Chapter 1
Edible Food Packaging: An Introduction

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1.1 Introduction

Edible food packaging is defined as a customized and sustainable packaging practice that can be consumed with the food product or can be removed before eating the edible packaged food, where the packaging materials have the characteristics features of biodegradability similar to the food materials. The current trend towards making a sustainable world, food processing industries are continuously developing the sustainable packaging materials as a replacement to available conventional packaging materials. The petrochemical plastics generate environmental pollution such as production of toxic components, increase in plastic-based waste. [1, 2]. In the USA, about one third of municipal wastes are generated from packaging and containers [3]. In this regard, several available biobased materials are continuously utilized for the upbringing of sustainable packaging due to their versatile nature such as non-toxicity, biocompatibility, biodegradability, renewability, easily available, degrade faster, no greenhouse gas emission, reduce carbon footprint. [1, 2, 4, 5]. Additionally, the food packaging is a very essential component for delivering the food products to targeted consumers in a safe condition. The benefits of using plastic packaging materials include flexible nature, versatility, lightweight, economic value, etc. Adversely, the drawbacks of using plastic as packaging materials include degradation of the environment, durability, generates harmful agents to the environment, etc. Thus, the plastic packaging materials are focused to be tailored for the various characteristics attributes, such as development of sustainable packaging materials in terms of edible or inedible packaging, which has an ability to reduce the generation of harmful agents to the environment.

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The use of edible films and coating started in the twelfth and thirteenth centuries [6] and now is one of the dominant food packaging materials throughout the world. This kind of packaging may be obtained in different forms and being developed from several substances. The development of edible packaging based on available materials generally selected targeting the food products. Further, the use of different edible materials should have the status of generally recognized as safe (GRAS) according to Food and Drug Administration (FDA). The most familiar use of edible packaging for consumers is found as the ice-cream cone, where waffles or sugar-based cones are utilized to carry ice-cream. The several innovations and development of edible ice-cream container [7], edible films for sundae ice cream cones (as moisture impermeable barriers) [8], combine edible cone and ice-cream [9] have put a remarkable impact in reducing the waste due to edible nature of the ice cream containers. Further, a fruit-like casing, known as WikiCell, has been developed by a company, viz. WikiFoods, which surrounds the foods, and further, the casing can be broken similar to the skin of the foods [10]. The WikiCell is a kind of film-like membrane having characteristics attributes of biodegradability, thin, soft, and held to carry a small portion of food products, which plays a role in replacing the plastic materials. The others include which are not available in the market are sugar casings, seaweed packaging, beeswax container, etc. The development of edible coffee cup using a hard cookie lined with a chocolate layer provides heat-resistant property. Further, cupcake wrappers and candy wrappers are also developed from starch (from potato fibers) and rice paper, respectively. The food-based industries such as grains, sugar, beverages, edible oils, fruits and vegetable processing industry, dairy industry, poultry processing industry, meat processing industry, fisheries, etc., are focused to utilize edible food packaging for reduced waste. Interestingly, the edible films and coatings as edible food packaging materials have a great deal of interest in both research and development section and industrial section because of the greenery and sustainable approaches. In this regard, the biobased polymers (as shown in Fig. 1.1) are thoroughly researched for the development of edible food packaging materials including cellulose, starch, chitosan (CS), gum arabic (GA), carrageenan, pectin, proteins (Sources: casein, whey, soy, zein, wheat gluten, cottonseed, collagen, egg white, wool keratin, collagen, etc.), lipids and waxes (fatty acids, acylglycerols, carnauba wax, beeswax, candelilla wax, rice bran wax, mineral oils, vegetable oils, paraffin wax, etc.), resins (wood rosin, shellac), etc. [11–29]. Ideally, the edible food packaging provides a remarkable opportunity in the innovations of food packaging materials due to their biodegradable nature.

However, the global market size of edible packaging is done based on (1) available sources such as plants and animals; between 2019 and 2025, among the two available sources, the plant-based sources are dominating the current market trends of edible packaging; (2) available input materials such as polysaccharides, proteins, lipids, waxes, plasticizers, and additives; (3) end use of developed materials such as pharmaceuticals, food packaging, beverages, edible cups,

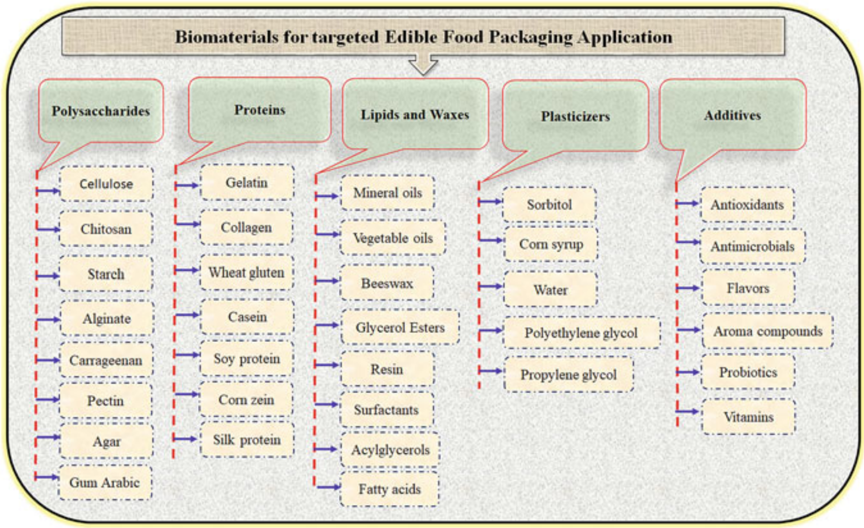

Fig. 1.1 Targeted biomaterials for Edible Food Packaging

cutlery items, fresh foods, baby foods, etc.; (4) targeted packaging application such as antimicrobial packaging, edible coatings, edible films; (5) regions such as North America, Asia-Pacific, Europe, South America, and others, etc.

