**“A Comprehensive Review on**  **Edible Packaging on Sustainable Food System”.**

**Abstract**

In recent years, edible coatings and films have drawn a lot of attention. There are clear benefits to using polysaccharide, lipid, and protein-based materials (and their composites) in edible packaging over synthetic films. It might help lessen the pollution in the environment. The primary benefit of edible films over synthetic ones is that they may be safely consumed as a component of food products and improve the shelf life of fresh goods while also being environmentally beneficial.In comparison to the more conventional non-environmentally friendly packaging materials, edible films can potentially replace synthetic polymer films by acting as barriers that minimize complexity and improve packaging materials' recyclability. Edible films are typically treated with plaster increase their pliability and resilience. Edible packaging materials are treated with antioxidants to slow down the pace of oxidation reactions. One of the important new uses for edible coatings is to extend the shelf life of food products by acting as carriers of antifungal and antibacterial chemicals.They are also employed as nutrient transporters to raise the final processed food products' nutritious content. Research is needed on the potential uses of edible films as smart packaging, as this technology is still in its infancy. Expanding its use in industry will be a packaging breakthrough industry.

**Keywords: Edible coating: polysaccharide:Proteins:lipids.**

**I. INTRODUCTION**

Edible packaging made up of natural biodegradable plant-based material can be eaten to go without a need for waste collection processing, recycling, or disposal[1]. Typically, edible packaging consists of coatings, pouches, sheets, or edible films. Edible films typically have a thickness of less than 254 um, while sheets typically have a thickness of more than 254 um These materials (films and sheets) are produced independently of food and then applied to food items or sealed as edible pouches. Edible coatings are typically applied directly to food products as sticky films composed of edible ingredients[1]. Soft and firm gel, tablet coatings, and microcapsules composed of edible material are a few examples of edible packaging. Due to consumer desire for safer, higher-quality food with longer shelf life, there is a surge in interest and a number of studies underway. Edible packaging is regarded as one of the best options for a variety of applications because of its special qualities, which include the ability to protect food due to its mechanical and barrier properties, enhanced sensory qualities, controlled mass transfer among heterogeneous foods, and controlled with longer shelf life, there is a surge in interest and a number of studies underway. Edible packaging is regarded as one of the best options for a variety of applications because of its special qualities which include the ability to protect food due to its mechanical and barrier properties, enhanced sensory qualities, controlled mass transfer among heterogeneous foods, and controlled release of active ingredients. Additionally, these edible packaging materials can be used for non-edible packaging, where they improve the ability by acting as an oxygen or gas barrier[2]. The advantages of edible packaging materials are distinct and multipurpose, offering customers convenience, product stability, variety, improved quality, and increased safety.

**2. Edible packaging**

The materials used to package edible foods can be intelligent, active, or neutral. With the addition of active ingredients like vitamins, antioxidants, or antimicrobials, which are carefully regulated in their release into the product, active packaging can extend the shelf life of food or enhance other qualities like product safety or sensory appeal. A thin layer of edible packaging can be placed to the food's surface or used as a coating which is a tiny layer that developed right on the food's surface. It can have protective substances like antioxidants and antibacterial agents [3]. Starches, cellulose, derivatives, chitosan, gums, plant or animal-based proteins, and lipids can all be included in this strategy. Compounds that are safe for human consumption are utilized to make the materials used to package food. Many kinds of films and coatings can be created from these materials by merely changing their thicknesses with minimal changes to the composition and structure of the substance. When creating edible films thickness is a crucial physical characteristic and less than 0.3 mm is preferable[4]. The authorities in charge of food safety must authorize edible packaging given the degree of respiration that fruit and vegetables have it is crucial that the packaging not be completely impervious to water, gas, and ethylene[5].If appropriate food safety procedures are followed throughout production, handling, and storage, edible packaging may be safe to eat. A standard edible film should be inexpensive, free of toxins, safe for human health, non-polluting, have acceptable mechanical capabilities, microbiological stability, and good sensory qualities. To guarantee that they are safe to eat edible packaging must be tested for each of its quality standards, much like other conventional packaging materials. The microbiological quality of edible packaging is a crucial criterion for evaluating its safety[6].

