Amrita Poonia · Tejpal Dhewa *Editors*

Edible Food Packaging

Applications, Innovations and Sustainability

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This book is dedicated to ***Shri Kashi Vishwanath Ji*** *located on the Western bank of the holy river* ***Ganga****, Varanasi, Uttar Pradesh, India, and is one of the twelve* Jyotirlingas.
The main deity is known by the names Shri Vishwanath and Vishweshwara, literally meaning **Lord of the Universe***. Varanasi city was called* Kashi *in ancient times, and hence the temple is popularly called Kashi Vishwanath Temple.*

&

Bharat Ratna, ***Mahamana Pandit Madan Mohan Maiaviya Ji****, Founder of Banaras Hindu University, the largest residential university in Asia and one of the largest in the world.*

Preface

Increasing industrialization and population has put forward two major challenges, namely waste management and continual surge in the global energy demand. Biofuels have recently emerged as ideal fuel carriers to meet these energy requirements in a sustainable manner. Bio-wastes can serve as a valuable renewable source for conversion into biofuels. Food and agro-industrial substrates, such as starch-based wastes, due to their high availability, biodegradability, and rich nutritional composition, can be effectively utilized for packaging edibles as well as eliminate waste disposal problems. Fruits and vegetable peels are suitable candidates to serve this purpose as they have a high fermentable carbohydrate yield. Packaging edibles have generated considerable attention over years as an alternative to synthetic plastics, considering their renewable and biodegradable characteristics. Packaging edibles could be prepared using fruits and vegetable peels as plant-based and biodegradable constituent that may result in high-value commercial use of the by-product. The packaging edibles prepared from these materials could be the best coatings having improved barrier and mechanical properties as compared to individual biopolymers. According to Food and Agriculture Organization (FAO), about three billion tons of food is wasted every year worldwide. Agro-based industries are producing large amount of by-products and waste. Various fruit wastes, i.e., peels, stems, shells, seeds, and trimmings, represent more than 50 % of the fresh produce and these by-products and wastes contain more functional compounds than the fruit. The by-products and wastes also effect the environment, social sector, and economy of a country, and management of these by-products is a big challenge for the society. Due to their functional and nutritional qualities, the utilization of these by-products for packaging edibles is a good solution for preservation of foods. The use of agro-industry and food industry wastes and by-products in preparation of packaging edibles, addition of functional and bioactive compounds with antioxidant and antimicrobial properties against the microbes, is the latest trend in packaging industry and finding a sustainable solution for the plastics. This type of value addition with variation of the productive chain revolutionizes the food industries. New research in the area of packaging edibles is a vital and exclusive field of study which comprises a lot of commercial and environmental potential in near future. In the area of packaging edibles, new research and development is the main area to explore its possibilities for commercialization as well as environmental potential.

The use of sustainable alternatives and innovative and new sources for the development of packaging edibles justifies the publication of this book.

This book is divided into five main parts:

- Sources and origin of packaging edibles
- Sustainable alternatives for packaging edibles
- Shelf-life and safety aspects
- Regulatory aspects
- Innovations and recent trends in edibles

The first part of the book addresses details of edible films and coatings, cups, spoons, and cutlery and various sources like fruit and vegetable industry by-products, grain and oilseed wastes, marine industry by-products, dairy by-products and wastes, and meat industry waste. It also covers animal- and plant-based packaging edibles, scope, and novel microbial sources. Part II addresses on different sustainable alternatives, i.e., seed gums, fruits and vegetable peels, sea weeds, fruits wastes, purees, extracts, juices, dairy by-products, black edible packaging using defatted oil cake, and antioxidant edible packaging. Other food industry by-products like apple pomace, citrus peels, cassava by-products, potato peels, fish skin, and algae have already been proposed as possible environment friendly alternatives for packaging edibles. These by-products are the potential source of biodegradable packaging edibles. They also contain polyphenols and play important role as antioxidants and antimicrobials to the packaging edibles. This may also provide the additional nutritional benefits to the consumers. Utilization of these products as a source of packaging edibles is not only safe for human consumption but also biodegradable in nature and environmental friendly.

