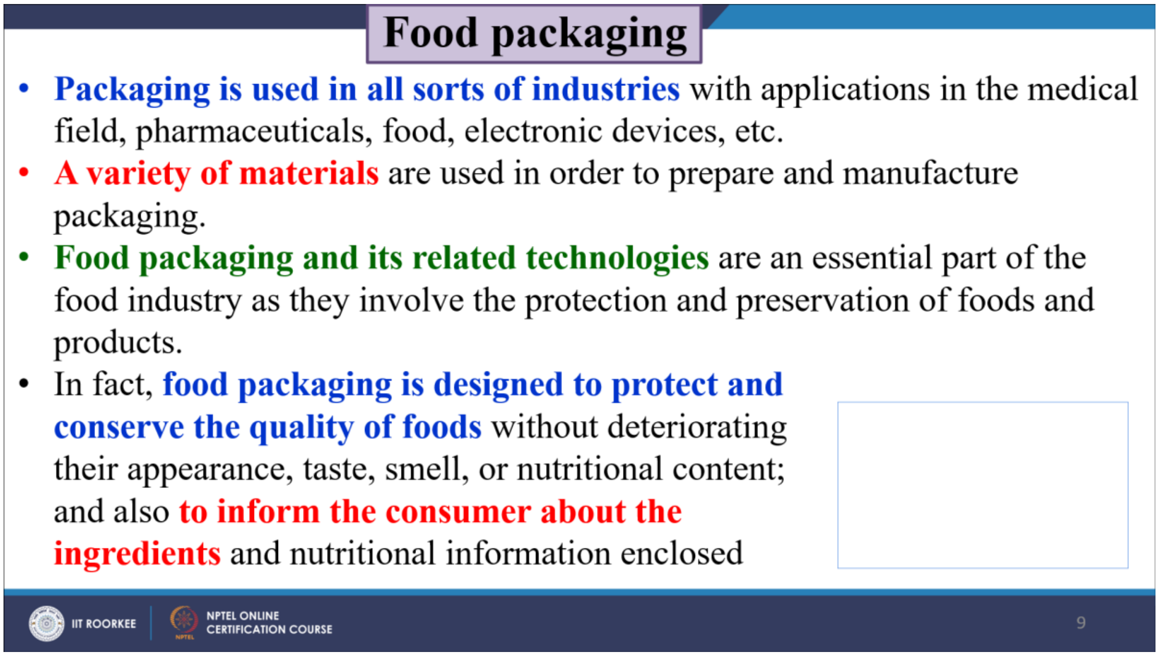
The use of renewable raw materials in biopolymers is desirable due to their availability and cost-effectiveness. Biopolymer materials can be designed to be edible, incorporating additives such as antioxidants or antimicrobial agents, which is crucial for food packaging. Additionally, these biopolymer materials can be formed as composites and laminates to enhance their properties.

Considering the primary purpose of food packaging, which is to preserve the quality of food products and prevent the escape of ingredients or the entry of atmospheric elements, the health and safety aspects of packaging materials are critical. The potential for migration of components from packaging materials into the food raises concerns about contamination, making it important to carefully choose materials.

Certain additives like antioxidant stabilizers and plasticizers used in packaging materials, as well as monomers, fillers, and dyes, pose potential risks of unintended transfer into the food. Scientists have identified various migrant compounds, including acetyl tributyl citrate, normal alkane tributyl aconitrate, and phthalates, in plastic samples. Many of these substances are not authorized for consumption by health and safety organizations, highlighting the importance of scrutinizing packaging materials.

As biopolymers progressively substitute common synthetic polymers derived from oil derivatives, they gain momentum. However, it's crucial to acknowledge the migration risk from bioplastics into food, which remains an inevitable and potential source of contamination. This consideration underscores the need for thorough evaluation and regulation to ensure the safety of biopolymer-based food packaging.

The use of bioplastics, made from natural ingredients, reduces the risk of food safety concerns as natural ingredients typically do not pose severe threats to food and consumer safety. Now, let's delve into the broader context of food packaging.



## Food packaging

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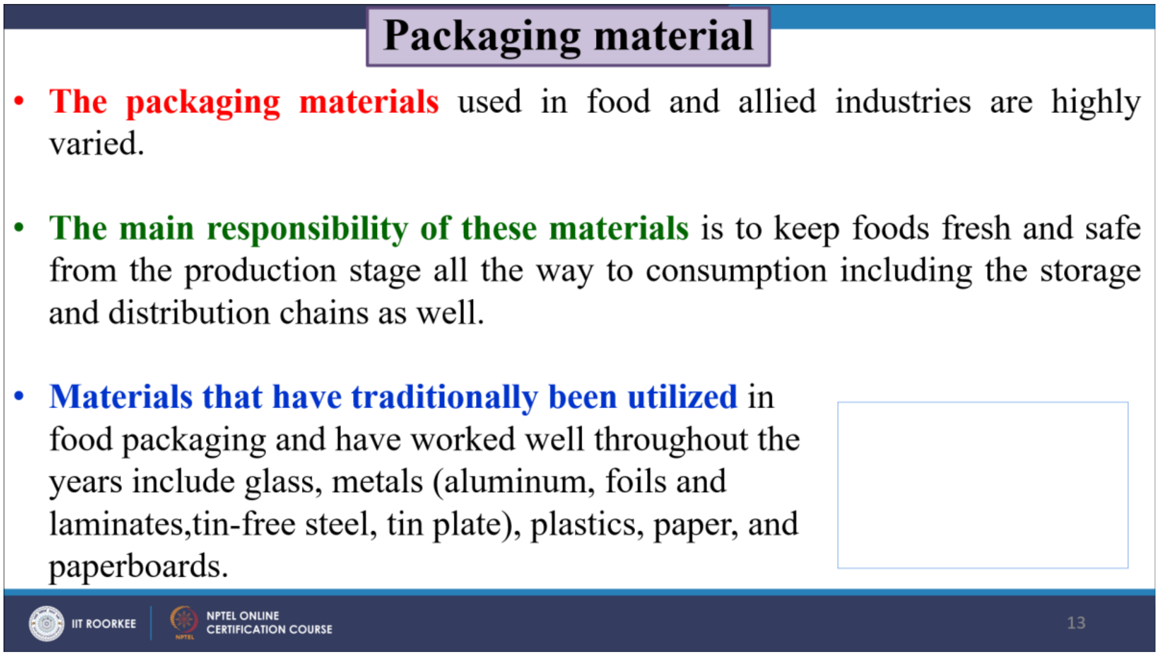
Packaging plays a crucial role across various industries, including medical, pharmaceuticals, food, and electronic devices, utilizing a variety of materials for preparation and manufacturing. In the food industry, packaging and related technologies are essential for protecting and preserving food products, ensuring their quality is maintained in terms of appearance, taste, smell, and nutritional content. Additionally, food packaging serves to inform consumers about the ingredients and nutritional information, adhering to regulatory guidelines.