**3. History of Edible packaging**

Despite its modern appearance, edible packaging is a centuries-old technology that has been used to preserve food items and prevent component deterioration. In order to stop water loss during storage and transportation, oranges and lemons were waxed in China in the 12th century [7]. "Larding" is the process of storing fresh fruits in lipids or wax for later consumption [8]. A compromise for preserving moisture was larding content and losing a number of attributes, such as the best possible taste and texture. The first edible films, referred to as "Yuba" films, were produced in Japan at the start of the 15th century by boiling soy milk proteins in pans and then letting them air dry [9]. Like waxing, larding was a prevalent practice in England during the 16th century to stop moisture loss from fruits, vegetables, meats, and fish. To protect a number of meat items, they issued the first gelatin film patent in the US in the 1800s. Nuts were coated with sucrose and sugar derivatives to reduce gas transfer through edible coatings and oxidative rancidity [10]. Commercial waxing and lipid coatings were used on fruits and vegetables in the 1930s to promote natural respiration and stop dehydration while in transit. Over the past century, this company has expanded significantly. Its main purpose was to give fruits and vegetables a glossy appearance and prevent water from leaking out. Prior to World War II, a wide variety of protein-based films, coatings, polymers, and textiles were available for purchase [11]. Because of the growing demand for textile items derived from high-protein agricultural commodities, the production of commercialized protein-based wool substitutes experienced a notable uptick in the early 20th century, during World Wars I and II. The advent of plastic far more affordable packaging material caused the development of edible films to stall in the first two decades of the twenty-first century [12] .The creation of commercial edible films for a range of food packaging systems is driven by the growing consumer requirements for quality, freshness, and healthy packaging options. Furthermore, non-polluting food packaging must be widely adopted as edible packaging due to rising environmental protection awareness.

**4 Materials required for edible films and coatings**

The use of edible films and coatings as packaging materials lessens the environmental impact of traditional, non-biodegradable packaging materials. Additionally, consumer demand is showing a growing tendency toward environmentally friendly and renewable packaging materials. Casting is used to create edible films, whereas extrusion and coating of the edible solutions are accomplished via dipping and spraying. The main distinction is that food items are encased in solid edible lamination in edible film. The food items, on the other hand, are coated with the edible coating producing solution.These packaging materials should have the ability to produce films and coatings and be edible. These materials include lipids, proteins, and polysaccharides, which can create coatings and films that are continuous [13]. A solvent, like water or ethanol, is used to dissolve the edible film-forming material during the casting process. The addition of plasticizes can increase the film's pliability. In the business world, a continuous film casting is employed. We refer to the mixture of proteins and polysaccharides as hydro colloids. These long-chain polymers are hydrophilic and hydro colloids. They can create a structure resembling gel when combined with the solvent, water. Unlike lipids, which are opaque, these coatings and films are translucent. Polysaccharides can develop a strong hydrogen bond with other active additives including colouring agents or flavoring agents. Hydro colloid films and coatings have a good oxygen barrier, but they have a poor water vapor barrier due to their hydrophilic nature. Due to their hydrophobic nature, lipids exhibit good water vapour properties [14].

**4.1 Polysaccharides**

Natural polysaccharides are abundant, edible, and harmless. A glycosidic bond allows monosaccharides and disaccharides to recur in a particular manner during polymerization, creating polysaccharides. Free hydroxyl groups in polysaccharides are what start the hydrogen bonding process with additional active ingredients. Along with its exceptional strength qualities, this coating has demonstrated superior oxygen and scent barriers. A possible explanation for this could be the densely packed nature of polysaccharides. Due to the hydrophilic nature of polysaccharides, excessive humidity will weaken the integrity of the packing. Wax and oil are examples of lipophilic substances that can be added to lessen this hydrophilicity. Enhancing the shelf life of food goods can be achieved by adding antioxidants and antimicrobial agents to the packing material. Polysaccharides derived from plants include cellulose, starch, and pectin. On Earth, cellulose is a very common bio-polymer. Granular forms of starch polyacrylamide are accessible and hydrophilic. They swell and create a gel-like structure when added to water. Pectin is a well-known polysaccharide that is taken from citrus and apples. The tree's stem can yield the other substance, Gum Arabic [15].