Part III of the book addresses about the shelf-life extension foods by using packaging edibles. The packaged food products can be prevented from oxidation and spoilage by microorganisms during storage. Nanolaminates are more advanced and more workable technology that offers maximum utilization potential. The layer-by-layer deposition (LbL) is one of the most powerful techniques whereby charged surfaces are coated on the food with interfacial films consisting of multiple nanolayers of different materials. Nanocoatings have been also studied to incorporate bioactive or functional compounds owing to their ability to control the release of such molecules by the manipulation of coatings' properties. Part IV covers the safety of these packaging systems that is also very crucial. Safety issues related to the microbial spoilage of packaged product had been discussed. Marketing of packaging edibles is affected by many factors such as cost of production, consumer acceptance of these materials, and consuming of these packaging edibles. Part V of the book addresses the innovations in packaging edibles in food as well as other sectors, applications of packaging edibles in liquid foods and pharma sector, and use of sea weeds, seed gums, and agro wastes such as bagasse, cellulose, cutin, molasses, lignin, and paddy straw.

Nowadays, sustainable packaging edibles are gaining considerable interest due to their potential to replace the plastics with food wastes and agro wastes. No book is available about the manufacture of packaging edibles using these types of by-products till date. All the contents of the book are unique and has vast commercial applications and environmental potential.

Varanasi, Uttar Pradesh, India Amrita Poonia
Mahendragarh, Haryana, India Tejpal Dhewa

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Amrita Poonia is working as an assistant professor in the Department of Dairy Science and Food Technology, Institute of Agricultural Sciences, Banaras Hindu University, Varanasi, Uttar Pradesh, India. She has published two laboratory manuals and more than 15 book chapters at national and international level. Dr. Poonia has conducted/offered a Massive Open Online Course (MOOC) under agMOOCs on Functional Foods: Concept, Technology and Health Benefits from (8 October, 2018 to 19 November, 2018) and was awarded with the Certificate of Appreciation for offering a Massive Open Online Course (MOOC) under agMOOCs, by Commonwealth of Learning (COL) Canada. She has published more than 50 publications in esteemed national and international journals. She has successfully completed a project on “Identification of Food Borne Pathogen (Listeria monocytogenes) in Shrikhand Using PCR (Polymerase Chain Reaction)” at BHU and supervised 2 PhD scholars and 28 MSc students and 2 PhD scholars are perusing their research under her supervision.

Tejpal Dhewa is a faculty in the School of Life Sciences, Central University of Haryana, Mahendragarh. He is the coordinator, Food Safety Training and Certification (FoSTaC) Centre, Food Safety and Standards Authority of India (FSSAI), and University SWAYAM Coordinator- Central University of Haryana. Dr. Dhewa is a course coordinator of SWAYAM UGC MOOC on “Food Microbiology and Food Safety.” Dr. Dhewa has a diverse industrial, teaching, and research experience. He has published his research works in national and international journals. Dr. Dhewa also supervised several master’s theses/dissertations. He has successfully completed DU innovation project (2013-2015) and has conducted short-term courses on “Food Safety, Food Security, and Food Regulations: A Primer” from September 16 to 20, 2018; “Metabolomics in Food and Nutrition Science Research: From Concepts to Applications” from February 15 to 19, 2019; and “Food Fortification and Human Health: From Concepts to Public Health Applications” from September 9 to 13, 2019, under the Ministry of Human Resource Development (MHRD).

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Abbreviations

AG	Arabic gum
Ag	Silver
AgNPs	Silver nanoparticles
Au-MSN	Gold mesoporous silica nanoparticles
BAW	Bulk acoustic wave
BSA	Bovine serum albumin
Ca	Calcium
CAP	Controlled atmospheric packaging
CAS	Controlled atmospheric storage
CFB	Corrugated fiberboard
CFB	Corrugated fiberboard
CFU	Colony-forming units
CMC	Carboxymethylcellulose
CMC	Carboxymethyl cellulose
CNC	Cellulose nanocrystals
CP	Conducting polymer
Cu	Copper
CW	Cellulose whiskers
DHS	Dynamic headspace
DNA	Deoxyribonucleic acid
EC	Edible coatings
ECs	Edible coatings
EOs	Essential oils
EVOH	Ethylene-vinyl alcohol
FAO	Food and Agriculture Organization of the United Nations
FDA	Food and Drug Administration
FLW	Food loss or waste
FSC	Food supply chain
FSSAI	Food Safety and Standards Authority of India
FTIR	Fourier transform infrared spectroscopy
G	A-l-guluronic acid
GRAS	Generally recognized as safe
HCA	Hierarchical cluster analysis

