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Mainak Debnath
Department of Applied Science and Humanities, Guru Nanak Institute of Technology, Nilgunj Road, Panihati, Sodepur, Kolkata, West Bengal, India

Sreyasree Basu
Department of Applied Science and Humanities, Guru Nanak Institute of Technology, Nilgunj Road, Panihati, Sodepur, Kolkata, West Bengal, India

Indrajit Bhattachayya
Department of Applied Science and Humanities, Guru Nanak Institute of Technology, Nilgunj Road, Panihati, Sodepur, Kolkata, West Bengal, India

Oindrila Mazumder
Department of Food Technology, Guru Nanak Institute of Technology, Nilgunj Road, Panihati, Sodepur, Kolkata, West Bengal, India

Corresponding Author
Sreyasree Basu
Department of Applied Science and Humanities, Guru Nanak Institute of Technology, Nilgunj Road, Panihati, Sodepur, Kolkata, West Bengal, India

Edible food packages: An approach towards sustainable future

Mainak Debnath, Sreyasree Basu, Indrajit Bhattachayya and Oindrila Mazumder

Abstract
Packaging is the covering of a material that not only protects it from being destroyed or spoiled but also increases the shelf life. Food packaging plays an important role to make a product stand out on the shelf as well as protects them from chemical, physical and environmental factors that can contaminate them. Thus, it is important to study the proper packaging types and the latest packaging trends to stay competitive in the global food market. Since the conventional packaging materials are generally found to be wasted and not suitable for reuse, demands for edible food packaging materials offer a better solution minimizing the environmental hazards.
Edible food packaging materials are often described as the covering of a thin continuous layer of edible materials placed on or between the fruits or vegetables that can be completely consumed. These materials are generally biodegradable as well as sustainable and thus can be easily treated as an integral part of the food staff. Moreover, they function as an efficient moisture and oxygen barrier with low oxygen permeability and physical protector and play an important role in reducing Municipal Solid Wastes (MSW) like common non-biodegradable packaging materials that have found to pose substantial threat to human race. The present article mainly aims to focus on a detailed survey on various edible food packaging materials and how they are able to minimize health hazards for next generation sustainability.

Keywords: Edible packaging, pollution, covering, packaging, food

1. Introduction

Food Packaging is considered to be an important aspect of packaged food items that not only assures the food quality and manufacturing details but also provides an added safety, freshness and hygienity and thus maintains the color, odor and other characteristics of the food within for a considerable period of time. Different non-biodegradable materials like, metal, plastics, glass, polymer, etc. are popularly used as common food packaging materials all over the world [1]. Among these, plastics, polymeric materials and plastic resins like Polyvinyl Chloride (PVC), polyethylenes and polystyrenes are easy to mold to any desired shapes and hugely used in food packages. To preserve canned food and beverages, steel, tin and aluminium are mostly used as the packaging material in the commercial food market. Glass being impermeable to gases and vapours are found to be useful for packaging in certain materials. These packaging materials may sometimes create several environmental and health hazards since they are difficult to reuse and recycle. On the other hand, paper cardboard, woods and few biodegradable polymers such as bioplastic which is made out of cellulose and easily breakdowns to water, carbon dioxide, inorganic compounds on decomposition [2, 3, 4] finds their applications in the preparation of biodegradable food packaging. Unlike the non-biodegradable packaging materials, completely biodegradable stuffs that are derived from consumable items and thus can be safely consumed along with the food itself are considered as the most suitable candidates to manufacture edible food packages. The outer coverings of some fruits and vegetables like apple, strawberry etc. can also be considered under this particular category. Thus Edible food packaging materials, such as, films, sheets, pouches or capsules made of different materials like, proteins, polysaccharides, lipids, resins, and other consumable contents are not required to get wasted, rather can be safely consumed and thus easily discards the possibilities of pollution. Common edible food packaging materials, such as Japanese rice candy, edible straws, ice-cream cones (of waffle, wafer, sugar) that can be directly put on to the food surface are found to be less permeable to oxygen and are proved to be an efficient moisture and aroma barrier. Moreover, they protect the food materials by minimizing the chances of oxidation, allow controlled exchange of essential gases like carbon dioxide, ethylene, etc., maintain the food quality along with other issues (like efficiency of food preservation, product stability, variety and convenience for consumers) and contribute efficiently in economic improvement [5, 6, 7, 8, 9, 10] [Figure 1].

