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A STUDY ON DIFFERENT TYPES OF EDIBLE PACKAGING MATERIALS (PLANTS BASED)

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Abstract— **The food and pharmaceutical industries recognized edible packaging as a useful alternative or addition to conventional packaging to reduce waste and to create novel applications for improving product stability, quality, safety, variety and convenience for consumers. This study was done to compare the different types of edible packaging materials, their classifications and their applications. The aim of this study was to better understand the potential of fruits and vegetables to be used as components of edible packaging materials is discussed. Such application of fruits and vegetables is possible to the presence of matrix-forming polysaccharides and proteins in their composition. The development of edible fruit and vegetable packaging materials is a promising way of combining the barrier and mechanical properties of biopolymers with the nutritional and sensory properties. The application of fruits and vegetables as a component of edible packaging materials enables the utilization of raw materials with low commercial value. Edible packaging materials are a new method of their utilizing. There is also the possibility of just decreasing the amount of synthetic packaging waste by application of fruit and vegetable packaging materials simply as a passive or active layer partially replacing the non-renewable materials. The dynamic forces behind the keen chase includes scientific innovation in the functionality of new materials, increased demand for novel foods and increased consciousness for environmental protection and conservation. In this study we'll know about the different characteristics of edible packaging materials like light weight, low cost with significant strength, good oil and chemical resistance, moderation of elongation, good tensile strength, and act as good oxygen barriers, retard moisture loss, flexible and generally have no taste or flavor. Materials that have traditionally been used in food packaging include glass, metals (aluminum, foils and laminates, tinplate, and tin-free steel), paper and paperboards, and plastics. Moreover, a wider variety of plastics have been introduced in both rigid and flexible forms.**

Keywords— **Edible packaging, polysaccharides, proteins, lipid, moisture barrier, gas barrier, composite films, permeability.**

I. INTRODUCTION

In order to prolong the shelf life of food and ensure the quality of this food during transportation, food packaging has become increasingly important. Sustainable development is currently a priority guiding principle for politics, manufacturers, scientists and common citizens. Despite this, around 1.3 billion tons of food is wasted globally per year [1] whence fruits and vegetables, along with roots and tubers, have the highest wastage rates of any food products- nearly half of all the fruit and vegetables produced are wasted. [2] The edible films are generally made from proteins, lipids and polysaccharides that are used either alone or together. [3,4] Edible packaging materials have their unique characteristics such as ability to protect foods with their barrier and mechanical properties and also enhance some other properties like sensory characteristics, control-release active ingredients and control mass transfer between components of heterogeneous foods. So edible packaging materials have been used as attractive alternatives for some applications. For non-edible packaging as an oxygen or grease-barrier layer to enhance protective functions and biodegradability of multilayer packaging, we can use edible packaging materials. [5] Now-a-days, edible wrapping is used as a replacement or fortification of the natural layers at the outer surfaces of product, which can prevent gas aromas, moisture losses and solute movements out of the food. [6] Moreover, the materials are used for either coating the food thoroughly or using as a continuous layer between the components of foods. [7] Researchers are constantly searching for enhancement of the properties of various biodegradable materials types for replacing conventional materials with high environmental impact. [8] Gradually, the

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dependency on synthetic material in food packaging industry is decreasing. [9]

By using primary edible packaging together with non-edible packaging as secondary packaging, the efficiency of food preservation can be improved to add additional protection from the atmosphere and to prevent contamination from any foreign particles. In this study, we have reviewed some properties, applications, advantages and disadvantages of few plant based edible packaging materials.

II. FUNCTIONS OF EDIBLE PACKAGING:

- Moisture and gas barrier
- Water vapor permeability,
- Oxygen permeability,
- Mechanical properties (tensile strength, percent elongation, elongation at break, elastic modulus and glass transition temperature),
- Chemical properties (solubility in water, alcohol and mixtures and hydrophilic – hydrophobic interaction),
- Organoleptic properties (color, taste, appearance and odor), physical properties (opacity and light transparency),
- Antimicrobial properties (minimum inhibitory concentrations, antimicrobial activity against target organisms for edible films containing natural antimicrobials).