Consumers have the right to know the contents of each package, and product information is mandated to be printed on the packaging. With consumers becoming more discerning, there is an increasing focus on creating attractive marketing solutions and improving packaging design for more ergonomic and effective products. As consumer demand rises, producers face challenges in maintaining product quality and addressing potential threats.

The functions of packaging are multifaceted, with some experts identifying four key functions: containment, convenience, protection, and communication. While the fundamental functions of packaging are logical and straightforward, they encompass aspects such as design, attractiveness, and eco-friendliness. Consequently, when designing suitable and attractive packaging materials, it's crucial to consider these integral functions to meet both consumer expectations and regulatory requirements.

In the context of convenience, packaging should prioritize user-friendliness, ease of opening, resealability, and ease of handling, carrying, recycling, and disposal. Various experts have different opinions on packaging functions, with some emphasizing authenticity, meaning, and the package's ability to convey brand image to consumers as three major classifications for successful packaging design.

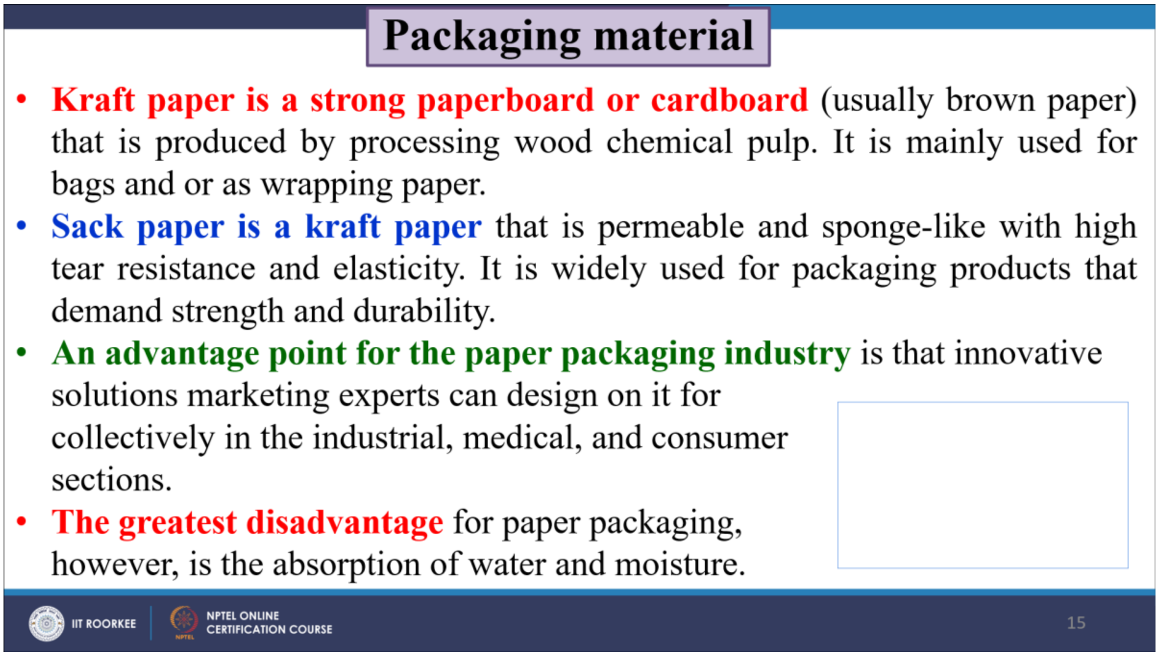
Now, let's explore the diverse range of packaging materials used in the food and allied industries. These materials play a crucial role in keeping food fresh and safe from production to consumption, encompassing storage and distribution chains while maintaining their original condition. Traditional packaging materials that have proven effective over the years include glass, metal, aluminum foils and laminates, tin, free steel, tin plates, plastics, papers, and paperboards. Both flexible and rigid synthetic packaging materials are commonly employed in the food industry. Throughout history, glass and paper have been the most common materials used to protect and cover goods.



**Packaging material**

- **The packaging materials** used in food and allied industries are highly varied.
- **The main responsibility of these materials** is to keep foods fresh and safe from the production stage all the way to consumption including the storage and distribution chains as well.
- **Materials that have traditionally been utilized** in food packaging and have worked well throughout the years include glass, metals (aluminum, foils and laminates,tin-free steel, tin plate), plastics, paper, and paperboards.

Glass containers, such as glass bottles, constitute one of the oldest packaging groups and are still utilized in various applications. They are well-suited for containing liquids due to their non-permeable barrier, but a significant disadvantage is their fragility. Kraft paper, which is a robust paperboard or cardboard, is commonly used for bags or wrapping paper. Sack paper, a type of Kraft paper, is permeable and sponge-like, offering high tear resistance and elasticity. It is often used for packaging products that require strength and durability.



### Packaging material

- **Kraft paper is a strong paperboard or cardboard** (usually brown paper) that is produced by processing wood chemical pulp. It is mainly used for bags and or as wrapping paper.
- **Sack paper is a kraft paper** that is permeable and sponge-like with high tear resistance and elasticity. It is widely used for packaging products that demand strength and durability.
- **An advantage point for the paper packaging industry** is that innovative solutions marketing experts can design on it for collectively in the industrial, medical, and consumer sections.
- **The greatest disadvantage** for paper packaging, however, is the absorption of water and moisture.

One notable disadvantage of paper packaging is its susceptibility to absorbing water and moisture, making it less suitable for certain types of food packaging where moisture entrapment could lead to microbial activities.

In recent times, the advent of new technologies like three-dimensional (3D) printing has revolutionized packaging materials. 3D printing technology allows for the creation of diverse, high-quality packaging materials. Its application in the packaging industry has brought about changes in various aspects, including the potential for full-color graphics and text for labels. 3D printing involves using computer-based control to create layers and coatings of materials, offering convenience in packaging design.

