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A review on the application of biopolymers in food grade packaging

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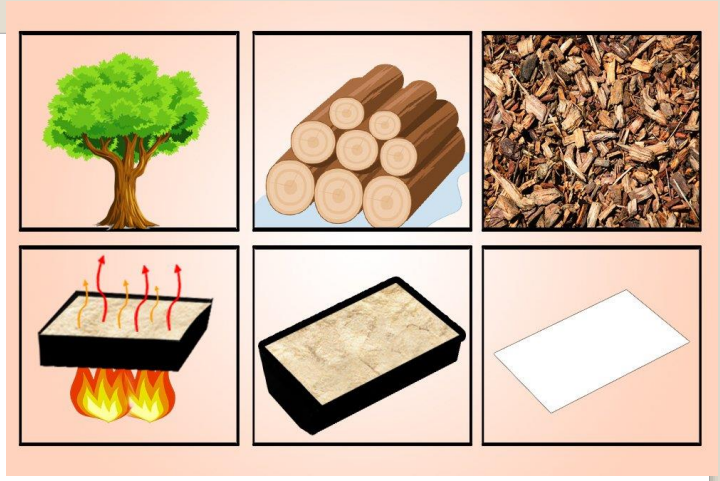
Outline of the presentation

- Introduction
- Biopolymers for Sustainable Packaging
- Protein Based Packaging Material
- Starch and Chitosan Based Packaging Material
- Polylactic Acid (PLA) Based Packaging Material
- Conclusion

Introduction

PAPER



- Most pulp is made from
  - wood
  - recycled paper
  - other plant sources, including hemp, cotton, esparto grass, sugar cane bagasse and bamboo, can also be used.
- Paper is a network of plant fibres laid down as a flat sheet.
- Paper is made from a suspension of plant tissues in water known as pulp.

Introduction

How is paper made

- Wood or other raw materials are source of papermaking fibers but they also has lignin.
- Separating the useful fibre from the rest of raw materials. (e.g. cellulose from wood, cotton, etc.) – Pulping (either chemical or mechanical actions) & Bleaching
- Beating of fibre into pulp
- Addition of different chemicals to attain mechanical, chemical, biological, and other properties of the paper
- Screening the resulting solution
- Pressing and drying to get the actual paper
- Surface sizing & Paper Coating

Introduction

- Packaging materials is used to contain, preserve, and protect a product. It also provides good presentation and information required by the user/customer.
- Few decades ago, packaging was done using metals, glass, ceramics etc.
- Paper doesn't have innate barrier properties as it has a heterogeneous structure made of cellulosic fiber which possesses voids or empty spaces allowing the passage of fluids.
- Barrier properties of paper can be enhanced with the use of polymers or additive either at wet-end of papermaking or surface sizing/coating.
- To address repulpability issue of paper/ paperboard in multilayer packaging material, one can utilize natural polymers either individually or in combination to create water-based barrier coatings.