**4.2 Proteins**

Amino acids combine to form polymers called proteins. Both fibrous and globular proteins are examples of natural protein structures. The poly-peptide chain runs parallel to fibrous proteins like whey, soy, and maize. Similar to collagen protein, globular protein is spherically folded and strongly folded. Whey protein, collagen, soy, and maize have all demonstrated superior film and coating-forming capabilities. Hydrophilic protein-based films have low to moderate water barriers and lose their integrity at high humidity levels. They are a great way to keep hydrophobic substances like oil and fragrance out. Antimicrobial and antioxidant compounds are also present in protein-based edible films [13] Milk protein films have a clear and flexible quality. To improve the quality of food, these films also include potent antioxidants and antimicrobial. The two protein components that make up milk protein are casein and whey. Animal tissues and muscles include collagen protein. Gelatine is created when collagen is hydrolyzed, or broken down with the aid of water. Dry gelatin is clear and has no taste. The solutions that form films are created by dissolving it in hot water. The casting process is used to create the film, and oven drying comes next [16].

**4.3 Lipids**

Lipids lack a self-supporting structure and are not polymers. Compared to films made of polysaccharides and proteins, lipids have a superior water barrier since they are hydrophobic by nature. Wax film exhibits the best moisture barrier qualities of any lipid-based packing. Since lipids are non-polar, they can be added to composite films to increase the moisture barrier's overall strength. In addition to these, lipids have distinct flavors and greasy surfaces. Plants and animals can yield edible waxes, which are lengthy chains of alcohol and esters. These coatings can lessen the permeability of water vapor since they are hydrophobic. Freshly cut fruits can be covered with gel that has been derived from the aloe vera plant. They have a semi-solid shape and range in color from brown to yellow. The tomatoes and green chilies have been coated with a resin-based substance. In addition to providing gloss and transparency, the coating acts as a barrier against oxygen and water [17] Plants and oil are used to extract fats and oils. Triglycerides are the main component of fat and oil. There are antibacterial qualities to the essential oil. They are hydrophobic and volatile. Lipids and hydro colloids both exhibit phase separation when employed to create edible packaging [18]

**5 Production of edible film and coating** The most common methods for applying edible materials on food are coating, spraying, immersion, or forming them in front of a film and employing it as food wrap [19].Edible films can be made in two different ways: wet and dry

**5.1 Wet process**   
The wet procedure creates a food film by combining the film-forming ingredients with a solvent and then drying the mixture. The casting method is primarily used to illustrate this procedure. The most popular technique for creating edible coatings and films at the laboratory and pilot scales is casting. Three phases are involved in this process. The initial step in making films is usually to dissolve or disperse the raw materials in either alcohol water a combination of the two, or a combination of other solvents. Additives such as coloring or flavoring compounds, plasticizers, and antibacterial agent[20] ..It could be necessary to raise the solubility by heating the solutions or adjusting the ph Following casting the film-forming solution is dried at the ideal temperature and relative humidity which are the second and third a step toward making pictures that stand alone. The casting phase involves pouring the film-forming solution into a glass plate coated with Teflon or a pre-made mold. The solvent that forms a polymer layer that sticks to the mold can evaporate during the drying process. Hot air ovens, tray dryers, microwaves, and vacuum dryers are examples of air dryers that are used during film casting in order to facilitate solvent removal and film peeling [21].