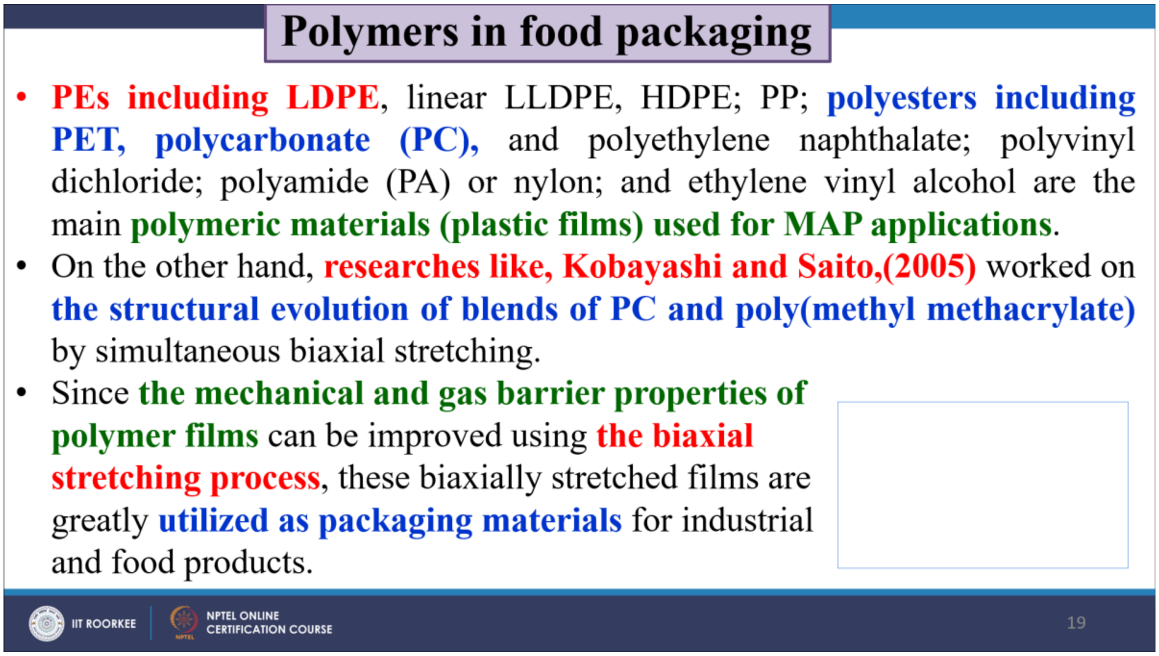
Plastics or polymers are widely employed in the packaging industry due to their versatility in molding and transforming. Various plastics, each with unique properties, offer a range of packaging options, including diverse shapes, sizes, weights, functions, and printing capabilities. Polymers have become integral to modern life, playing a role in various everyday items.

The favorable properties of plastics, such as stability, resilience, and ease of production, make them preferred for packaging. Their lightweight nature, malleability, and flexibility allow for shaping through processes like blowing, extrusion, co-extrusion, casting, and lamination. This versatility enables the creation of unique packaging objects tailored to fit specific containers.

Plastics are particularly useful in food packaging due to their barrier properties, helping to maintain the freshness of products by preventing moisture and contaminants from entering or leaving. This results in increased shelf life and reduced chances of contamination, benefiting both consumers and the environment.

Polymer packaging can contribute to environmental sustainability by reducing waste. Preserving foods for longer periods with polymer packaging helps minimize food spoilage and waste. Researchers have explored various polymers for applications like Modified Atmosphere Packaging (MAP), which involves altering the composition of gases surrounding packaged food to extend shelf life.

Polyethylene, including low-density polyethylene (LDPE), linear low-density polyethylene (LLDPE), and high-density polyethylene (HDPE), along with polypropylene, polyesters (such as PET), polycarbonates, polyethylene naphthalate, polyvinyl dichloride, polyimide or nylon, and ethylene polyvinyl alcohol, are commonly used in MAP applications. Additionally, researchers have investigated the structural evolution of polymer blends, such as polycarbonate and polymethyl methacrylate, under simultaneous biaxial stretching.

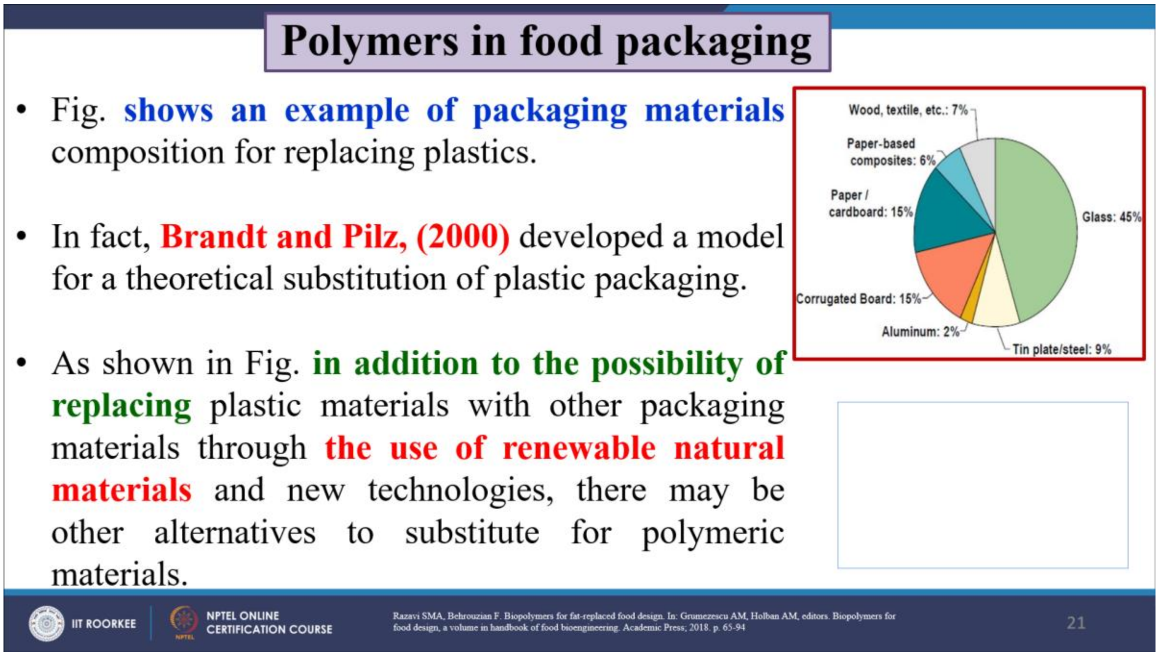


### Polymers in food packaging

- **PEs including LDPE**, linear LLDPE, HDPE; PP; **polyesters including PET, polycarbonate (PC),** and polyethylene naphthalate; polyvinyl dichloride; polyamide (PA) or nylon; and ethylene vinyl alcohol are the main **polymeric materials (plastic films) used for MAP applications**.
- On the other hand, **researches like, Kobayashi and Saito,(2005)** worked on **the structural evolution of blends of PC and poly(methyl methacrylate)** by simultaneous biaxial stretching.
- Since **the mechanical and gas barrier properties of polymer films** can be improved using **the biaxial stretching process**, these biaxially stretched films are greatly **utilized as packaging materials** for industrial and food products.