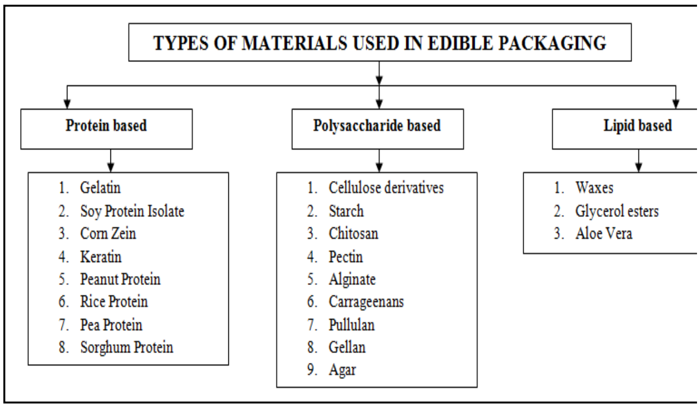

Fig 1: TYPES OF MATERIALS USED IN EDIBLE PACKAGING

III. PROTEINS WHICH CAN BE USED FOR EDIBLE PACKAGING:

A. Soy protein isolate:

Film thickness: The values increased from 52.6± 2.6 µm for the 6% SPI content to 83.6± 5.3 µm for the 9% SPI. The difference in thickness was significant ($p< 0.05$) between films made from the different concentration of SPI and the same concentration of GLY 50% (w/w).

Table 1: Composition of soy protein isolate-based film-forming suspensions before drying:

Table 1: Composition of soy protein isolate-based film-forming suspensions before drying:

Film	SPI (g)	SPI (%)	GLY (%)	GLY (%/SPI)	Water
6SPI 50GLY	6	67	3.0	50	91.0
7SPI 40GLY	7	71	2.8	40	90.2
7SPI 50GLY	7	67	3.5	50	89.5
7SPI 60GLY	7	63	4.2	60	88.8
7SPI 70GLY	7	59	4.9	70	88.1
8SPI 50GLY	8	67	4.0	50	88.0
9SPI 50GLY	9	67	4.5	50	86.5

db: dry basis.[11]

Table 2: Effect of soy protein isolate (SPI) and glycerol (GLY) concentrations on the film thickness:

Film	Thickness (um)
6SPI 50GLY	52.6±2.6a
7SPI 50GLY	63.8±5.2b
8SPI 50GLY	77.6±4.6c
9SPI 50GLY	83.6±5.3d
7SPI 40GLY	61.2±4.1b
7SPI 50GLY	63.8±5.2b
6SPI 60GLY	64.0±5.9b
7SPI 70GLY	63.6±4.0b

Mean± standard deviation, n=5[12]

Differential scanning calorimetry: The protein content affects the initial temperature of degradation when films contain 6, 7 and 8% of SPI. There is no significant difference between 8 and 9% of protein ($p< 0.05$). [13]

Table 3: Different scanning calorimetry (DSC) measurement results of soy protein isolate-based films:

Film	T_d (°C) ab	T_{max} (°C)	H_f (J g^{-1})
6SPI 50GLY	63.9±1.5bc	69.2±3.3ac	0.34±0.15a
7SPI 50GLY	57.6±3.5a	64.9±0.8a	0.17±0.05a
8SPI 50GLY	71.1±0.2d	71.6±0.3bcd	0.15±0.07a
9SPI 50GLY	68.9±2.3cd	71.8±2.4bcd	0.18±0.14a
7SPI 40GLY	69.9±1.9cd	74.5±1.5bcd	0.32±0.24a
7SPI 50GLY	57.6±3.5a	64.9±0.8a	0.17±0.05a

7SPI 60GLY	**61.9±4.8ab**	**68.3±3.3ab**	**0.40±0.12a**
7SPI 70GLY	**69.7±0.1cd**	**75.3±2.8d**	**0.20±0.04a**

T_d: initial temperature of degradation, T_{max}: temperature at maximum degradation rate, H_f = DELTA apparently enthalpy of fusion, n=2. Mean+- standard deviation.[14]

B. Corn zein:

- Biomedical applications. [15]
- Drug delivery [16]
- Substitution of synthetic polymer. [17]

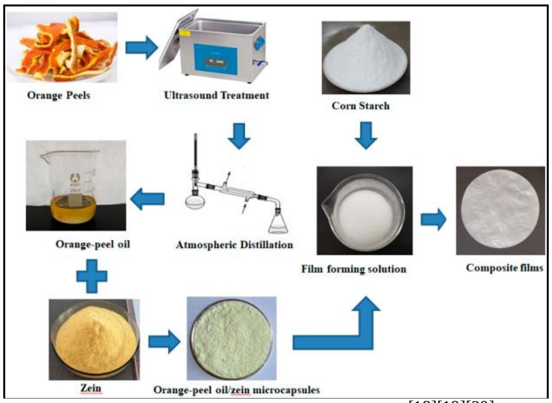

Fig 2: Corn Zein composite film [18][19][20]

C. Peanut protein:

The properties of peanut protein films were modified using physical and chemical treatments, and their effects on color, mechanical strength, water solubility and barrier to water vapor and oxygen of the films were investigated. Physical treatments consisted of heat denaturation [21] of film-forming solution for 30 min at 60°C, 70°C, 80°C and 90°C, ultraviolet irradiation of films for up to 24 h, and three ultrasound processes of film-forming solution. Chemical treatments consisted of addition of aldehydes and anhydrides.[22][23] [24]