**5.2 Dry process**

In the dry processes, added components were converted into the film by utilizing the thermoplastic behavior at low moisture levels . The wet processes consist of the film by extrusion, compression molding, and injection molding The extrusion process is another method of producing edible films on a commercial scale which consists of three zones: feeding zone, kneading zone, and heating zone. This method alters structural properties and enhances the physio-chemical characteristics of extruded substances. In the feeding zone, the film components are mixed and air compression is used to reduce the moisture content of these components. This process is also known as a "dry process" because it functions best with a small amount of water or solvents. As the ingredients move through the kneading zone the strain temperature, by adjusting the speeds enable the addition and removal of stabilizers and other additives and density of the mixture rise. Then they are heated above their glass transition temperature to convert into a melt form, which is extruded through a suitably- shaped nozzle by rotating forces of an extrusion screw. The resulting material is then subject to cooling to the formation of the film [22] They used mechanical and thermal energy in this process to create the extrusion based film. Screw speed also has some impact on specific mechanical energy. Different screw speeds alter film properties, such as its homogeneity, and stress and control the residence time which allows for the addition and removal of additives including stabilizers.The torque value of the technique used to generate films through extrusion decreases as screw speed increases. Energy input, barrel temperature, screw speed, die diameter, die pressure, feed moisture content, and other variables[23].

**6 Advantages of Edible packaging**

These packaging materials do not damage animals and can be eaten directly with food products [24] When certain naturally occurring bio-active substances and agents are added to edible packaging, it serves as a carrier for the globally triggered dosage release of vitamins, antioxidants, and antimicrobial into the particular alimentary matrix as shown in (fig 1 ).It can also aid in improving food quality and lowering the microbial load.Any kind of food product is covered with a thick layer that prevents oxygen from escaping and causing the food products to lose their flavor. Anaerobic respiration occurs in fruits and vegetables due to the edible coating's significant function as a gas barrier, delaying the ripening process. Additionally, some edible packaging materials are hygroscopic, which helps to prevent the growth of microorganisms .Although edible materials have several advantages over synthetic materials it is still unknown how beneficial some of these features are. In addition to preventing the loss of moisture, scents, and ingredients between foods, edible packaging can serve as a substitute and possible strengthening of the outer surface layers of packaged goods. It also allows for the controlled exchange of carbon dioxide, oxygen, and ethylene—essential gases involved in the respiration of food products [25]. (Additionally, edible packaging can improve the organoleptic qualities of packed meals by adding different flavors and colors and adjusting surface characteristics (such as hydrophobicity and hydrophilicity). Furthermore, these can act as a carrier of useful elements that may have further advantages for health or well being [26].

Comparing polysaccharides and proteins to lipids, the hydrophilic nature of the former results in reduced moisture resistance and barrier qualities [27]. Proteins have a fair amount of mechanical strength and can be applied to fruits and vegetables to keep them from getting damaged during transit, while polysaccharides are also good oxygen barriers.

**6.1 Disadvantages of Edible packaging**

Conversely, lipids have comparatively strong moisture barrier qualities and low water vapor permeability. The color, flavor, sweetener, and salt concentrations are typically preserved in lipid-based edible packaging, which is frequently opaque, slippery, and waxy tasting [28]. However, due to their relative thickness and ease of breaking, lipids have poor mechanical and optical qualities. Additionally, these polymers can have poor adherence to hydrophilic food surfaces . It is suggested that the composite edible packaging enhance the necessary qualities based on the eventual use for various food items. Composite films often consist of hydro colloid components supported by a polysaccharide, a protein, and a lipid layer, or lipid material distributed inside a polysaccharide or protein matrix [29] These kinds of edible packaging suggest combining at least two ingredients, with the addition of the other ingredient compensating for the weakness of the separate ingredients. Adding lipids, for example, can increase the water vapor permeability of proteins and polysaccharides, creating an edible composite with both hydrophilic and hydrophobic qualities.It is also possible to modify the overall mass transfer in consumable material and enhance the mechanical strength of lipids by adding proteins or polysaccharides. Innovation in the edible packaging industry has the potential to become a commonplace aspect of consumers' lives. Edible packaging can make a significant contribution to the fight against plastic waste pollution, but it is unlikely to be the answer.