HDPE	High-density and low-density polyethylene
HGA	Homogalacturonan
HM	High methoxyl
HPMC	Hydroxypropyl methylcellulose
LM	Low methoxyl
M	B-d-mannuronic acid
MAP	Modified atmospheric packaging
MMT	Million metric tonnes
MOSFET	Metal oxide semiconductor field effect transistors
NFC	Nanofibrillated cellulose
OMLs	Overall migration limits
P&T	Purge and trap
PCA	Principal component analyses
PEG	Poly-ethylene glycol
PET	Polyethylene terephthalate
PHA	Polyhydroxyalkanoate
PP	Polypropylene
PPP	Public-private-partnership
PVC	Polyvinyl chloride
ROS	Reactive oxygen species
RSM	Response surface methodology
SEM	Scanning electron microscopy
SH	Sulfhydryl
SHS	Static headspace
SiO_2	Silicon dioxide
SnO_2	Stannic oxide
SPC	Soy protein concentrate
SPI	Soy protein isolate
SS	Disulfide
TDS	Thiamine di-lauryl Sulfide
TiO_2	Titanium oxide
UV	Ultraviolet
WO_3	Tungsten trioxide
WP	Whey protein
WPC	Whey protein concentrate
WPC	Whey protein concentrates
WPI	Whey protein isolate
WVP	Water vapor permeability
ZnO	Zinc oxide
ZnS	Zinc sulfide

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Sources, Origin and Characterization of Edible Packaging

2

Padma Sangmu Bomzon

Abstract

Edible packaging is generally available commercially as edible films or edible coatings depending upon their structural composition and end utilization or function towards food preservation. Edible coatings comprise those materials that are applied directly on food surfaces, either on the outer surface or between layers, and are generally consumed directly as a part of the food that they protect. On the other hand, edible films are usually manufactured separately and applied on the food surface for packaging, and can be removed from or peeled off the food before consumption. Edible packaging should be, as the name suggests, edible and easy to digest. They should be non-toxic to human beings while also being biodegradable. Depending on the function of the end product, a wide range of biodegradable components such as hydrocolloids/polysaccharides, lipids and proteins are extracted from plant sources, animal sources and microorganisms for the process of manufacturing various edible coatings and films. The materials, thus, sourced can be categorized into three broad types as those originating from natural sources, such as agro sources, meaning the biopolymers are extracted directly from the natural biomass; those extracted from biomass developed by action of microorganisms or fermentation or those that are chemically synthesized from biomass. Apart from the characteristics that ensure edible packaging to be used as a food component, the packaging material should also possess various other properties that will allow it to effectively protect food materials from various external factors, while also preserving the structural integrity of the food materials. Edible biopolymers that make up edible coats and films inherently possess the property to form multiple layers or films, which is the most vital

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property for the development of any packaging material. This is in most part due to their ability to form a structural matrix that is both continuous and adequately cohesive. This property of forming a continuous structural matrix enables the resulting packaging film or coating to exhibit a myriad of essential characteristics like the ability to limit or prevent the transfer of moisture, gases (viz. oxygen and carbon dioxide), aroma, lipids, etc. that may affect the shelf life or important organoleptic properties of the food material. Such functionalities aid in the preservation of mechanical integrity of the food being packed. In order to optimize the functionality of edible packaging, their quality is inspected and characterized with regard to various properties including water vapour permeability (WVP), thickness, water solubility, oxygen permeability (OP) and mechanical properties (elongation, tensile strength, etc.). Sensory properties such as appearance (whether transparent/coloured/opaque), odour, taste and texture of the packaging material are also some of the important determinants of quality. As edible packaging is, in its essence, organic and biodegradable, care needs to be taken to ensure that the resulting edible films or coatings do not degrade easily when exposed to various external factors such as moisture, heat and light, among others. The various sources of edible biopolymers required for the development of edible packaging, their origin and characterization have been discussed in detail in this chapter.