Moreover, there are many benefits of using edible food packaging in regard to other available packaging materials such as the edible packaging are eatable, edible packaging have a biodegrading nature within a very short period of time, no waste cycling is required, provide health beneficial agents to human health, etc. Additionally, this kind of packaging is used as single-served food products. The limitation of edible packaging includes the water solubility of edible packaging, which may degrade the quality at humid climates; further, edible packaging needs another packaging material as secondary packaging for the transportation of the products due to hygiene concern. The edible food packaging should be compatible with consumers, where some of the edible packaging's may create allergies due to variations in components. The chapter will give an overview of the available food preservation techniques giving an emphasized focus on edible food packaging, related aspects including the use of nanotechnology in edible food packaging. Additionally, in this book, the emerging research fields related to nanotechnology in edible food packaging will be discussed.

1.2 Overview of Edible Food Packaging: History Outline, Classification and Current Prospects

1.2.1 Edible Coating: A Class of Edible Food Packaging

The edible coating is commonly used as a food preservation approach, where various edible materials are used to provide a thin layer of barrier on targeted food products. In the twelfth century, the edible coating was noted to be developed in China for the first time to coat citrus food products (oranges and lemons) using waxes to prevent water loss. In England, the lard or fats are used to develop a coating material on meat products during the sixteenth century, which was known as larding. During the 1930s, the citrus food products are coated with hot-melt paraffin waxes. In later days, the fresh fruits and veggies are coated with the aid of carnauba wax and oil-in-water emulsions. In the past days, the various beneficial properties of edible-coated food products were not well known by the consumers, which resulted in their unacceptability. However, the edible-coated food products obtained consumers' acceptance after they became familiar with the beneficial properties of edible-coated food products. The edible coating can be obtained by utilizing various kinds of approaches such as dip coating, spray coating, foaming, brushing, wrapping, dripping, fluidized bed coating, and panning, which help to create a barrier between the food product and the external environment. The inclusion of edible coating also helps to improve the appearance of food products with the aid of edible materials on the surface of food products. The edible food packaging in terms of coatings is used to give a semipermeable barrier against harmful environmental agents such as light, temperature, gaseous agents, microbial agents, etc. Further, this kind of postharvest preservation technique is extensively utilized for reduced respiration rate, maintaining weight of fruit products, total soluble solids, appearance, and others. The respiration of fruit and vegetables is also affected by storage temperature, time and gaseous conditions, etc. [30, 31]. The application of edible coating is utilized to coat cut pineapple using CS [32, 33], kiwifruits using aloe Vera [34]. The edible coating materials also include the widespread use of biopolymers including polysaccharides, protein, lipids and waxes, bioactive compounds, and others. The materials that are used for edible coating should be safe for human consumption, nutritionally rich, and are accepted by consumers. GA is another kind of polysaccharide used in food industry having several beneficial attributes such as antimicrobial, stabilizers, adhesiveness properties. [35].

The edible coating on food products is obtained by various processes, where dip coating of fruit product is one of the widely used processes. A detailed discussion about the available edible coating approaches has been made in Chap. 2. The dip coating is obtained by dipping the selected food product in selected coating solutions, and drying of the coated food products. In some cases, multiple layers of coating are also applied to obtain more effective food properties. The application of edible coating using dripping (applying the coating materials on the food products) is very cost effective, where the uniform coating can be obtained. Foaming-based edible coating is obtained by using a foaming agent, which is added to coating solution, where compressed air is further blown into the applicator tank. Spray coating involves the spraying of coating solution on the food products; this technique is used when a thin layer of coating is needed on food products. Besides biopolymeric materials, the components from fruits and vegetables are also used for the development of edible food packaging such as purees, pomaces, juices, active components, etc. [36]. The details of potential candidates used in edible packaging will be discussed in Chap. 2. The use of edible coating on food products has several aspects such as providing sweet flavor, enhanced texture of cereal products, reduce moisture loss of dried fruit (using mineral oil), improve appearance in fruits and chocolate candy, use as a carrier for active compounds, reduce mold growth in cheese, smoked fish, reduce fat uptake in fried products, etc. [37]. The critical concerns of edible coating materials include chemical safety, eatable food products, cost, barrier property, shelf life, food quality, nutritive value, environment, etc.

1.2.2 Edible Film: A Class of Edible Food Packaging

The edible films are another class of edible food packaging which have been an attractive packaging material in the current trend of packaging market with the immediate effect in commercialization of developed materials. The term "edible films" has two considerations, where the first term "edible" defines the designing of eatable materials and considered safe, non-toxic and the second term "films" defines about the film-forming properties of the materials similar to packaging materials [6]. Edible films are a thin layer of edible materials including polysaccharides, proteins, lipids and being used as pouches, films, wraps, and others on food products or between food components as sandwich materials. During fifteenth century, the development of edible films using soymilk, known as yuba film was done in Japan, which is the first free standing edible film. The yuba is developed by using denatured soy protein, and the film is used for ground meat, vegetables, and as a component in the soups [38]. The yuba film has gained a popularity in China and Japan having high nutritional and digestible property. Further, the edible films are developed using casting [39], extrusion, and compression molding [40], compression molding [41], and others which can further be used on or between food products. The proper application of edible food packaging depends on various characteristics such as selected food properties, selected materials, effect of materials, cost, etc. The properties of edible films are improved by adding various food additives such as natural food coloring agents, spices, antimicrobial agents, plasticizers, antioxidants, and others, which help in improving film properties such as optical properties, microbial properties, roughness, etc. The focused characteristics features of edible films include biodegradability, enhanced shelf life of food products, improved sensory properties, active functions of films, physical properties, optical properties, etc. The properties of food products are dependent on