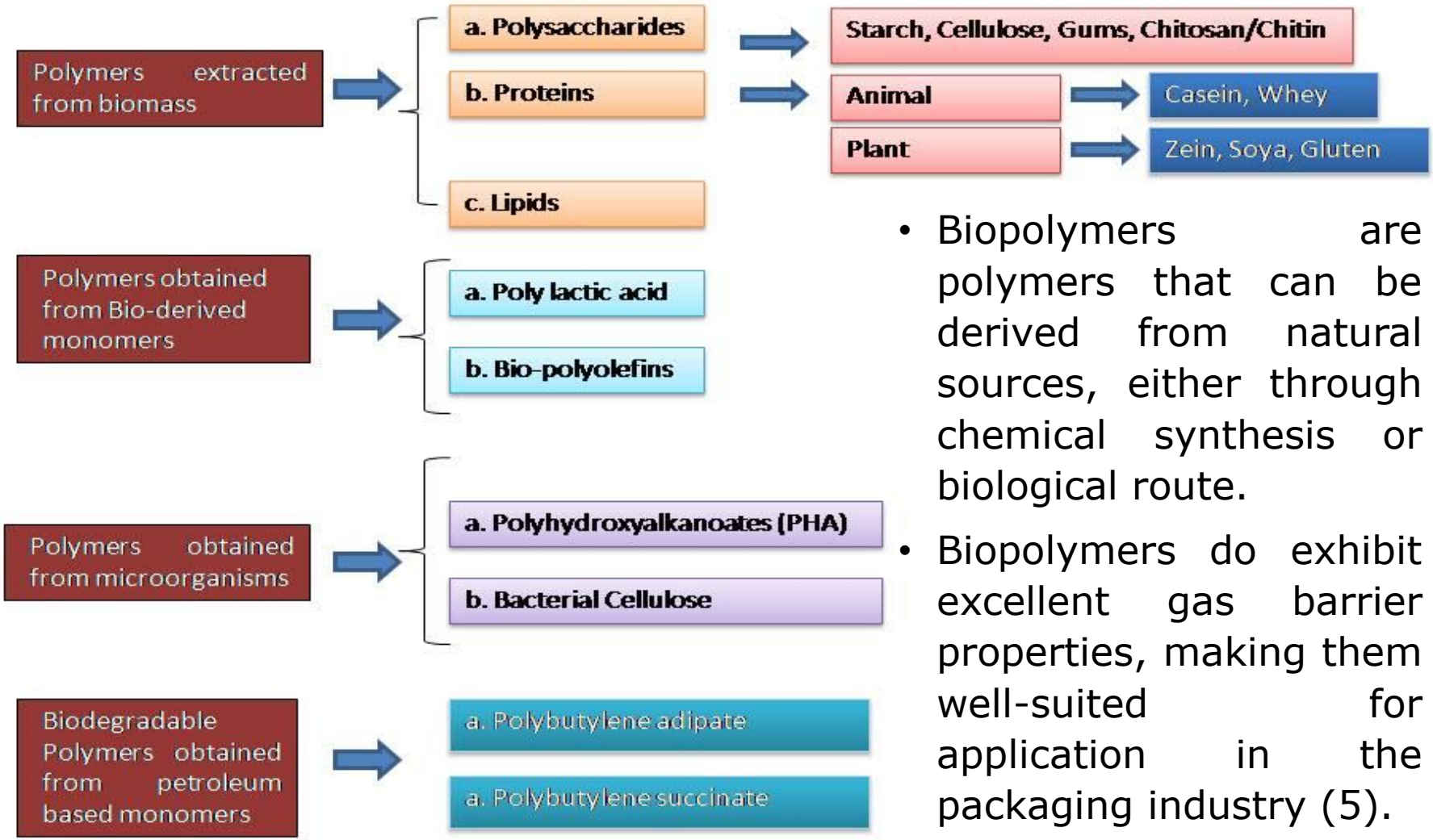
Introduction

- Such coatings, unlike their non-water-based counterparts, do not negatively impact the repulpability of paper or paperboard.
- The use of biopolymers as food packaging materials has certain limitations like inferior strength, thermal and barrier properties in comparison to that of petroleum-based polymers.
- The global food packaging market is projected to experience substantial growth and reach an estimated value of around USD 592.8 billion by 2032. This represents a robust compound annual growth rate (CAGR) of slightly above 5.3% during the period from 2023 to 2032 (1).

Introduction

- In 2022, the food and beverage packaging market in India was valued at USD 31.75 billion. Looking ahead to the forecast period from 2023 to 2029, the market size is anticipated to witness significant growth, with a projected CAGR of 14.8% (2).
- In 2022, the market size of starch-based plastics was assessed at USD 1,804 million. It is projected to experience substantial growth, with an estimated value of USD 4,059 million by 2031. This indicates a CAGR of 9.43% during the forecast period from 2023 to 2031 (3).
- The bioplastics market in India is anticipated to witness significant growth, with a projected CAGR of 24.36% (4).

Biopolymers for sustainable packaging



- Biopolymers are polymers that can be derived from natural sources, either through chemical synthesis or biological route.
- Biopolymers do exhibit excellent gas barrier properties, making them well-suited for application in the packaging industry (5).

Protein Based Packaging Material

- In Packaging, proteins are extensively used due to their inherent qualities, such as their ability to form strong films, biodegradability, effective gas barrier properties, and high nutritional value. Additionally, proteins are widely available (6).
- Gluten films exhibit high uniformity, excellent gas barrier properties and good mechanical strength (7).
- The water vapor barrier property of wheat gluten films is relatively low due to the protein's hydrophilic nature, as well as the addition of plasticizers for flexibility (8).

Protein Based Packaging Material

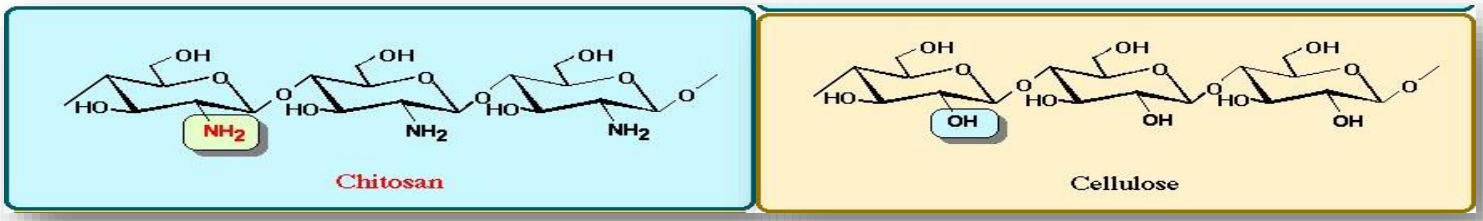
- Whey protein offers good oxygen barrier properties, making it an ideal bio-based and biodegradable solution for blended, composite, or multilayer film structures (9).
- Corn zein [principal protein of maize] films exhibit superior barrier properties, particularly in terms of water vapor, compared to films made from other proteins (10).
- The combination of organically modified clay with soy protein offers dual benefits of enhanced thermal stability and reduced oxygen permeability in comparison to pure soy protein (11).