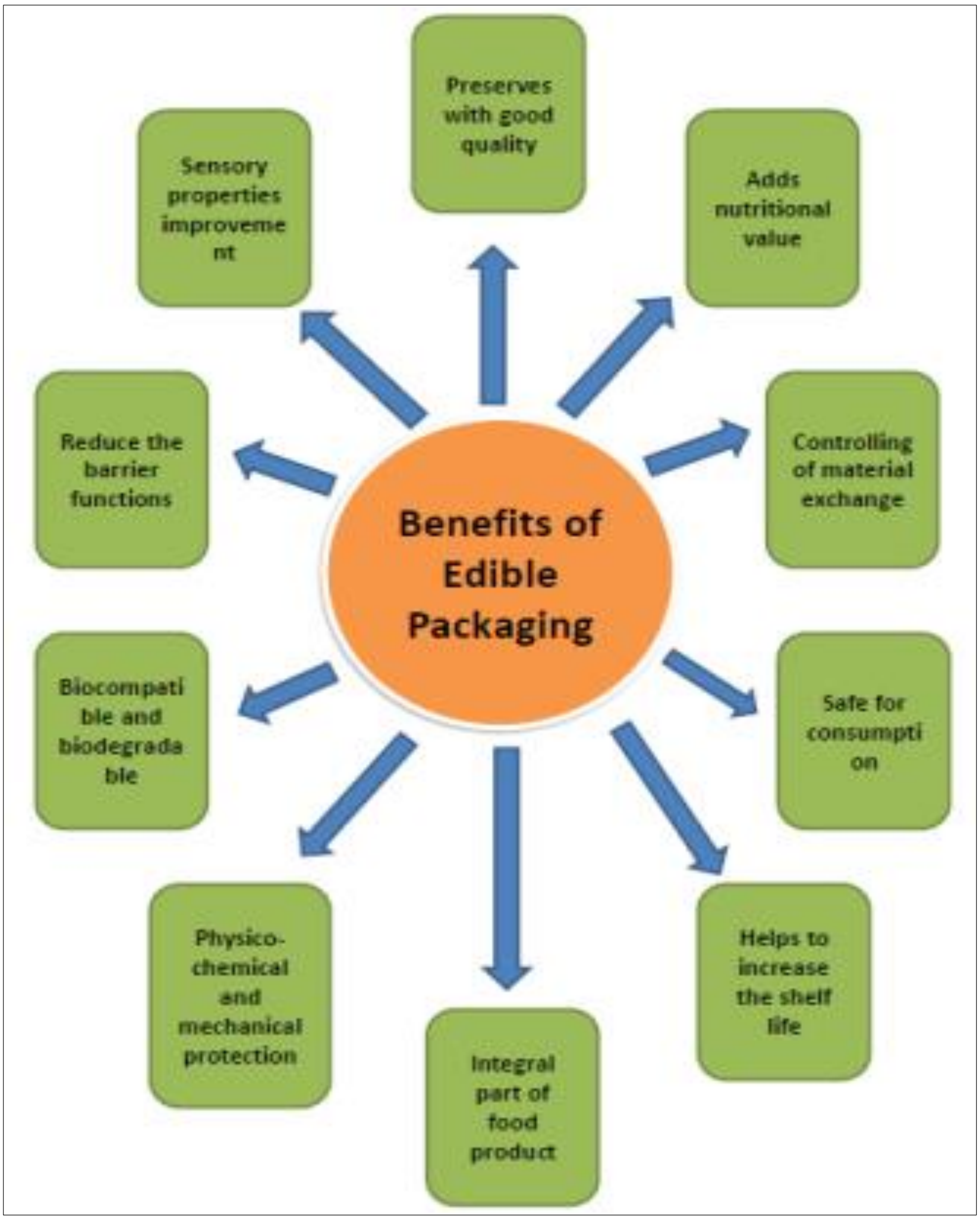

Fig 1: Benefits of edible packaging

2. Types of Edible Food packaging

Depending on the method of production and the manufacturing materials, such as, polysaccharides, protein and lipids [11], edible food packages are classified into different categories. Edible packaging materials are conventionally prepared by dissolving edible food materials into water, alcohol or a mixture of solvents, where plasticizers are often added to the mixture to enhance the flexibility and elasticity of the resulting material. Edible films are produced by various processes, such as continuous film casting, mold casting and drawdown method [12].

2.1 Protein-based edible packaging

Protein based edible packaging materials are found to be suitable carriers for antibacterial and antioxidant agents. They are commonly used to pack beans, nuts and cashew nuts [13]. Popular materials under this category include collagen, wheat gluten, corn zein, soy protein, wheat protein and mung bean protein. Besides these, emulsified film can be produced from Caseinate that exhibits an amphiphilic character of both fibrous and globular proteins [14] and thus finds widespread applications in the packaging industry. Such films are found to offer efficient barriers to oil, oxygen and aroma but provide limited resistance to moisture [15].