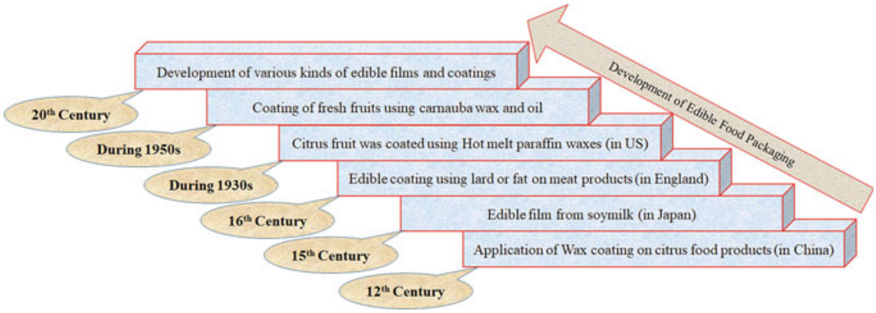

Fig. 1.2 Development of edible food packaging in terms of edible films and coatings

several factors such as film compositions, thickness of the film, transparency, etc. The versatile application of edible films includes as active packaging, oral-disintegrating films, edible oven bags, fruit and vegetable leathers, food wrappings, etc. The edible food packaging in terms of edible films and coatings provides various benefits for improved life of food products by reduced water leakage from food products, reduced gas diffusion, reduced solutes movement, improve appearance of food products, reduce microbial growth, reduce oil and fats movement, and others. The most crucial characteristics features of edible food packaged products are microbiological test, sensory properties, nutritional properties, wettability, mechanical properties, optical properties, etc. Additionally, the edible food packaging is also involved in the encapsulation of active compounds, aroma compounds, antioxidants, pigments, and others [42]. The development of edible food packaging in terms of edible films and coatings are displayed in Fig. 1.2.

1.3 Synergistic Use of Edible Packaging and Other Preservation Approaches

The synergistic use of several available postharvest approaches with edible food packaging helps to reduce the degradation of available food produces; however, packaging of food products may serve as a mean of protection, preservation, and promotion of food produces. The inclusion of preservation techniques (as shown in Fig. 1.3) such as thermal treatment, cold processing, use of preservatives, water controlling, and packaging (edible and inedible) can help to minimize the postharvest loss of fruit produces by reducing postharvest diseases, senescence, microbial count, reduced respiration rate, and others. The thermal processing of food products may be low-heat, medium-heat, or high-heat processing techniques, where the low-heat processing of food products is not effective toward thermoduric microorganisms. The selection of heat treatment generally depends on nature of

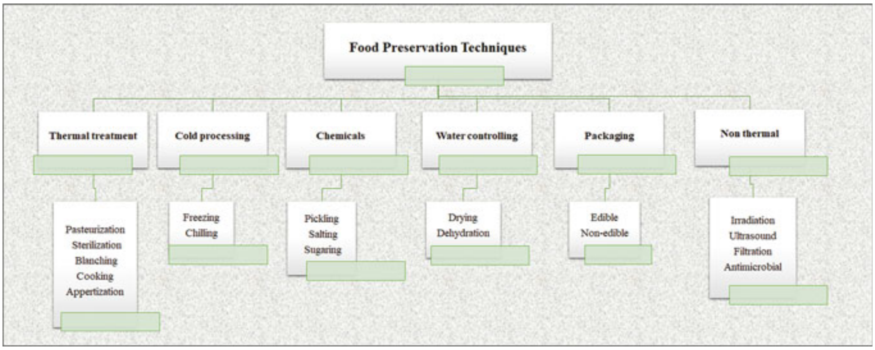

Fig. 1.3 Several food preservation techniques for improved products life

food products, nature of microorganism, nature of process, and others. In this regard, the use of several food preservation techniques reduces the food loss which in turn may help to meet the global food requirement. Additionally, the inclusion of several postharvest techniques help to make available seasonal food products and make easy transportation and exportation of food products. The extensively used conventional food preservation techniques include drying, dehydration, pasteurization, sterilization, pickling, freezing, edible films, and coatings, etc. The food product degradation occurs due to microbiological, enzymatic, chemical, physical, and mechanical reasons, where (i) the microbiological attack includes microbial growth, toxin production; (ii) enzymatic attack creates browning, color change, off flavor; (iii) chemical reasons are color loss, flavor loss, non-enzymatic browning, nutrient loss, rancidity; (iv) physical reasons are collapse, controlled release, crystallization, shrinkage, transport of component; and (v) mechanical reasons are bruising (due to vibration), cracking, damage due to pressure, etc. The traditional methods which are widely utilized for food preservation techniques are boiling, heating, drying, canning, cooling, freezing, salting, sugaring, smoking, pickling, etc. On the other hand, the industrial-based modern methods for food preservation includes vacuum packing, modified atmosphere, pasteurization, artificial food additives, irradiation, pulsed electric field electroporation, biopreservation, non-thermal plasma, etc.