**Fig 1 : Benefits of edible food packaging**.

**7 Applications of Edible Packaging**

The food being packaged and its storage conditions have an impact on the choice of material used to create edible packaging. The various kinds of ingredients utilized to coat and film food items include lipids, carbohydrates proteins as well as two or more of these mixtures. According to [30] Edible packaging is crucial for prolonging the shelf life of food goods. The following explains how edible packaging is used on different food items as shown in( table 1).

**7.1Fruits and Vegetables**

Microbial growth and gas exchange during storage are the main causes of fruit and vegetable spoiling [31]. Edible packaging materials for fruits and vegetables include mineral oils, paraffin, beeswax, candelilla shellac and waxes. Enhancing the fruit and vegetable natural barrier is the primary goal of edible coating. This coating substance can be consumed as food extends food's shelf life and is environmentally benign[32].

**7.2 Dairy Products**

Dairy products are defined as goods that are produced by processing milk; they may include food additives or other components. Due to changes in dietary habits and population growth, there has been an increase in the demand for milk products especially in developing nations (FAO 2019). Dairy products are a good source of vital nutrients that are necessary for both children's development and adults' continued good health[33]. Cheese quality losses can be reduced by using edible packaging materials. According to [34] These alterations were mostly brought about by the activity of microorganisms and enzymes the formation of undesirable chemicals, modifications in sensory characteristics, and moisture loss.

**7.3 Meats, Poultry, and Seafood**

Edible packaging improves the quality of meat, poultry, and seafood items by reducing moisture loss, preventing oxidation, improving overall appearance, improving sensory qualities, and extending shelf life . It is well known that meat stored in edible films made of carbohydrates would retain its quality better. Carrageenan's weak water barrier qualities, in contrast to polysaccharides aid in preventing moisture loss when applied to fresh and frozen meat, poultry, and fish . The application of this packaging technique entails several steps, such as spraying.

**Table 1:Application of edible packaging on different foods**

|  |  |  |  |
| --- | --- | --- | --- |
| **Foods** | **Edible food packaging** | **Outcomes and result obtained** | **References** |
| Strawberries | Pectin, lemongrass essential oil and cellulose nonocrystals. | The edible coating is effective to minimize weight loss without affecting the chemical parameters. | Velickova, E., Winkelhausen,E.,Kuzmanova, S., Alves, V. D., & Moldão-Martins, M. (2013). Impact of chitosan-beeswax edible coatings on the quality of fresh strawberries (Fragaria ananassa cv Camarosa) under commercial storage conditions. LWT-Food |
| Orange | Salicylic and aloe vera gel. | It help to maintain the quality during cold storage and inhibits growth of microorganism. | Maftoonazad, N., & Ramaswamy, H. S. (2019). Application and evaluation of a pectin-based edible coating process for quality change kinetics and shelf-life extension of lime fruit (Citrus aurantifolium). Coating |
| Tomatoes | Almond gum and gum arabic. | Increase the self life and effect change in weight, firmness Titratable acidity TSS, Color, Vitamin C content and deacy percentage of tomatoes. | Nawab, A., Alam, F., & Hasnain, A. (2017). Mango kernel starch as a novel edible coating for enhancing shelf-life of tomato (Solanum lycopersicum) fruit. International Journal of Biological Macromolecules, 103, 581-586. |
| Paneer | Casein and clove bud essential oil. | Maintains the sensory quality of paneer. | Cardador, M. J., & Gallego, M. (2016). Origin of haloacetic acids in milk and dairy products. Food Chemistry, 196, 750-756. |
| Cheddar | Cheese, linalool, carvacrol and thymol. | Reduce the growth of A. Niger on the surface of cheddar cheese after 35 days of storage at 15c | Cardador, M. J., & Gallego, M. (2016). Origin of haloacetic acids in milk and dairy products. Food Chemistry, 196, 750-756. |
| Kashar Cheese | Sorbitol, alginate, and ginger essential oil. | Decrease the growth of E. coli. | Suhag, R., Kumar, N., Petkoska, A. T., & Upadhyay, A. (2020). Film formation and deposition methods of edible coating on food products: A review. Food Research International, 136, 109582. |
| Fresh pork | Grape seed extract, nisim, and chitosan alginate. | Inhibit pork Oxidation and microbial spoilage. | Krishna, M., Nindo, C. I., & Min, S. C. (2012). Development of fish gelatin edible films using extrusion and compression molding. Journal of Food Engineering, 108(2), 337-344. |