2.2 Polysaccharides based edible packaging

Polysaccharides that are derived both from animal and plant resources are also commonly used as important ingredients to manufacture edible food packages. Chitosan, which is well known for its antibacterial and antifungal activities [16], is a cationic polysaccharide and is derived from animal resources to make edible packages. On the other hand, pectin, alginate, carrageenan, gum xantan and starch are the examples of polysaccharides that originate from plant bodies and replace traditional plastic packaging significantly. There are few polysaccharides that offer selective permeability to oxygen and carbon dioxide, resulting in prolonged shelf life [17, 18].

Cellulose and its derivatives like starch are made of amylase and amylopectin. These polysaccharides are mostly colorless, tasteless, odourless, transparent or translucent [19, 20] biodegradable substances with low application cost. Pectin group of polysaccharides which are anionic in nature, are derived from fruits and vegetables, mostly from citrus peel and apple pomance [21] and are commonly used for gelling, stabilizing and thickening of food products like yogurts, jams, ice-creams and milk [22]. Arabic gum, obtained from stems of various acacia species, is also commonly used in food industries due to its emulsification and film-forming properties [23].

2.3 Lipid based edible packaging

Like protein and Polysaccharide based edible packaging materials, Lipid based food packaging stuffs such as Oils and fats derived from both plants and animals are also well known for their applications in food package manufacture. Essential oils that is rich in hydrophobic and volatile compounds exhibit antimicrobial activity due to terpenes, terpenoids and other aromatic constituents [24] are commonly used for this purpose. Waxes derived from esters help in reducing the moisture permeability due to high hydrophobicity and thus are used as edible packaging [25, 26]. Resins such as Shellac, which is a complex mixture of aliphatic and alicyclic hydroxyl acid polymers are mostly derived from plants and commonly used as the coating of pharmaceutical products [27, 28].

3. Functions, properties and application

Edible packaging inhibits moisture exchange between the food products and the atmosphere. Detail studies also prove that the water vapour permeability of edible packaging is also quite low compared to other packaging materials [6]. Mostly degradation in the food quality results from the oxidation of lipid or other food ingredients. Edible packaging also offers suitable solutions for this problem, too. Due to low oxygen permeability, they increase the shelf life [6]. Moreover, they offer efficient barriers to volatile organic compounds, which prevents food materials from losing volatile flavour or aroma and thus the food quality is also preserved [6]. Edible coatings based on hydrocolloids are found to retain moisture and reduce fat uptake in deep fat fried food [28, 29].

Edible packaging materials are popular for their use as a matrix and carrier of different functional additives that offer additional nutritive and health benefits to the packaged food [30]. In order to enhance the shelf-life and/or increase the nutritional value of the final packaged food stuffs, different antimicrobial and antioxidant substances, prebiotics or other nutrients are conventionally added to edible matrices [31, 32]. Plasticizers like glucose, sucrose, glycerol, lipids, phospholipids, fatty acids etc [31] are often added with the materials to improve the mechanical property [33] and enhance the flexibility and durability of the edible packaging materials. Emulsifiers having both polar and non-polar character are capable of modifying interfacial energy at immiscible systems, such as, water-lipid or water-air surface [33] and thus find applications as popular additives in such manufactures. Natural and synthetic antimicrobials, such as, organic acids, nisin, chitosan, and some plant extract (like cumin, clove, etc.) and their essential oils [31] serve as additives to prevent microbial growth [33]. Chitosan is not only well known for its antimicrobial activity but also restricts toxin production and thus has been found to be very effective against yeast and molds. Oil extracts from plants, like grapefruit seed, allspice, clove, rosemary, onion, garlic, and oregano, provide many biological effects like antioxidant and antimicrobial activity and thus could be used as antimicrobial agents without labeling [34, 35]. A brief summary on applications of edible food packaging materials has been provided in Table 1 [36].