Protein Based Packaging Material

Subtract	Protein	Impact	References
Paper/ paperboard	Wheat gluten	Reduced oxygen permeability	12
	Whey protein and glycerol (60:40)	Increased the paper's resistance to oil without significantly degrading its strength properties	13
	Corn zein	Grease resistance of corn zein-coated paper is comparable to that of polyethylene laminate, making it a potential substitute for polyolefin materials	14
	Corn zein	Exhibits barrier properties similar to PE-coated paper	15

Starch and Chitosan Based Packaging Material

- Starch consists of two different types of polymers: 1) amylose (linear: molecular weight several hundred thousands) and 2) amylopectin (branched chain: molecular weight several millions).
- The starch films are widely used to produce soluble films, loose films, bags and sacks etc.
- Chitosan is a pseudo natural polymer prepared by enzymatic and chemical deacetylation of chitin.
- Due to presence of amino group chitosan become cationic in nature and it will assist it to better interact with the cellulosic fibers (16).
- The strength properties of chitosan films are almost similar to polyethylene and cellophane (17).



Starch and Chitosan Based Packaging Material

S. No.	Main material	Other material added	Impact on starch	References
1	Thermoplastic starch	Chitosan nano crystals/ fibers	Reduced oxygen permeability by 25-30%	18
2	Sago starch and bovine gelatin	Zinc oxide nano rods	Reduced oxygen permeability by 40-55%	19
3	Starch	lignin	Reduced water vapor permeability by 40-55%	20
4	Thermoplastic starch	Cellulose nanofibers	Reduced moisture sensitivity of the material	21
5	Oxidized starch plasticized using glycerol	Nano clay	Increased young modulus of films by more than 70%	22
6	Starch and glycerol	Nano clay	Enhanced mechanical strength and resistance to water vapour barrier	23
7	Corn starch plasticized using glycerin	Kaolin clay	Enhanced the tensile strength and modulus	24

Starch and Chitosan Based Packaging Material

S. No	Base paper (BP)	Details of chitosan (CH) usage for surface application	Properties improved	Ref.
1	Handsheets made of unbleached Kraft bagasse pulp (68 g/m2)	Degree of deacetylation (DD): 85%. Paper sheets were dip coated in different concentrations (0.05% to 0.75%) of CH solution for 30 seconds. The coat weight: 0.06 to 0.79 g/m2.	Strength	25
2	BP made from bleached Kenaf kraft pulp	DD: 85.4% and Molecular wt.: 900000 Dalton. CH solution used : 0.5% to 2% (done by spraying)	Strength & barrier	26
3	BP – (78 g/m2)	(CH in coated on precoated CMC sheets). CH solution used for surface application: 1%. Coat weight : 2 to 8 g/m2. DD: >75% and Molecular wt.: 150000 Dalton	Barrier, strength & thermal	27
4	Paper made of bleached kraft pulp (74 g/m2)	DD:90% and Molecular wt:90000 g/mol was used to synthesize the water soluble CH. CH solution used: 2%. To achieve different coat weights (1 to 5 layer coating was done using size press). 1 layer of CH and water soluble CH coating provides the coating of 0.76 g/m2 and 0.68 g/m2, respectively.	Strength & barrier	28
5	BP – printing paper (80 g/m2)	CH solution used : 2%	Strength	29

Polylactic Acid (PLA) Based Packaging Material

- PLA is widely used bioplastic because it is renewable, biocompatible and biodegradable.
- PLA belongs to the family of synthetic aliphatic polyesters. PLA is thermoplastic in nature.
- It has several advantages like good transparency, biodegradable, biocompatibility, processability etc. when compared with petroleum-based polymers usually used in food packaging.

Polylactic Acid (PLA) Based Packaging Material

- Certain disadvantage like thermally unstable due to which its usage as an effective material to produce packaging grade paper is still challenging (30)
- The water vapor transmission rate of nanocellulose/PLA coating was lower than that of only PLA coating. The composite structure of paperboard/nanocellulose/ PLA had shown 98% lower oxygen transmission rate in comparison to paperboard only coated with PLA (35).

Polylactic Acid (PLA) Based Packaging Material

S. No.	Main material	Other material added	Impact on PLA	References
1	Semi-crystalline PLA	Organo clays	Reduced the OTR and WVTR by around 50%	31
2	PLA	Graphene oxide nanosheets	Reduced gas permeability by around 45% (for oxygen) and 68% (for carbon dioxide)	32
3	PLA	Chitosan + clay	Reduced the OTR by around 99%.	33
4	PLA	Silica	Improved transparency and reduced oxygen permeability (69%) and water vapour permeability (45%)	34

Conclusion

- Packaging serves not only as a means for storing, shipping and selling products but also as a platform for presenting product information, quality and brand identity.
- Traditional packaging based on petroleum fuels has become a major environmental concern, due to its non-biodegradable nature.
- This raised global attention towards the production of biopolymers and use them in packaging as an alternative to petroleum based non-biodegradable packaging.
- Promising alternatives for petroleum based packaging are biopolymers derived from plants, animals, agricultural waste such as cereal straws, kenaf, bagasse, and other non-wood sources.
- The review paper summarizes different properties of various biopolymers alone and in combination with others to achieve a better food packaging material.

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