The inclusion of pretreatment can improve the quality of food products such as edible coating and blanching as a pretreatment technique is a promising method for drying of pumpkins [43]. The formation of acrylamide (a procarcinogen) in banana chips can be reduced with the aid of pre-frying treatments such as blanching and pectin-based coating [44]. The application of coating materials based on starch and pectin for osmotic dehydrated and convective dried food products can effectively influence the drying attributes, where the drying characteristics also depend on the type of coating materials [29]. A report suggests that the use of edible coatings (whey protein isolate and pullulan) on freeze-dried Chinese chestnut can effectively improve the quality and shelf life of chestnut [45]. The growth of *Listeria* *monocytogenes* (a pathogen which causes foodborne infections) in roasted turkey (at chiller storage) can be effectively controlled with combined processing techniques such as edible antimicrobial coatings (pectin) with frozen storage [46]. In this regard, the application of freezing with edible coating can further minimize the risks of listeriosis (an infection) caused by the germ *L. monocytogenes*. A report further suggests that the application of pectin and green tea powder as edible coating materials can effectively improve the quality of irradiated pork patty (Irradiation at 0 and 3 kGy using cobalt-60 gamma rays) [47]. The edible-coated pork patties have a reduced count of total aerobic bacteria in comparison to uncoated pork patties. Further, in 2003, **Vachon et al.** have studied the effectiveness of edible coating (based on caseinate) and gamma-irradiation treatment on the keeping quality of fresh strawberry fruit products [48]. The application of both the treatment helps in delaying the mold growth and the irradiated caseinate is more effective in comparison to the unirradiated caseinate for obtaining improved storage life of strawberry. The combined application of gamma irradiation, ascorbic acid, and protein-based edible coating can help to improve the keeping quality of ground beef in terms of biochemical and microbial attributes [49]. Additionally, the edible films based on milk protein such as calcium caseinate and whey proteins cross-linked using radiative and thermal treatments can also provide tunable mechanical and structural properties [50]. The storage quality of fresh-cut pears can be maintained with the aid of pure oxygen pretreatment, CS, and rosemary extract-based edible coating [51]. The combined effect of the treatments has an ability in inhibiting polyphenol oxidase activity and further increases the beneficial properties of fresh-cut pears and reduces the browning effect, etc. There are various other pretreatments using additives (ascorbic acid, citric acid, sodium benzoate, and others), controlled atmosphere storage, and CS coating can improve the quality of fresh-cut jackfruit bulbs slices by retaining phenolic content, sensory attributes, and phenolic content, etc. [52]. A report suggests that the characteristics quality attributes of strawberries can be monitored during freezing when whey protein-based coating is used as a pretreatment method [53]. Thus, the inclusion of food preservation technique and edible food packaging has a beneficial property of improved product life as represented in Fig. 1.4. The available food preservation techniques are used for improved shelf life of food products, however, the inclusion of some preservation techniques may alter the taste and nutritional quality of specific food products due to different processing conditions and use of different agents. In this regard, edible food packaging in terms of edible films and coatings helps in maintaining the nutritional quality of food products. Further, the edible coating and films enhance the nutritional quality of food products by delivering active agents from available natural agents. The use of edible coating and films is different, where edible coating is developed on food products by developing a thin layer of edible material on food products and edible film is used as a layer of edible material between food products or onto food surface.

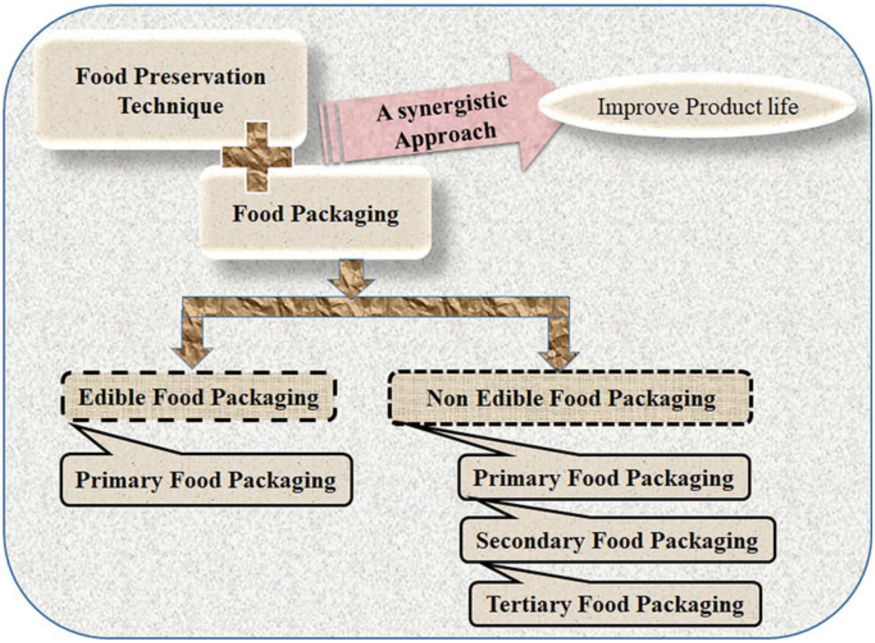

Fig. 1.4 Synergistic approach of several food preservation techniques and edible food packaging

1.4 Transportation of Edible Packaged Food Products

The food packaging is classified into three categories such as primary packaging, secondary packaging, and tertiary packaging. The primary packaging materials remain in contact with food products. The secondary packaging materials are used to transport the primary packaged food products such as carton boxes, paper boxes. On the other hand, the tertiary packaging materials are used to carry the secondary packaged food products. The secondary and tertiary food packaging materials can be recycled and reused if used properly. The edible food packaging materials are generally considered as primary food packaging materials, which are a potential candidate in preserving, transporting, and marketing of food products. The edible food packaging in terms of edible films and coatings is used to provide tailored food properties. The addition of various plasticizers and additives can be added to different biopolymeric materials to obtain the improved physical properties, surface functionality of the biopolymeric materials. The intermolecular forces within biopolymeric materials include electrostatic, hydrophobic, covalent bonds, ionic interaction, and others. The main difference in application of edible films and coatings is that edible films are applied in solid forms, and on the other hand, edible coatings are applied as liquid form and then get dried for easy transportation [54]. The use of edible materials in improving the shelf life of food products depends on some of the characteristics attributes of used materials such as availability, functional properties, cost, optical properties, barrier properties, sensory properties, safety of materials, etc. Edible coatings provide a passive modified atmospheric environment for the fruits and vegetables which help in reducing respiration rate in terms of oxygen and carbon dioxide, increasing the shelf life of food products. In this way, the use of edible food packaging with available inedible packaging materials as secondary and tertiary packaging can be utilized.