Keywords

Edible packaging · Sources · Polysaccharides · Proteins · Wax

2.1 Introduction

Edible packaging is generally available commercially as edible films or edible coatings. Edible coatings comprise of those materials that are formed directly on food surfaces, while edible films are manufactured separately and placed on the food surface for packaging. The materials required to manufacture edible packaging comprise of a wide range of biodegradable components found in plants, animals and microorganisms.

Edible biopolymers that make up edible coats and films inherently possess the property to form multiple layers or films, which is the most vital property for the development of any packaging material. This is in most part due to their ability to form a structural matrix that is both continuous and adequately cohesive. This property of forming a continuous structural matrix enables the resulting packaging film or coating to exhibit a myriad of essential characteristics like the ability to limit or prevent the transfer of moisture, gases (viz. oxygen and carbon dioxide), aroma, lipids, etc. that may affect the shelf life or important organoleptic properties of the food material. Such functionalities aid in the preservation of mechanical integrity of the food being packed.

In order to optimize the functionality of edible packaging, their quality is inspected and characterized with regard to various properties including water vapour permeability (WVP), thickness, water solubility, oxygen permeability (OP) and mechanical properties (elongation Eb%, tensile strength [TS], etc.). Sensory properties such as appearance (whether transparent/coloured/opaque), odour, taste and texture of the packaging material are also some of the important determinants of quality. As edible packaging is, in its essence, organic and biodegradable, care needs to be taken to ensure that the resulting edible films or coatings do not degrade easily when exposed to various external factors such as moisture, heat and light, among others.

2.2 Sources and Characterization

Edible biopolymers, which are utilized in the production of edible packaging, are broadly classified according to their structural framework into polysaccharides, proteins and lipids and composites (Suput et al. 2015; Cerqueira 2015). The biopolymer is usually supplemented with a plasticizer (e.g. glycerol). This is done to optimize the elasticity and flexibility of the end product. Additives, such as antimicrobial agents, artificial food-grade colours and flavour enhancers, can also be added to modify and improve functionality of the packaging material. Various sources of edible packaging are given in Fig. 2.1.

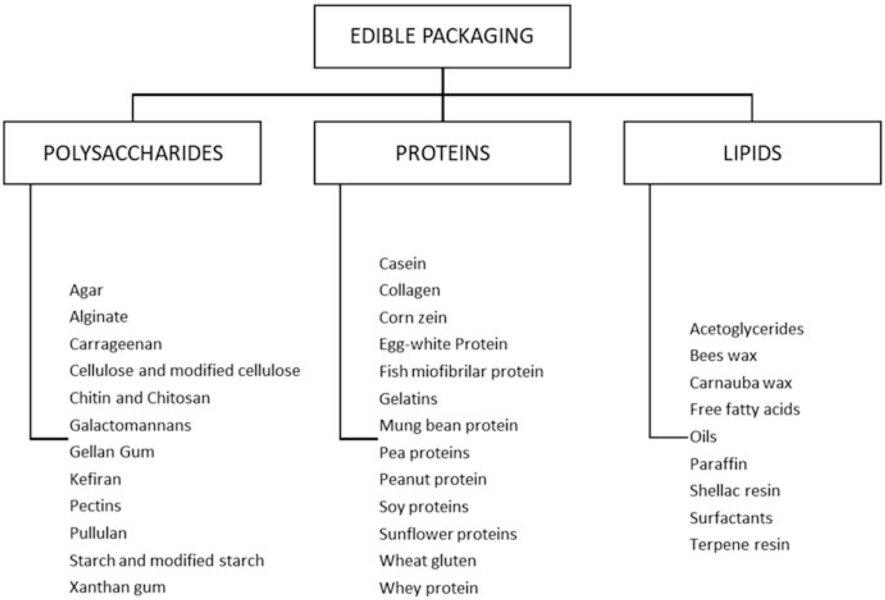

Fig. 2.1 Sources of edible packaging

The sources and characterizations of some commonly used sources of edible packaging are discussed in detail below.