Biaxial stretching processes have been employed to enhance the mechanical and gas barrier properties of polymer films, making them valuable as packaging materials for both industrial and food products. However, one of the significant challenges associated with plastics is their environmental impact. The production and processing of plastics are energy-intensive, resulting in the emission of greenhouse gases and contributing to global warming. Improper disposal of non-degradable plastics, such as bags, food containers, straws, and bottles, poses a severe threat to the environment, wildlife, and marine life.

To address these issues, there is a growing need to reduce dependence on traditional plastics and explore alternative packaging materials. The figure provided exemplifies various substitutes for plastic packaging materials, including aluminum corrugated board, paper, cardboard, paper-based composites, wood, textiles, and glass. The use of renewable materials and new technologies offers alternatives to polymeric materials.



## Polymers in food packaging

- Fig. **shows an example of packaging materials** composition for replacing plastics.
- In fact, **Brandt and Pilz, (2000)** developed a model for a theoretical substitution of plastic packaging.
- As shown in Fig. **in addition to the possibility of replacing** plastic materials with other packaging materials through **the use of renewable natural materials** and new technologies, there may be other alternatives to substitute for polymeric materials.

Razavi SMA, Behrouzian F. Biopolymers for fat-replaced food design. In: Grumezescu AM, Holban AM, editors. Biopolymers for food design, a volume in handbook of food bioengineering. Academic Press; 2018. p. 65-94

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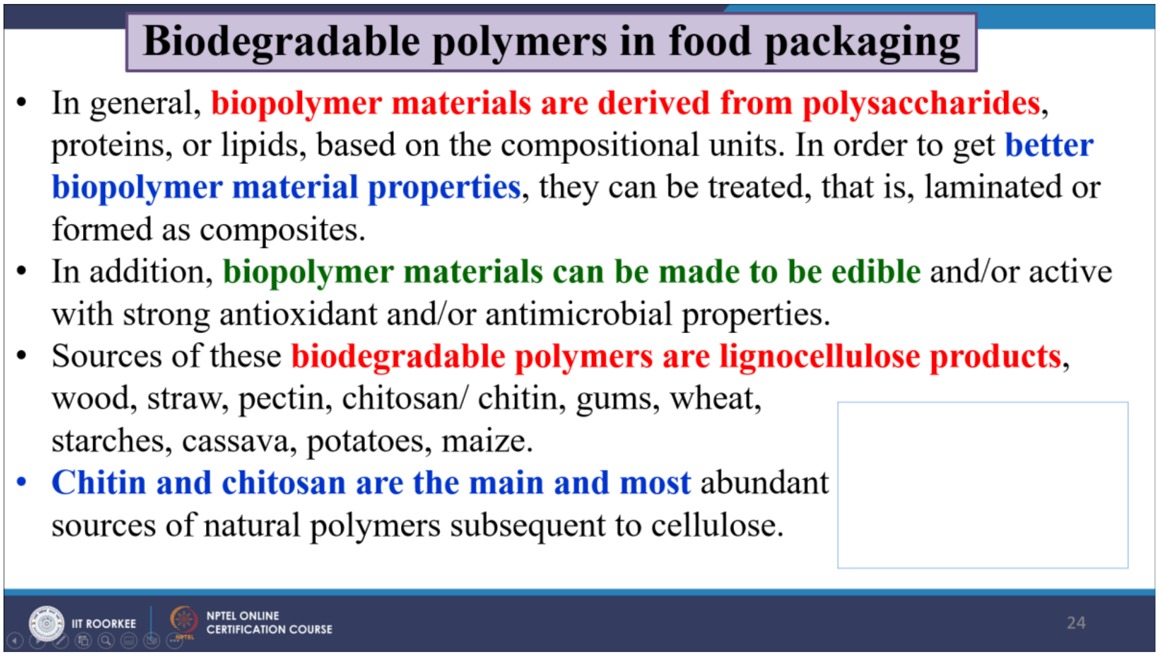
Biodegradable polymers have emerged as a promising solution for more sustainable food packaging. The term "biodegradable" refers to materials that decompose through enzymatic action, either by living organisms or naturally in the atmosphere or soil. The end products of the decomposition process include water, carbon dioxide, and biomass under hydrocarbon and aerobic conditions, and biomass and CH4 under anaerobic conditions. Various biodegradable polymers, such as polybutylene adipate, cotethlylate (PBS), polylactic acid (PLA), and polyhydroxy alkanol starch blends, are being explored for their potential in replacing conventional packaging materials.

It is important to note that a plastic material is considered a bioplastic if it is bio-based, biodegradable, or possesses both properties, as defined by some organizations like the European Bioplastics. This signifies a transition towards materials that are more environmentally friendly and sustainable in the packaging industry.

Bioplastics, currently representing about 1 percent of the approximately 320 million tons of plastic produced annually, are gaining momentum due to increasing demand and the emergence of high-level biopolymer applications and products. The market for bioplastics is continuously growing, leading to ongoing research in various laboratories. Biopolymer materials are generally derived from polysaccharides, proteins, or lipids, and to enhance their properties, they can be treated, laminated, or formed as composites. Additionally, biopolymer materials can be made edible and endowed with strong antioxidant and antimicrobial properties.

The sources of these biodegradable polymers include lignocellulose products, wood, straw, pectin, chitosan, chitin, gums, wheat, starch, cassava, potatoes, and maize. Chitin and chitosan, derived from shells, are significant sources of natural polymers. Other materials like bamboo, wood, recycled paper, bagasse, sugarcane, etc., are used to create bioplastic and paper products. Bioplastics made from plant components, such as hemp oil, soybean oil, and corn starch, are increasingly popular.



## Biodegradable polymers in food packaging

- In general, **biopolymer materials are derived from polysaccharides**, proteins, or lipids, based on the compositional units. In order to get **better biopolymer material properties**, they can be treated, that is, laminated or formed as composites.
- In addition, **biopolymer materials can be made to be edible** and/or active with strong antioxidant and/or antimicrobial properties.
- Sources of these **biodegradable polymers are lignocellulose products**, wood, straw, pectin, chitosan/ chitin, gums, wheat, starches, cassava, potatoes, maize.
- **Chitin and chitosan are the main and most** abundant sources of natural polymers subsequent to cellulose.