Table 1: Applications of edible packaging on some important food products [35]

Name of the Food Product	Edible materials	Beneficial effect
Banana	A rice starch edible coating blended with sucrose esters.	Post harvest quality during ripening (at 20 ± 2 ◦C) is extended; effective in delaying ethylene biosynthesis and reducing respiration rate. Shelf life prolonged for 12 days.
Lime fruit	Pectin-based coating.	Progressive increase in shrivelling or wilting and loss in green colour during storage time; higher temperatures accelerated these changes.
Grape berry	Coatings based on carnauba wax-lemongrass oil nano-emulsions.	Antimicrobial effect by inhibition of Salmonella typhimurium and Escherichia coli. Effective at reducing weight loss, firmness, phenolic compounds, and antioxidant activity.
Strawberry	Prickly pear cactus mucilage (Opuntia ficus indica). Composite films made from banana starch-chitosan and Aloe vera gel (AV) at different concentrations.	Extended shelf-life. Reduced fungal decay, increased shelf life up to 15 days during storage at 20% AV gel, while maintaining physicochemical properties (colour and firmness). Weight loss reduced 5%; limited water vapour transfer.
Strawberry (fresh cut)	Gellan-based coatings (Gel) with Geraniol (G) and Pomegranate extract (PE) incorporation (in different concentrations).	Gel + G coatings significantly reduced microbial counts; improved microbiological stability. PE incorporation did not control microbial growth. Samples with coatings + G showed a better firmness loss than control.
Blueberries and raspberries	Carrageenan and green tea extract.	Antiviral activity against murine norovirus, hepatitis A virus.
Strawberries and raspberries	Alginate-oleic acid based coatings with green tea.	Antiviral effect against food borne pathogens.
Tomato	Aloe vera based edible coating.	Delayed ripening and extended shelf life (up to 39 days compared to 19 days for control sample).
Cherry tomato	Edible film incorporated with chitosan and liposome encapsulation of Artemisia Annua oil. Edible coating based on nanoemulsion-thymol-quinoa protein/chitosan	Inactivation of Escherichia coli O157:H7. Inhibition of Botrytis cinerea.

Brocolli (fresh cut)	Chitosan coatings with bioactives: tea tree, rosemary, pollen and propolis, pomegranate and resveratrol.	Inhibitory effects on survival of Escherichia coli and Listeria monocytogenes
Green beans	Antimicrobial coating formulation consisting of modified chitosan containing a nano-emulsion of mandarin essential oil.	Reduction of L. Innocua over the storage time, owing to synergistic antimicrobial effects. A strong impact on green beans firmness.
Sliced ham	Na-alginate edible films as vehicles for delivering probiotic bacteria. Oregano essential oil (OEO) incorporated in Na-alginate edible films.	Probiotic bacteria successfully delivered in the products by edible films. Reduction of Listeria population. Presence of OEO in the films resulted in colour differences which compared to control samples was the decrease of the product's quality, whilst the aroma of samples was improved.
Muscle foods	Collagen edible films.	Reduced moisture loss, minimized lipid oxidation, prevented discoloration, and reduced dripping.
Lamb meat	Nano-encapsulated Satureja khuzestanica essential oils (SKEO) in chitosan coatings (containing free or nano-encapsulated SKEO).	Effectively retarded microbial growth and chemical spoilage; encapsulation decelerated release of SKEO and led to prolonged antimicrobial and antioxidant activity; improved sensory attributes.
Shrimps	Bilayer films based on agar and Na-alignate with cinnamon oil.	Antioxidant activity; effective against photobacterium phosphoreum
Fresh pork	Chitosan-gelatine edible coatings incorporating grape seed extract and/or nisin.	Effectively inhibited pork oxidation and microbial spoilage; grape seed extract further enhanced antioxidant activity against meat oxidation, but incorporating nisin into the coating did not further improve the antimicrobial and antioxidant effects.
Beef meat	Antioxidants naturally present in olives, hydroxytyrosol (HT) and 3,4-dihydroxyphenylglycol (DHPG) added to a pectin-fish gelatin edible film. A new composite film included beeswax is also compared	Film with antioxidants reduced formation of oxidation products compared to control film without antioxidants. Suppressed lipid oxidation. Combined effect of acting as an oxygen barrier and the specific antioxidant activity of beeswax-based composite film (lipid oxidation was supressed, stored for 7 days at 4 0C).
Sea bass (Dicentrarchus labrax) fillets	A combination of liquid smoke and thymol encapsulated in chitosan nanofibers.	Delayed growth of total mesophilic aerobic bacteria, psychrophilic bacteria and yeast and mold during storage period.
Cheese	Edible coatings based on: sodium alginate, sodium alginate + Lactobacillus acidophilus and sodium alginate + Lactobacillus helveticus	The L. acidophilus and L. helveticus inclusion in edible coverings reduced the total coliforms presence at 10 days. Probiotic bacteria reduced coating flexibility. Lactobacillus helveticus added in the cover diffuse to the cheese interior, ensuring that the cover can be a vehicle for dairy bacteria.
Nuts	Chitosan incorporating green tea extract, carboxymethyl cellulose (RP-CMC), methyl cellulose (RP-MC) and whey protein (RP-WPI).	Antioxidant and antifungal effects: Significant inhibition of lipid oxidation and fungal growth, Chemical indicator values and intensity ratings of oxidized and cardboard flavors had lower increase during storage. The stability of RP-CMC is approximately twice as long with respect to RP.
Bakery Muffins, Fruit bars	Triticale-based edible film coating, Edible films based on sodium alignate, carboxymethyl cellulose and whey protein isolate.	Retard the staling process, No significant effect on chemical properties. Maintained textural properties, limited moisture loss, loss of total phenolic content and radical scavenging activity during storage was prevented.