1.5 Global Overview of Edible Food Packaging in Research and Development

In this section, the past and existing trend in edible food packaging obtained by using continuous matrices of polymers, nanoparticles, and active agents, etc., will be discussed. Edible food packaging is one of the potential candidates utilized as a food preservation technique for the improved shelf life of food products. The global consumerization of edible food packaging as edible coating and films are increasing due to several advantageous features such as reduced plastic waste, use of naturally availbility, biocompatibility of materials, renewable materials, non-toxicity, increase food value, ready-to-eat food products, etc. The improved food quality generally depends on several factors such as type of coating materials, processing condition, concentration of materials, storage condition, type of food products, etc. The existing biomaterials or biopolymers are used individually or in a combined form for maintaining the food property during storage. Based on the discussion, the present chapter will provide a general global status of edible food packaging materials.

The materials in edible packaging should be eatable both in the initial and in the final packaging forms [55]. The edible packaging is a remarkable candidate in using biobased packaging materials throughout the world. The first patent on edible coating was available in the year 1933 in the USA, where wax coating was mainly applied to citrus fruit products [55]. In later days, the many inventions have been done on edible coatings such as edible film-coated dried fruits [56]; coating of dehydrated foods [57]; meat [58]; frozen confection [59]; fruit pieces [60]; frozen fish [61], etc. Edible coatings provide a lot of beneficial properties in retaining food factors such as reduction of fat uptake in the deep fat-fried food products (meat, potatoes) based on hydrocolloids as edible coating with better nutritional quality [62]. In this regard, the edible oil barrier properties in edible films and coatings are very essential to obtain nutritional-fried products. The patents on edible films available are CS or mixture of quinoa protein-CS [63], gelatin [64]; films and edible food casings from carboxymethyl cellulose [65]; casein-based edible films [66], etc. The patents on edible films for their versatile use are also available such as transmucosal delivery of terpenes [67]. Further, the tunable film-forming properties of edible food packaging materials are attained via heating, enzymatic modification, salt addition, drying, cross-linkers, food additives, etc. In this way, the innovations in research and development are providing a new trend in the field of food packaging with many beneficial traits.

1.6 State of Global Market and New Trends in Edible Food Packaging

The global consumerization and market value of the edible food packaging market are increasing day by day. In this regard, according to the available report on Global Opportunity Analysis and Industry Forecast, 2017–2023, the edible food packaging market was marked at $697 million in 2016, which is forecasted to reach $1097 million by 2023. The popularization of edible food packaging market relates to the increase hygiene concern, reduced conventional packaging waste, etc. The plastic-based waste is a critical concern to the society which further increases the carbon footprint, global warming, which acts as a catalyst for market growth of edible food packaging. On the other hand, the manufacturing regulations, high manufacturing cost, safety concern may lead to a decrease the market value of edible food packaging. The main marketing features of edible food packaging include class of materials, targeted end users, and major market areas. The principal class of materials includes polysaccharide, proteins, lipids and waxes, biocomposites, blends, surfactants, active agents, etc. The targeted consumers of edible food packaging include food and beverages, pharmaceuticals, medicinal use, etc. The major market area of edible food packaging includes North America, Europe, Asia-pacific, etc. The global food packaging markets are WikiCell Designs Inc., MonoSol LLC, Tate & Lyle Plc, JRF Technology LLC, Safetraces, Inc., Bluwrap, Skipping Rocks Lab, Watson, Inc., and Devro plc., etc. The region-wise analysis of the global edible packaging market covers North America (US, Canada, Mexico), Europe (UK, Germany, France, Rest of Europe), Asia-Pacific (India, China, Japan, Rest of Asia-Pacific), and LAMEA (Latin America, Middle East, Africa) as represented in Fig. 1.5. Various countries covered under each region are studied and

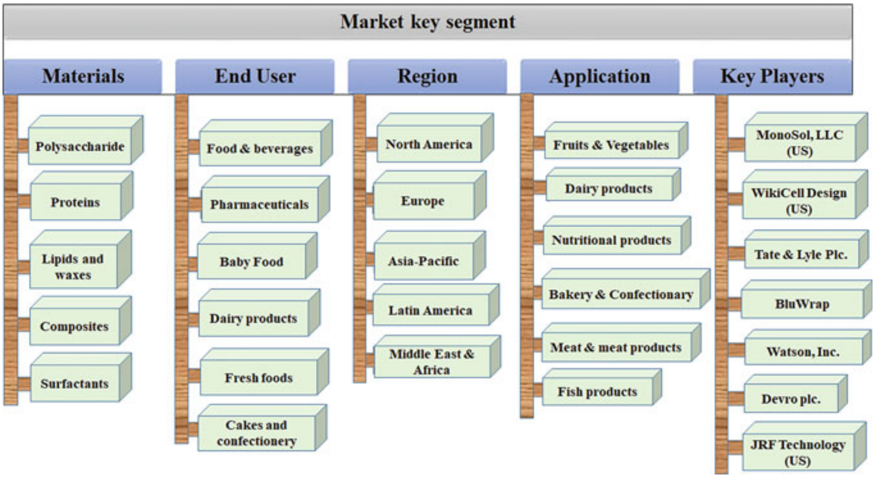

Fig. 1.5 Market key segment of edible food packaging

analyzed to identify the major trends demonstrated by these respective regions. Europe dominated the global edible packaging market in 2016, followed by North America.

The global market for edible food packaging products is available with many products such as seaweed, edible cutlery, Ooho edible water, LOLIWARE edible cups, casein, etc.