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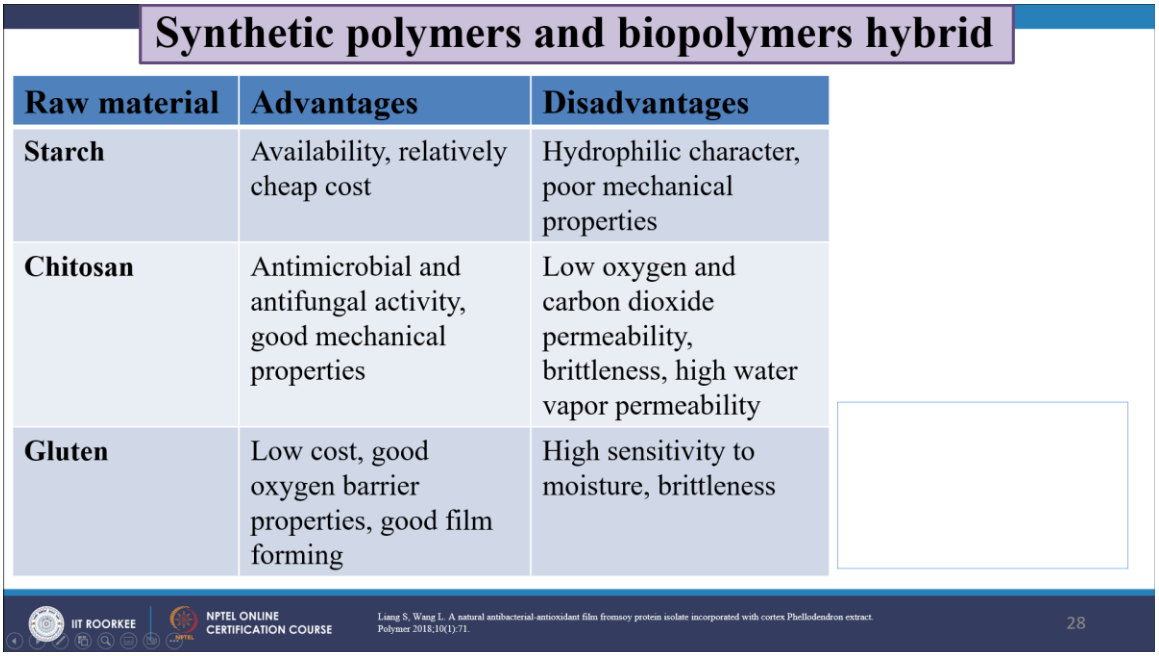
Bagasse, a byproduct of sugarcane processing, has minimal environmental impact, being strong, resistant to deformation, heat, and water, making it suitable for take-away boxes, plates, bowls, and ice cream cups. Bamboo is another plant-based material used for packaging, sourced from renewable resources and known for its compostable and biodegradable nature.

The concept of synthetic polymers and biopolymer hybrids involves combining both natural and synthetic polymers. This approach offers versatility and allows for the creation of materials with enhanced properties and reduced environmental impact. The exploration of hybrid materials represents a promising avenue in the development of sustainable packaging solutions.

Researchers have conducted various studies focusing on the preparation of synthetic polymer and biopolymer hybrids, aiming to reduce the consumption of synthetic polymer materials while enhancing certain properties of biopolymers, such as their mechanical properties. Some studies have explored the substitution of PVC film with biodegradable polymers to preserve meat characteristics like color and inhibit microbial contamination.

One study involved packaging organically raised meats with polystyrene plates using both PVC film and biodegradable polyesters. The results suggested that the biodegradable polymer film could effectively replace PVC film in packaging fresh processed meat. Another study created blown film using modified starch polyethylene, exhibiting superior characteristics compared to common polymers.

However, it's essential to note that achieving complete biodegradability is challenging when using a mixture of synthetic and natural polymers. The study highlights some synthetic polymer and biopolymer hybrids with basic raw materials like starch. These hybrids offer advantages such as easy availability and relative affordability. However, they may have drawbacks, including hydrophilic characteristics and poor mechanical properties.



## Synthetic polymers and biopolymers hybrid

| Raw material | Advantages | Disadvantages |
|---|---|---|
| **Starch** | Availability, relatively cheap cost | Hydrophilic character, poor mechanical properties |
| **Chitosan** | Antimicrobial and antifungal activity, good mechanical properties | Low oxygen and carbon dioxide permeability, brittleness, high water vapor permeability |
| **Gluten** | Low cost, good oxygen barrier properties, good film forming | High sensitivity to moisture, brittleness |

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Liang S, Wang L. A natural antibacterial-antioxidant film fromsoy protein isolate incorporated with cortex Phellodendron extract. Polymer 2018;10(1):71.

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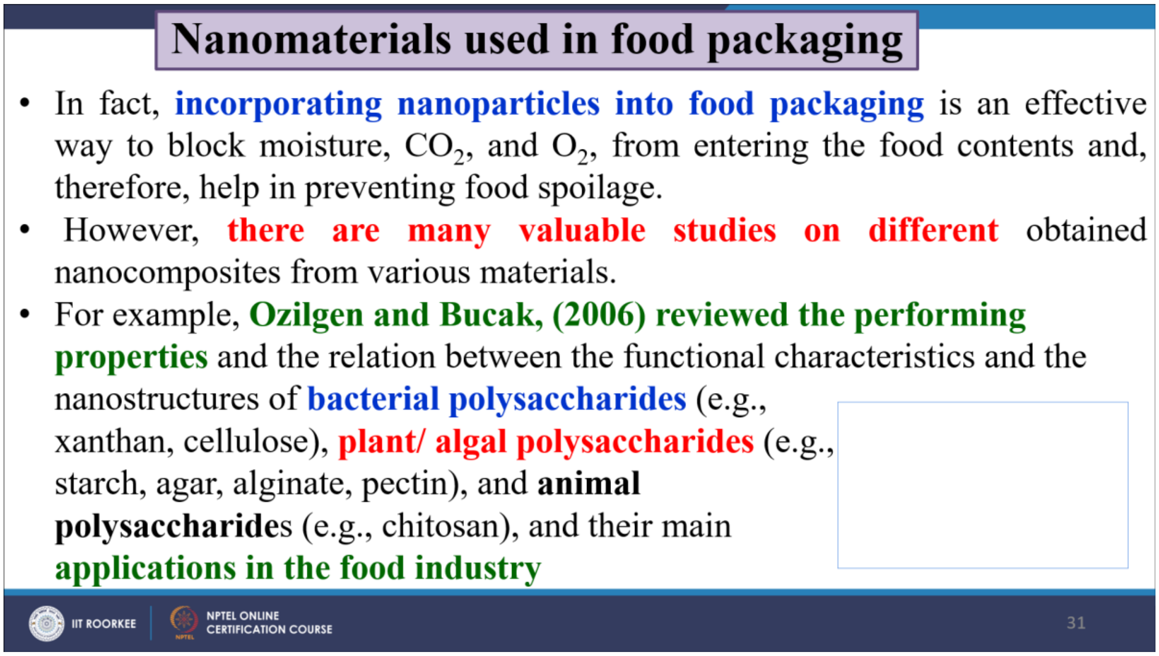
Chitosan, another biopolymer, possesses antimicrobial and antifungal activity, along with good mechanical properties. Nevertheless, its low oxygen and carbon dioxide permeability, brittleness, and high water vapor permeability can be disadvantages. Gluten, known for its low cost, good oxygen barrier properties, and film-forming abilities, is sensitive to moisture and can be brittle.