D. Rice protein:

Rice protein hydrolysates (RPH) are incapable of film formation by self-cross linking due to low molecular mass. Hence, we used chitosan (CS) as a modifier and developed rice protein hydrolysates/chitosan (RPH/CS) edible composite films by means of ultrasound.[25]

E. Pea protein:

- It contents as 5% to 10% and 20% for oil packaging.[28]
- Microbiological preservation on bioplastics.[29]
- Effect of the injection moulding processing conditions on the development of pea protein-based bioplastics.[30]

F. Sorghum protein:

- Kafirin, the prolamin protein fraction of sorghum, is similar to zein in molecular weight.[31]
- Used in encapsulation. [32]
- Tend to have lower tensile strengths and elongation values than synthetic films, but these are generally sufficient to allow usage for wraps. [33]

Sl No.	Proteins	Applications	Advantage	Disadvantage
1.	Gelatin	Packaging films can be successfully produced from all gelatin sources and the behavior and characteristics of gelatin-based films can be altered through the incorporation of other food ingredients to produce composite films possessing enhanced physical and mechanical properties.[14][16]	Excellent film-forming ability Gel-forming properties around 35°C Excellent versatility due to its α-amino acid composition, Abundance, Low cost [17][18]	Rheological properties Being less stable than the obtained from mammalian sources. [25][26]
2.	Soy protein isolate	The thickness increased slightly when the SPI (soy protein isolate) amount was increased in the film-forming solution. [29][26]	Ability to reduce the risk of cardiovascular diseases in humans by decreasing serum cholesterol levels. Renewability Biocompatibility Biodegradability.	Water vapor permeability and mechanical properties as affected by plasticizers. Not easily digestible. Not helpful for the people having allergies (rash, itching & breathing) or intolerances
3.	Corn zein	As Drug Carriers for Drug Delivery. As Enzymatic Hydrolysate Peptides for Reducing Blood Pressure.[13][14]	excellent film-forming ability good solubility in ethanol compatibility with many natural active agents. [17][16]	Not applicable for the people having corn allergy. [22][23]
4.	Peanut protein	good emulsifying activity, emulsifying stability, foaming capacity, excellent water retention high solubility. [23][24]	An excellent plant-based source of protein, High in various vitamins, minerals, Plant compounds. They can be useful as a part of a weight loss diet	Itchy skin hives, which can appear as small spots or large welts on your skin itching or tingling sensations in or around your mouth or

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			May reduce your risk of both heart disease and gallstones.[26][29]	throat runny or congested nose nausea. [19][20]
5.	Rice protein	Rice protein hydrolysates (RPH) are incapable of film formation by self-cross linking due to low molecular mass. [11][12]	Enhance nutrition profile Functional added proteins Replacement of ingredients. [34][25]	Too much water soluble Can't hold up in humid climates. [33][34]
6.	Pea protein	Microbiological preservation on bioplastics.[22][29]	Permeability to water vapor (WVP) Physical characteristics same as soy protein, zein protein. Low cost. [17][10]	Less iron absorption High in sodium Low in methionine+ cysteine, an incomplete protein [13][14]
7.	Sorghum protein	Used in encapsulation. Tend to have lower tensile strengths and elongation values than synthetic films, but these are generally sufficient to allow usage for wraps. Used in encapsulation. [12][11]	Biodegradable, Doesn't require any recycling [34][35]	Breakdown easily Will not fill up landfills. [33][36]

IV. LIPIDS WHICH CAN BE USED FOR EDIBLE PACKAGING:

Lipid coatings are used for reducing surface abrasion in case of handling fruits and vegetables [36]. Lipids do not have a greater number of repeating units. So, they cannot form a large macromolecule as well as self-supporting film structures like polysaccharides and proteins. There are some drawbacks of lipids which include waxy taste, texture, rancidity and greasy surface [*37*]. Lipid films are very sensitive to oxidation and brittle, opaque [*38*].

Sl no.	Lipids	Application	Advantage	Disadvantage
1	Waxes (Candellila, Carnauba, Paraffin)	Used to coat food directly such as fruit and cheese [36][39]	Solid waxes can resist water vapor and gas transfer better than oily waxes. They are very common lipids which can extend the shelf-life of fruits and prevent the moisture loss [41]. Moreover, during transport and handling a wax coating may protect food stuff.	Waxes and their other components may be transferred into food stuff, especially if they are in contact with food. A study showed that measuring benzophenone in paraffin waxes used in food contact materials was possible, but no migration studies are obtained. [31]
2	Aloe vera	As edible films for ice-cream, drinks and beverages [34]*[36] [35]*	It is observed that Aloe vera gel-based edible coatings can prevent loss of moisture and firmness, control maturation development and respiratory rate, retard oxidative browning and decrease microorganism proliferation in fruits such as table grapes [35], sweet cherries [36] and nectarines [37]	Over consuming causes stomach cramp, heart diseases, muscle weakness and kidney problem
3	Glycerol esters (Acetylated monoglycerides, Fatty acids, fatty alcohols, and sucrose fatty acid esters)	They can be used alone or in combination with other edible ingredients for coating food products.	The WVP of acetoacylglycerol improved as the degree of acetylation increased, which was hypothesized to be a consequence of differences in crystal packing or removal of free hydroxyl groups that would otherwise interact with migrating water.	Certain associated problems include an acidic, bitter aftertaste and the tendency of highly saturated acetylated glycerides to crack and flake during storage [38].