The company for edible food packaging materials are Bakeys, India (sorghum, rice, wheat flours), Coolhaus, Los Angeles (potato wafer paper wrapping), Do Eat, Belgium (water and potato starch), Ecovative, New York (mycelium packaging and Founder: Gavin Mcintyre), Eco Six Pack Ring (E6PR), Mexican (compostable matter and by-product waste), Evoware, Indonesia (seaweed), LOLIWARE (seaweed, organic sweeteners, fruit and vegetable coloring), MonoSol, Indiana (edible pods for instant beverages), NVYRO, UK (Cassava plants), Poppits, Florida (food-grade edible films), Scoby, Poland (edible, recyclable package), TIPA, Israeli (biomaterials and technology), etc. In this regard, the available edible food packaging in the worldwide has been represented in Table 1.1. Further, the commercial

Table 1.1 Global market of edible packaging

Sl. No.	Company	Components of packaging	Product and properties	References
1	Bakeys, Hyderabad, Telangana, India Trade Name: Bakeys Foods Private Limited	**Different types of flour** such as Sorghum, wheat, rice, millet **Several flavors in spoon:** cumin, mint-ginger, sugar, carrot-beetroot	Edible Cutlery, Edible spoons, Edible forks, Edible chopsticks	[70–72]
2	Coolhaus, Los Angeles, California	Potato starch	Edible wrappers for ice-cream sandwich	[73]
3	Do Eat, Belgium	Water and Potato starch	Edible Tableware, Verrines, Sandwich rings, Cupcake Holders, Food bags	[74]
4	Ecovative Design, New York	Mushroom materials from Fungal mycelium, Non-food agricultural materials	Mycelium packaging, MycoComposite, MycoFlex, Atlast Protective packaging, structural biocomposites, thermal insulation, etc.	[75]
5	Eco Six Pack Ring (E6PR), Mexico	Compostable matter and by-product waste	Holder for beer cans	[76]

(continued)

Table 1.1 (continued)

Sl. No.	Company	Components of packaging	Product and properties	References
6	Evoware, Indonesia	Burger wrapper, Instant noodle seasoning sachets, Coffee pouches	Seaweed	[77]
7	MonoSol, Indiana, US	–	Food-grade and water-soluble films, edible pod for instant beverages, wrapper and sachets, soluble in hot and cold water, water-soluble films	[3, 68, 69]
8	NVYRO, United Kingdom	Cassava starch Tapioca starch	**Nvyro disposable food packaging products:** Plates, Cups, Lunch boxes, Trays, Lunch plates, Ready to eat foods, Eatable plates **Suitable food products**: Liquid, cold, hot, dry, semi-liquid foods	[78, 79]
9	TIPA, Israel	Fully compostable plastic packaging, end life is like orange peel, decomposting in 180 days Can be used for dry, baked and frozen products	Biomaterials and technology	[80, 81]
10	Scoby, Poland	Kombucha	Edible, recyclable package **Properties**: Fully edible and recyclable, Sachet, bag, and bowl Zero waste production	[82]
11	Loliware, New York	Alginate (Seaweed), agar (Red algae)	Flavored straws **Properties**: Behave like plastic for 24 h	[77]

edible coatings and films available in market are BioEnvelop®, Chris-Kraft Polymer Inc. COGIN®, ENAK®, Freshseel™, Fry Shield™, GREENSOL®, Nature Seal™, Nutrasave™, Opta Glaze™, Seal gum, Spray gum™, Semperfresh™, SHELLAC(E904), Z-Coat™, etc. [6]. The market trend in edible food packaging is growing day by day due to the increased socio-scientific demand in the current situation.

An overview of the available global market of edible food packaging has been made as listed below:

I. The edible packaging from seaweed is created by Evoware, an Indonesian company. The seaweed-based edible packaging is eatable and developed using sustainable materials, heat sealable, printable, dissolve in warm water and provides complete biodegradability, which further acts as fertilizer for plant materials. The Indonesian company used this seaweed for packaging dissolvable coffee sachets, burger wraps, sandwich wraps, etc.

II. The edible cutlery such as Bakey's edible cutlery can be developed from sorghum, wheat, and rice having a very delicious taste, which acts as a great replacement for disposable cutlery and replaces the plastic-based waste decreasing global warming. The Bakey's company was founded in India by Narayana Peesapaty due to groundwater depletion and the creation of plastic-based toxins on human systems.

III. The edible potato wafer paper wrapping was developed by Coolhaus, a Los Angeles-based ice-cream company. The edible potato wafer is a sustainable and environmental friendly replacement to the other available plastic-based wrappers.

IV. Another Belgium-based company, viz. Do Eat offers edible packaging materials using potato starch and water which provide gluten free packaging material.

V. MonoSol is another packaging company in India, which developed edible pods for instant beverages, where the pod completely dissolves in water and are safe for eating; thus, the company is trying to replace the wrapping of food products [3, 68, 69].

VI. The edible water ball has been developed by Skipping Rocks Lab, a startup in London using naturally available plants and seaweed. The developed edible water ball is developed from natural agents, and further, it can flavored, colored, and biodegrade within 4–6 weeks, if not consumed.

VII. The edible and biodegradable cups by Loliware's are developed from seaweed, organic sweeteners, color materials (available from fruits and vegetables) and exists in various flavors like cherry, grapefruit, and yogurt.

VIII. The casein-based films are edible, degradable, and are very effective in the prevention of spoilage of food products. The development of WikiCells similar to eggshells is a kind of edible packaging materials which are launched by David Edwards in 2012. Further, the WikiCells are developed using charged polymers and food particles, where wine, chocolates, and juices can be filled.