Nanomaterials play a crucial role in addressing the limitations of biodegradable films and natural polymers, particularly their weak barrier and mechanical performance in food packaging applications. The use of nanocomposites holds significant potential to enhance the utility of biodegradable and edible films, thereby reducing waste from packaging processed foods and extending the shelf life of fresh produce.

Nanotechnology involves creating and utilizing structures with at least one dimension in the nanometer scale ($10^{-9}$ meters). Nanocomposites, resulting from nanotechnology, exhibit modified material properties to achieve desired modifications and interactions between the nanofiller and the polymer matrix. Incorporating nanoparticles into bio-based films is an excellent method for enhancing their properties.

Nanotechnology can be employed in food packaging applications to construct polymer structures that are stronger or lighter, contributing to better performance. One effective method for preventing food spoilage involves using nanoparticles of titanium dioxide or silver dioxide as antimicrobial agents. By incorporating nanoparticles into food packaging materials, it becomes possible to block moisture, carbon dioxide, and oxygen, preventing their entry into the food content and helping to prevent spoilage.

Numerous studies have explored different aspects of nanocomposites, examining materials such as bacterial polysaccharides, plant and algal polysaccharides, starch, agar, alginates, proteins, pectin, and animal polysaccharides. Researchers have investigated the functional characteristics and nanostructure of these materials, with a focus on their applications in the food industry.



### Nanomaterials used in food packaging

- In fact, **incorporating nanoparticles into food packaging** is an effective way to block moisture, $CO_2$, and $O_2$, from entering the food contents and, therefore, help in preventing food spoilage.
- However, **there are many valuable studies on different** obtained nanocomposites from various materials.
- For example, **Ozilgen and Bucak, (2006) reviewed the performing properties** and the relation between the functional characteristics and the nanostructures of **bacterial polysaccharides** (e.g., xanthan, cellulose), **plant/ algal polysaccharides** (e.g., starch, agar, alginate, pectin), and **animal polysaccharides** (e.g., chitosan), and their main **applications in the food industry**

The application of nanotechnology in food packaging has been explored by scientists in various studies. For instance:

1. **Titanium Nanoparticles in Biopolymer Films:**

- Scientists developed a film incorporating titanium nanoparticles using sonic technology to achieve consistent distribution. The result indicated improved mechanical properties and increased film thickness.

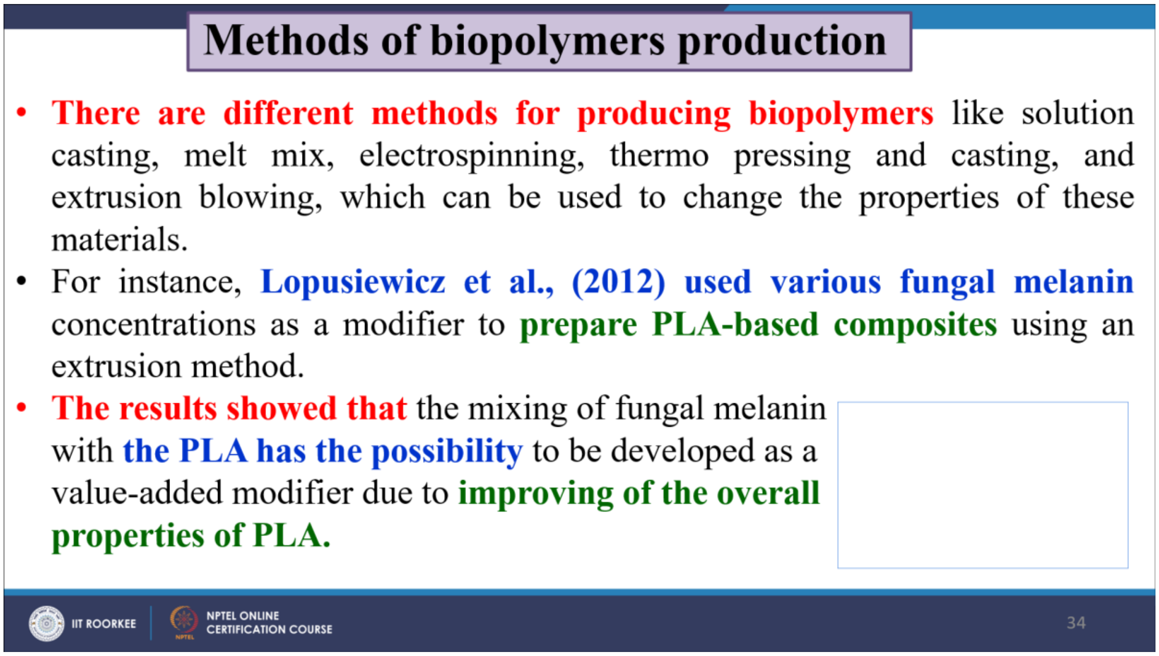
2. **High Pressure Treatment on Polylactic Acid-Silver Nanocomposite Film:**

   - Researchers studied the effect of high-pressure treatment on polylactic acid-silver nanocomposite films. They also investigated the migration behavior of nano-silver from the film under ethanol, a food simulator.

3. **Chitosan Nanofilm with Nano-Encapsulation:**

   - Studies focused on analytical techniques for developing chitosan nanofilm for active food packaging. Nano-encapsulated chitosan films demonstrated decreased water vapor permeability and improved mechanical strength.