**8 Physical and mechanical properties**

Food items are shielded from physical harm by edible packaging materials like coatings and films. Impact or pressure (compression) are two examples of mechanical variables that might cause damage. Standard mechanical tests are employed to assess the edible film's strength. Tests are required to ascertain the film's tensile strength, tearing strength, elongation at the break point, and abrasion resistance. Generally speaking, edible films are less tensile strong than traditional packaging films made of plastic. When it comes to elongation, edible films can outlast plastic ones. Unwanted particle and scent component penetration degrades food quality and influences consumer approval of the product [35]. The coating in edible films acts as a moisture barrier and lessens the movement of nutrients from food to the environment.

.By forming a barrier, these coatings lessen the amount of oxygen that is transferred between the environment and the meal. This prolongs the food product's shelf life by slowing down the pace of food oxidation. Excessive atmospheric moisture has an impact on the film's physical durability. Tensile strength, film integrity, and barrier qualities are compromised when the moisture content interacts with the edible polymer matrix. Because they are hydrophilic, polysaccharides and protein-based edible films will lose some of their structural integrity and the food product will not be protected by the packaging. Edible waxes like candelilla and carnauba are typically added to hydrophilic bio polymers.These hydrophobic waxes keep the film's structural integrity intact by forming a barrier against water vapor..

**9 Regulations**

The edible packaging must adhere to food safety requirements since it is an essential component of the food products' edible portion. For the formulation of films and coatings, food components and additives that are approved by Codex Alimentarius, the US Food and Drug Administration, or EU standards may be utilized. The edible packaging materials can be classified according to their role as food contact materials, food packaging materials, food products, or food additives. A number of edible coatings and films contain substances that can cause allergic reactions in certain users. Thus, it is necessary to appropriately label any coating that contains a known allergy.It is forbidden to utilize organic solvents in the manufacturing of edible packaging materials because they can contaminate food items and cause more toxicological problems. To guarantee adherence to food safety rules, all edible packaging materials must be certified by official food safety institutes and must not be harmful to human health. In order to guarantee the safety of edible packaging materials, local and federal food safety regulations must be followed during development and use.Marketing techniques like awareness campaigns, price reductions, and advertising should be employed to draw clients. It is essential to adhere to good manufacturing practices (GMP) while using edible packaging materials and additives [36]. Since eggs, fish, milk (casein and whey), wheat, peanuts, and soy proteins make up the edible packaging materials, it must disclose all information to consumers in accordance with the Food Allergen Labeling and Consumer Protection Act of 2004 [37].

**10 Conclusion**

All manufacturing sectors have been compelled to adapt their methods due to the need for sustainable packaging solutions, which has had a major impact on the packaging sector as well. When opposed to plastic packaging materials, edible packaging is acknowledged as being more affordable, sustainable, biodegradable, and healthful. The edible packaging, which includes coatings, sheets, pouches, and films, offers the qualities of an oxygen, moisture, and odor barrier. Edible packaging materials are made from a variety of substances, such as flavorings, additives, antioxidants, and antimicrobials, which improve the handling and packaging materials' quality. Fruits, vegetables, dairy products, meat, poultry, fish, nuts, and cereals are among the foods that are packaged in edible form. It is now crucial to use sustainable and long-lasting packaging materials to prevent food waste and pollution of the environment. In addition to extending food products' shelf lives, edible packaging has shown promise in lowering reliance on petroleum-based resources.

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