4. Advantages of Edible Food Packages and Customer acceptance

Edible packaging provides replacement and potential barriers for the layers at the outer surface of packaged products that prevent loss of moisture, aromas and ingredients out and between the foods. Moreover, they accelerate controlled exchange of essential gasses, such as, carbon dioxide, oxygen, and ethylene that are involved in food product respiration [37, 38] Edible packages provide various flavors and colors and reduce surface properties like hydrophobicity, hydrophilicity that enhances the organoleptic properties of the packaged foods and thus serve as a carrier of functional components with potentially added health or well-being benefits [39-42]. Lipid-based edible packages usually preserve the color, flavor, sweetener and salt concentrations though they have poor mechanical and optical properties due to their thickness, fragility and hydrophilic nature [39, 42-45].

Recent studies reveal that the preparation methods, types of the additives, nature of the materials, such as, the composition, molecular properties, crystallinity index etc, of the package forming materials can significantly affect the digestibility and digestion rates. Although edible packages are consumed along with the contained food often, very few evidences on biodegradability and edibility of the packaging materials are reported in literature [46]. The acceptability of edible food packages from customers significantly depends on several factors, such as, the film appearance, organoleptic properties, marketing cost etc. Thus in order to draw customer attention, it is important to emphasize on marketing strategies, such as, conduction of awareness programs, price discounts along with attractive offers and advertisements [46]. Moreover, special care related to the labeling strategies like information regarding allergens and presence of animal derived materials [40] should be properly incorporated and all ingredients used for making an edible film must attain Generally Recognized As Safe (GRAS) status, as per Food and Drug Administration (FDA) regulations [40] to improve the customer acceptability. Issue related to Customer acceptance can also be improved through suitable cost-benefit analyses and adapting edible films or packages the cost of which should be lower than or equal to petroleum derived plastics.

5. Nanotechnology in edible packaging

Development of nanoscale edible coatings (around 5 nm thickness) that contain essential- bioactives are found to enhance smart packaging options [47-51] and thus being expected to be potentially promising materials to manufacture edible packaging for food like meat, cheese, fruits, vegetables, confectionery, bakery and fast food items. Like other edible coating materials, these nanoscale coatings not only provide efficient moisture barrier for food stuffs but also control gaseous exchange, act as vehicles to deliver color, flavors, antioxidants, enzymes and anti-browning agents and thus enhance the shelf life of manufactured foods [52-57].

Conventionally, nanopackaging is manufactured with nanoparticles or nanomaterials that possess different chemical and physical properties than that of larger particles [51, 56].

Nanoparticles, such as, silver, gold, iron, zinc oxide, silicon dioxide, titanium dioxide, titanium nitride, alumina, iron oxide, copper, copper oxides, gallium and palladium [58-61] are incorporated into edible packaging materials to improve the mechanical, physical and barrier properties of the coatings that leads to the manufacture of reinforced edible materials commonly known as 'nanocomposites' [52, 56, 57, 60, 62-64]. Besides these, nanoparticles like nanostarch, starch nanocrystals, chitosan, nanoclay, and nanocelluloses [51, 54, 65-69] that are well known for the preparation of nanoparticle based edible coatings are also derived from non-metals, clays or organic materials [51], food grade biopolymers such as polysaccharides, proteins or natural bioactive compounds (e.g. curcumin, lipids) and naturally occurring compounds with antimicrobial and antifungal activities [70-71].

Though recent studies reveal that the demand for food products derived from nanotechnology will grow very fast among the consumers worldwide in near future [52, 72], more knowledge and rigorous analysis on standard test procedures to study the potential hazards relating to human exposure to nanoparticles originating from food stuffs are yet to emerge.

6. Conclusion

Edible packaging is the ones which can be used for packing food by increasing food preservation capacity, shelf life and other properties, without wasting materials or reduced pollution in the environment. It is efficient but also sometimes costly and otherwise products to be used for the packaging are not easy to receive.

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