1.7 Significance of Edible Food Packaging

Several traits of edible food packaging have been displayed in Fig. 1.6. The addition of health beneficial agents such as antioxidant agents, antimicrobial agents, to food products by means of edible food packaging is considered as another effective way for an enhanced product life of perishable food products. The edible food packaging acts as a safeguard against various kinds of injuries such as mechanical, thermal, chemical, physical, microbiological, and others [54]. The

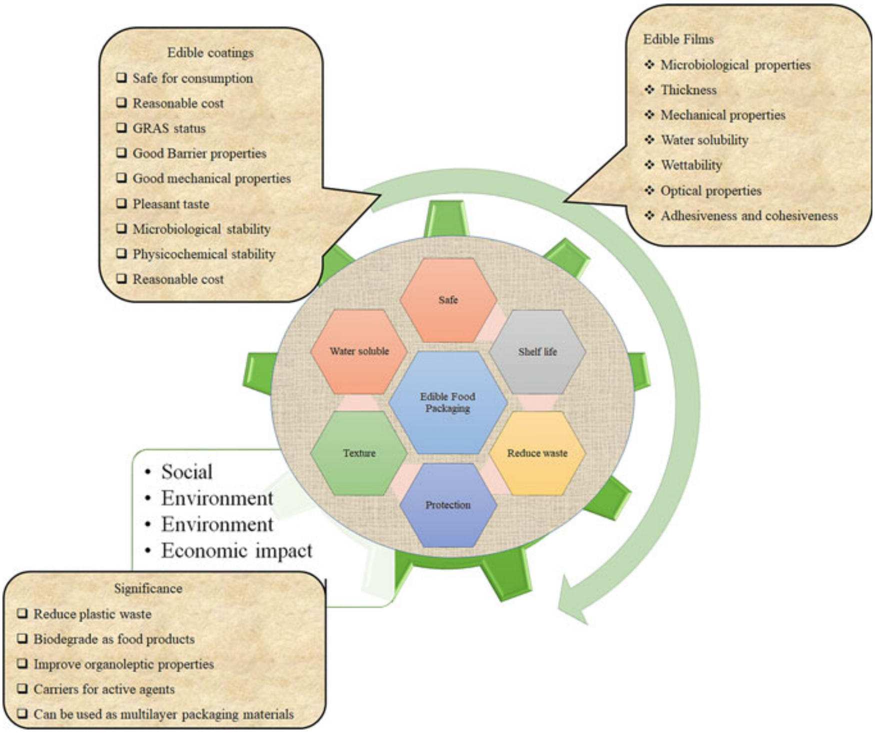

Fig. 1.6 Significance of edible food packaging

single-layer edible coating cannot provide effective barrier agents against the environment. Thus, a multiple layer of edible coating can serve the purpose of improved shelf life of food products efficiently. From very early days, cellulose-based biopolymers are widely utilized for food packaging applications such as paper, polymer composites, edible packaging. The biopolymer extraction and their usability are dependent on several factors such as temperature, relative humidity, microbial spoilage, etc. In recent past years, the use of biopolymers has attained a remarkable attention in food packaging technology for its wide applicability. Based on this, the use of biopolymers as an edible food packaging materials are gaining significant attention.

There are several advantages of edible packaging, such as:

- Reduce plastic-based waste and solid waste
- Reduce carbon footprint and global warming
- Increase the nutritional value of food products
- The edible packaging can act as a carrier for antimicrobial, antioxidant, or other active agents

- The edible packaging can capture various active agents as encapsulation
- Improves aesthetic property of food products.

The limitations of edible packaging include:

- Increased cost
- Secondary packaging is required to carry edible-coated food products such as blown film materials [83]
- Secondary packaging materials are costly
- Environmental sensitive packaging materials.

1.8 Edible Food Packaging with Medicinal Effects

In the modern world of fast moving people, health-preserving diet is an essential need of a healthy lifestyle. However, we also tempted to eat unhealthy food which may have harmful effects, especially to the diseased person. Therefore, it is proposed herewith to develop an approach to administer the required amount of nanomedicinal doses along with food without compromising the essence of food products. This will avoid the consumption of high doses of drugs at once when administer using tablets which lead to the possible toxicity. Further, the nanodispersion of natural medicinal agents in the form of nanocoating on the restricted diet may tune it as a balance diet with no adverse effects on the body. Thus, targeting various diseased conditions, preparation of coating material from various herbals plant materials, and others such as extract of karela, *Terminalia chebula*, punarnava, ginger, seeds of bitter apricot, green tea extract, fig, and chirayta medicinal plant on the restricted diet of a diseased person can be obtained. The edible medicinal food packaging can be developed through incorporating medicinal filler materials which can be extracted from available medicinal plants. Further, the nanofiller materials can be used to deliver medicinal agents to food products. The medicinal agents added edible packaging can be applied on food products as a human disease suppressing agents.

1.9 Nanotechnology in Edible Food Packaging

The nanotechnology in food processing has a great deal of interest to provide potential benefits such as producing functional food products, extended shelf life of food products, intelligent packaging using nanosensor, increase food production, etc., as shown in Fig. 1.7. In the present book, the inclusion of nanotechnology in edible food packaging developed from available biocompatible and non-toxic biopolymeric materials obtained from available sources will be summarized to highlight the necessity and applicability of edible packaging in today's world.