In the realm of biopolymer production, various methods play a crucial role in altering material properties. These methods encompass solution casting, melt-mix, electrospinning, thermos-pressing and casting, and extrusion blowing. Lopusiewicz et al., (2012), explored the use of fungal melanin concentration as a modification agent for preparing PLA-based composites through extrusion. The study revealed that the incorporation of fungal melanin could serve as a value-added modification, enhancing the overall properties of PLA. The resultant mixture of PLA and melanin film exhibited notable antioxidant activity, displaying effectiveness against different bacterial strains, including *Pseudomonas aeruginosa, Enterococcus faecalis, and Pseudomonas putida.*



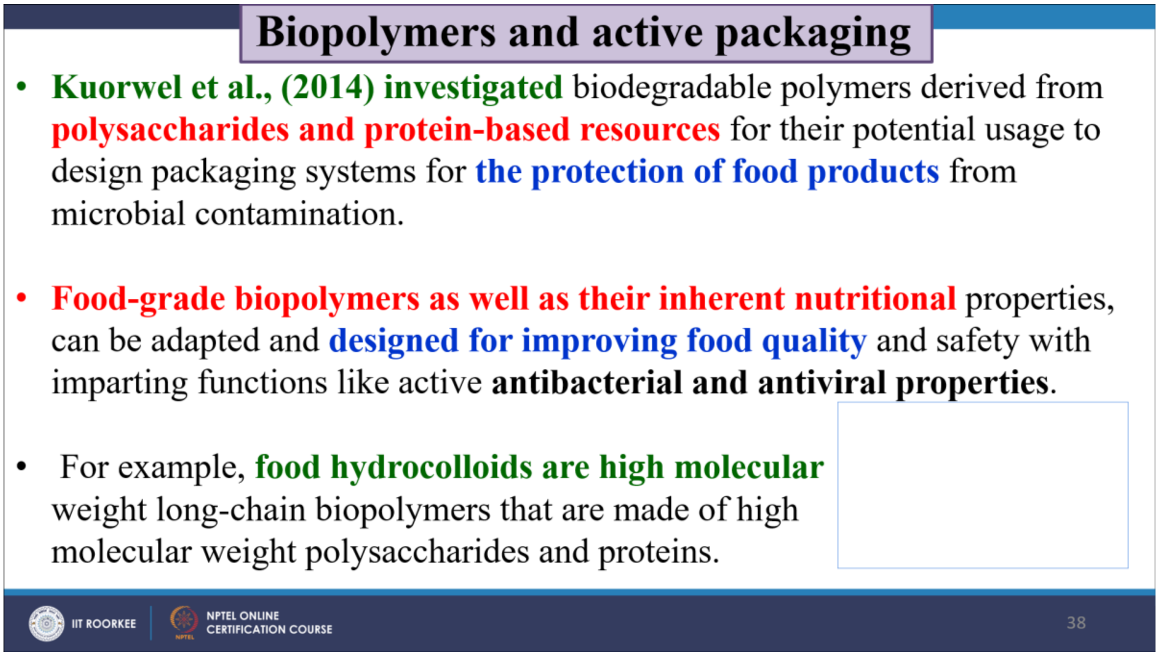
## Methods of biopolymers production

- **There are different methods for producing biopolymers** like solution casting, melt mix, electrospinning, thermo pressing and casting, and extrusion blowing, which can be used to change the properties of these materials.
- For instance, **Lopusiewicz et al., (2012) used various fungal melanin** concentrations as a modifier to **prepare PLA-based composites** using an extrusion method.
- **The results showed that** the mixing of fungal melanin with **the PLA has the possibility** to be developed as a value-added modifier due to **improving of the overall properties of PLA.**

In another study, Thanakkasaranee et al. (2012) prepared a series of poly(etherblock-amide) (PEBAX)/polyethylene glycol (PEG) composite films (PBXPG) using the solution casting procedure to investigate the effects of the integration of different molecular weight PEGs into PEBAX, and it would improve the composite films' performance in as permeability as a function of temperature. Furthermore, research findings suggested the suitability of high PBX-PG composite films for applications such as safe microwave cooking, emphasizing their role as self-ventilating products. In addition, Guidotti et al., (2012) synthesized a bio-based polyester (butylene 1,4-cyclohexane dicarboxylate) consisting of random copolymers as a material for flexible and sustainable packaging solutions using the lamination method. The replacement of the linear butylene moiety with glycol subunits featuring alkyl pendant groups of diverse lengths was explored. Simultaneously, copolymers with varying cis/trans isomer ratios of the cyclohexane ring were produced.

In the dynamic landscape of packaging design, a significant trend involves incorporating additives into packaging materials to enhance functionality. Antimicrobial packaging stands out as a prominent example, integrating antimicrobial additives into polymer films to provide effective barrier protection. These films not only maintain robust physical barrier properties but also contribute to preserving the quality of enclosed food products. Recent developments in this area have attracted considerable attention from the food industries, reflecting a growing interest in applications for packaging and preserving perishable goods.

Moreover, food-grade biopolymers, with their inherent nutritional properties, offer a promising avenue for improving food quality and safety while imparting active functionalities such as antibacterial and antiviral properties. Notably, food hydrocolloids exemplify high molecular weight, long-chain biopolymers composed of polysaccharides and proteins. These hydrocolloids are widely used as functional food additives in various food products, serving to enhance sensory characteristics, improve shelf life, simplify production processes, and create functional food items.



## Biopolymers and active packaging

- **Kuorwel et al., (2014) investigated** biodegradable polymers derived from **polysaccharides and protein-based resources** for their potential usage to design packaging systems for **the protection of food products** from microbial contamination.

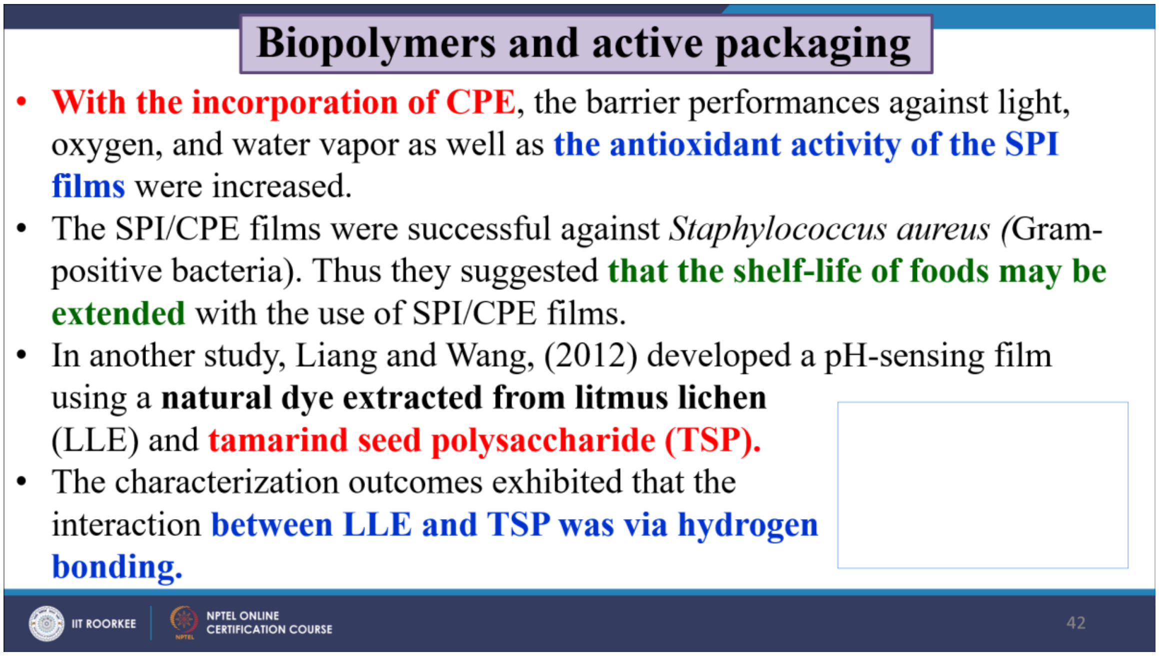
- **Food-grade biopolymers as well as their inherent nutritional** properties, can be adapted and **designed for improving food quality** and safety with imparting functions like active **antibacterial and antiviral properties**.