V. POLYSACCHARIDES WHICH CAN BE USED FOR EDIBLE PACKAGING:

Polysaccharides or polycarbohydrates, are the most abundant carbohydrate found in food. They are long chain polymeric carbohydrates composed of monosaccharide subunits bound together by glycosidic linkages. Examples of monosaccharides are glucose, fructose, and glyceraldehyde.

Name	Application	Advantages/ Disadvantages

Cellulose	**Edible composite films, based on glycerol- plasticized sodium caseinate / carboxymethyl cellulose/ cellulose casting.[49] Pea starch one of the cellulose derivatives composites were prepared by a screw extruder.[50]**	**Helps to keep the food material fresh and maintain its quality & shelf-life.**
Starch (Syzygiumaromaticum and Cinnamomum)	**Starch-based peelable food coating film layers via mould dipping.[51] Zein, corn starch, and orange peel oil extracted from orange peels were used to prepare novel corn starch/ orange-peel oil/ zein ano capsules bio-active food packaging materials.[52] To produce and optimise spice fused tamarind seed starch edible films for meat packaging.[53]**	**High brittleness, lack of compatibility with hydrophobic polymers due to its highly hydrophilic nature, poor processing quality resulting from its high viscosity, low resistance to external factors during storage mainly moisture are its main disadvantages, However, advantage is that it is environment friendly and biodegradable.**
Chitosan	**Possibility of improving the shelf-life of fresh sea bass fillets by using vacuum packaging and wrapping with chitosan-based edible films during cold storage at 4°C.[54] The inhibitory activity of the chitosan-based edible coatings was observed and checked against 2 food pathogens and 1strain involved in food alteration on model agar medium and on a real cheese food product.[55] Coating with chitosan-based edible films for mechanical/ biological protection of strawberries.[56]**	**Biodegradable film with good thermal and chemical resistant properties and extends the shelf life.**
Pectin	**Through evaluation of sweet potato starch and lemon-waste pectin based edible films with nano-titania inclusions for food packaging application.[57]**	**Extends shelf-life & helps in thickness and density.**
Alginate	**Modified atmosphere packaging of fresh – cut papaya using alginate based edible coating: Quality evaluation and shelf-life study.[58]**	**Helps to improve the quality.**
Carrageenans	**Formation mechanism of egg white protein/k-Carrageenan composite film and its application to oil packaging.[59]**	**Some studies proved that it can cause inflammation, gastro problems and can even damage digestive system.**
Pullulan	**Pullulan is a suitable biopolymer for antimicrobial food packaging applications.[60] Reducing meat perishability through pullulan active packaging.**	**Good antimicrobial activity, and nano-silver particles help to improve the quality.**
Gellan	**Optimization of alginate and gellan-based edible coating formulations for fresh-cut pineapples.[61]**	**nontoxic, biocompatible, biodegradable and the resulting hydrogel is transparent and stable. However, gellan gum-based hydrogels have intrinsic defects such as lack of toughness and tissue tolerance as tissue engineering materials that restrict their use in biomedicine field.**
Agar	**Functional properties of edible agar-based and starch-based films for food quality preservation.[62]**	**Biodegradable and edible in nature.**

VI. CONCLUSION-

Nowadays in the market edible food packaging is an inventive technology which will bring a new era in the food packaging industry. Food companies have been searching substitutes and development to their packaging design for eco-friendly packaging. Thus, the demand of edible packaging in the food industries is increasing day by day. They have certain important properties like moisture and gas barrier, water vapor permeability, oxygen permeability, mechanical properties (tensile strength, percent elongation, elongation at break, elastic modulus and glass transition temperature), chemical properties (solubility in water, alcohol and mixtures and hydrophilic – hydrophobic interaction), organoleptic properties (colour, taste, appearance and odor), physical properties (opacity and light transparency), antimicrobial properties (minimum inhibitory concentrations, antimicrobial activity against target organisms for edible films containing natural antimicrobials). Food packaging industries may use edible packaging method not only for their profit but also adding values to the stakeholders and the community.

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