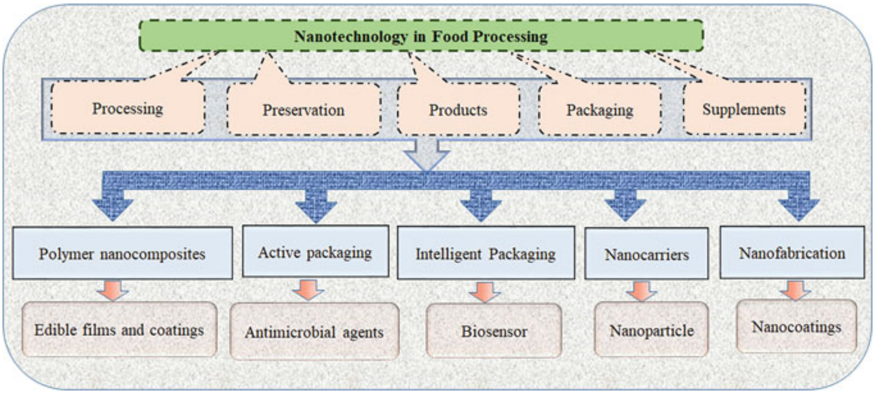

Fig. 1.7 Nanotechnology in food processing

Further, the present book will also discuss the synthesis strategies of edible packaging utilizing different methods, targeted food products, characterization techniques, and related other multifaceted applications. Based on this, the book has been classified into four different distinct areas such as recent advances in edible food packaging, edible films and coating application, packaging technology for the prolonged shelf life of edible packaged food products, and targeted food products and characterization tools. However, the current trend of the food packaging market is widely utilizing the sustainable nanostructured materials for delivering tailored-made properties of eco-friendly food packaging.

The present book provides a complete overview of the current trend and need for nanostructured materials in the field of edible food packaging as shown in Fig. 1.8. A brief overview of the various types of edible food packaging in terms of edible coating, films, and others including the global market of edible packaging with related pros and cons will be discussed in this chapter. The future prospects of market growth and the customer prospects in edible food packaging will also be discussed in this chapter. There are various naturally available materials which are utilized to develop edible packaging, which will be detailed in Chap. 2. Further, a detailed about the available materials and their derived forms for the synthesis of edible packaging of food products will be deliberated in Chap. 2. In Chap. 3, the extraction of cellulose and its derived forms including nanostructured materials for edible packaging will be mentioned. Similarly, a detailed discussion about other nanoforms of some of the polysaccharides such as CS, starch, and others are elaborated in Chaps. 4 and 5. The another kind of biopolymeric materials such as protein which is one of the crucial materials for the development of edible packaging in terms of edible films and coatings will be discussed in Chap. 6. Further, the nanostructured form of protein-based materials for edible packaging is another remarkable area for edible food packaging. In Chap. 7, the use of lipid-based nanostructured materials in the field of edible food packaging will be discussed. In Chap. 8, the utilization of various available inorganic nanofiller materials including

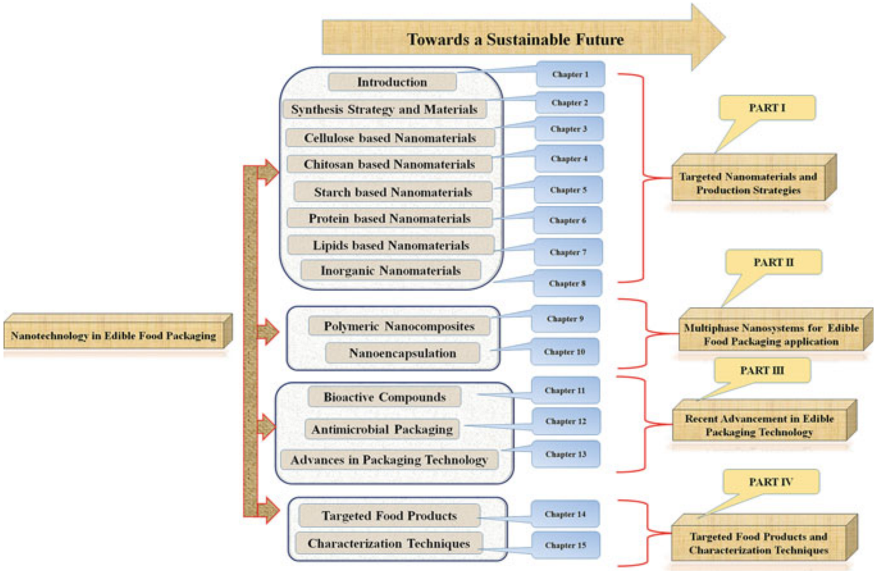

Fig. 1.8 Overall representation of the book "Nanotechnology in Edible Food Packaging"

titanium dioxide, silicon dioxide, zinc oxide, iron oxides, and others in the development of edible food packaging will be discussed. Additionally, an elaborate discussion on using biopolymeric composites and their modified forms in edible food packaging has been made in Chap. 9. Nanoencapsulation is a category of edible packaging, where active compounds are captured using nanomaterials for improved properties, which is a matter of discussion in Chap. 10. In Chap. 11, a discussion on bioactive compounds for edible films and coating with the aid of nanostructured materials of biopolymers such as CS, pectin and dextran with enormous potential will be made. In Chap. 12, the application of various antimicrobial property assisted materials such as CS, essential oils for edible food packaging and others will be done. Further, the application of several advanced packaging technologies such as modified atmospheric packaging, controlled atmospheric packaging, active packaging and smart packaging can help to safe transfer of food products to distant places (Chap. 13). The edible packaging in terms of films, coatings, and others are extensively utilized to improved product life of various perishable and semiperishable food products. Further, the targeted food products such as fruits and vegetables, meat and meat products, dairy products, bakery products which are packed using edible packaging (Chap. 14). Finally, the various characterization techniques needed to analyze edible materials, their products and shelf life analysis of edible food packaged products will be discussed in Chap. 15.

1.10 Conclusion

The production of edible food packaging is continuously being researched to aid functionality and to develop different types of packaging materials. The use of nanotechnology in edible food packaging has brought a real sense in making a large contribution to the food industry. However, nanotechnology has brought a revolution in the field of food packaging industry with the use of various nanostructured materials such as nanocellulose, nanochitosan, nanostarch, protein nanoparticles, lipid-based nanoparticles, inorganic nanoparticles, and others. The addition of nanostructured materials fortifies the food products and further can act as a delivery agent for bioactive components to improve shelf life.

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