- For example, **food hydrocolloids are high molecular** weight long-chain biopolymers that are made of high molecular weight polysaccharides and proteins.

Hydrocolloids represent the largest category of biopolymers, boasting functional properties such as textural attributes, viscosity, and sensory characteristics that mimic the behaviors of fats. Their incorporation into food products not only addresses sensory aspects but also contributes to improve the shelf-life of the food products, to formulate the production processes to be simpler and more efficient, and to produce functional food products. The ongoing academic research and continuous technological advancements in the packaging industry result in innovative solutions, aiming to enhance food safety, improve quality, and extend shelf life. Razavi and Behrouzian, (2007) considered biopolymers from food hydrocolloids as fat replacers within foods such as cheese, ice cream, sauce, and yogurt due to consumer demand for low-fat or fat-free food products. A noteworthy research initiative aimed to compare the performance of two barrier materials: biodegradable natural Polyhydroxybutyrate (PHB) and petrochemical Polyurethane (PU). The primary focus of the study was to assess their respective performances in realizing antibacterial agents. In a notable research endeavor, the objective was to compare two barrier materials, specifically biodegradable natural polyhydroxybutyrate (PHB) and petrochemical polyurethane (PU). The primary focus was on evaluating their performance in realizing antibacterial agents. The study revealed significant differences in the kinetic energy released by chlorhexidine digluconate, the active agent in both polymers. This disparity was attributed to surface degradation and the superposition of diffusion in PHB, shedding light on the impact of active biodegradable packaging based on PHB.

Additionally, Liang and Wang (2011) conducted a study in which they developed an active film by incorporating various concentrations of cortex philodendron extract (CPE) as an active agent into soy protein isolate (SPI). The outcomes of the study indicated a reduction in the crystallinity of the films, accompanied by the formation of new hydrogen bonds between molecules in the films. This research contributes valuable insights into the influence of active agents on film properties, offering potential applications in the realm of active packaging materials.

The introduction of cortex philodendron extract (CPE) into soy protein isolate (SPI) films brought about notable enhancements in barrier performance against light, oxygen, and water vapor. Simultaneously, an increase in antioxidant activity was observed. The SPI/CPE films exhibited efficacy against Staphylococcus aureus (Gram-positive bacteria), suggesting their potential in extending the shelf-life of food products. This exploration into SPI/CPE films showcases their multifunctional attributes in active packaging.



### Biopolymers and active packaging

- **With the incorporation of CPE**, the barrier performances against light, oxygen, and water vapor as well as **the antioxidant activity of the SPI films** were increased.
- The SPI/CPE films were successful against *Staphylococcus aureus* (Gram-positive bacteria). Thus they suggested **that the shelf-life of foods may be extended** with the use of SPI/CPE films.
- In another study, Liang and Wang, (2012) developed a pH-sensing film using a **natural dye extracted from litmus lichen** (LLE) and **tamarind seed polysaccharide (TSP).**
- The characterization outcomes exhibited that the interaction **between LLE and TSP was via hydrogen bonding.**

In a related study, Liang and Wang (2012) focused on developing a pH-sensing film utilizing a natural dye extracted from litmus lichen (LLE) and tamarind seed polysaccharide (TSP). Characterization results highlighted hydrogen bonding as the interaction mechanism between LLE and TSP. The film displayed a color transition from orange (pH 4.0) to blue/violet (pH 10.0). A spoilage test using full cream milk demonstrated the film's potential as a reliable indicator for detecting spoilage issues, making it a promising solution for food safety applications.

Gomez-Mascaraque et al. (2015) delved into the exploration of various food-grade biopolymers, primarily carbohydrates, proteins, and some biopolyesters. These were investigated as potential solutions for encapsulating matrices to protect sensitive bio-actives or as nanostructured packaging layers capable of regulating the growth of pathogenic bacteria and viruses. This study adds to the evolving landscape of biopolymer applications in food packaging for improved food safety and quality.

In the contemporary era, synthetic polymers, primarily derived from petrochemicals, dominate the packaging industry. However, these non-degradable materials contribute significantly to environmental pollution. To address this issue, the utilization of biodegradable polymers has gained traction, mitigating the toxic impact of traditional plastics on the environment. Despite the eco-friendly nature of bioplastics, they come with certain limitations. The incorporation of nanoparticles emerges as a promising strategy to enhance the performance of bio-based films and overcome the shortcomings associated with bioplastics.

The integration of nanoparticles into packaging materials not only contributes to the development and efficacy of bio-based films but also plays a crucial role in reducing waste related to the packaging of processed food. This, in turn, extends the shelf life of fresh food products. However, the presence of nanoparticles, particularly metallic nanocomposites in bioplastics, raises concerns about their potential migration into food, leading to contamination and posing health and safety risks. Therefore, it is imperative to thoroughly study, assess, and comprehend the properties, structure, and behavior of advanced materials intended for future food packaging applications.

In pursuit of a greener tomorrow, it is essential for both the packaging industry and consumers to actively participate in reducing the production and usage of packaging materials. By adopting sustainable practices, the industry and consumers alike can contribute to a more environmentally friendly future. To facilitate further exploration on this subject, four distinct references have been enlisted for the convenience of researchers and scholars. These references serve as valuable resources for in-depth studies and understanding. Thank you very much for your attention.