2.3 Edible Polysaccharide Packaging

Polysaccharides are long-chain polymeric carbohydrates formed by the glycosidic linkages between monosaccharide units. The H-bonds play significant roles in the formation of films and their characteristics.

Polysaccharide packaging provides strength and mechanical integrity to the food by creating a barrier against oxygen, aroma and lipid transfer. However, they fall short in terms of protection against moisture.

2.3.1 Agar

Agar is found in the cell walls of algae of the *Rhodophyta* phylum (red algae), also known as agarophytes. It comprises of agarose, which makes up the gelling portion, and agaropectin, which makes up the non-gelling fraction. Usually, agaropectin is removed during commercial processing in order to manufacture agar powder with a higher gelling strength. Apart from being biodegradable, Agar possesses a continuous film-forming ability, has a high retraction ratio, is transparent, heat sealable and, most importantly, it is biologically inert. All these properties are highly favourable for edible food packaging. However, pure agar film has low elasticity, high WVP, high water sensitivity and poor thermal stability because of which it requires to be used in combination with additional substances such as plasticizers, biopolymers, nanoparticles, etc. (Mostafavi and Zaeim 2020).

2.3.2 Alginate

Alginate is a salt of algin (alginic acid), which is a polysaccharide found in the cell walls of brown algae (*Phaeophyceae* sp.). Alginate is a natural hydrophilic polysaccharide biopolymer and is highly favoured for food packaging. In addition to important film-forming properties, they also exhibit characteristics such as moisture retention, maintenance of structural integrity and overall enhancement of various organoleptic properties of the food items being packed. Alginate is known to exhibit antimicrobial properties. These have also been shown to protect food from lipid oxidations (Theagarajan et al. 2019).

2.3.3 Carrageenan

Carrageenan is a polysaccharide found in seaweeds and red algae. Carrageenan biopolymer is a complex hybrid chemical structure comprising of λ-carrageenan, ι-carrageenan and κ-carrageenan, together with non-gelling biological precursors like monomers of ν-carrageenan or μ-carrageenan. These enable the biopolymer to exhibit a myriad of gel-forming properties (Sanchez-García 2011). Carrageenan coatings are mostly used for their anti-microbial properties in gel matrices containing antimicrobial agents. Carrageenans are good lipid and oxygen barriers, and are generally used for packaging of sensitive food items such as meat and its products. These edible films are water soluble.

2.3.4 Cellulose

Cellulose is a polysaccharide that exists in the cell walls of all plants. Its structure comprises a linear chain made up of β-1,4-linked D-glucose units. Owing to its complex crystalline structure of tightly packed polymer chains, ranging from hundreds to several thousands, cellulose possesses high strength, is insoluble in water and exhibits many attractive mechanical properties. Derivatives of cellulose are formed from etherification of cellulose which enhances water solubility. Carboxymethyl cellulose, methyl cellulose, hydroxypropyl cellulose and hydroxypropyl methyl cellulose are some common water-soluble cellulose derivatives used commercially for making edible films.

Edible packaging made from cellulose derivatives provides effective barriers against moisture, oxygen and lipids. Such packaging is generally tasteless, odourless, transparent, water soluble, flexible and resistant to oxygen and carbon dioxide. Bacterial cellulose, such as of *Acetobacter xylinum,* have also been utilized in the production of edible packaging. Bacterial cellulose exhibits high structural strength, high purity and a high moldability factor (Brigham 2018).

2.3.5 Chitosan

Chitosan is a polysaccharide made up of a linear chain comprising of β-1,4-linked D-glucosamine and N-acetyl-D-glucosamine. When Chitin, which is derived from exoskeletons of crustaceans and cell walls of fungi, undergoes deacetylation, it leads to the formation of Chitosan. Edible packaging made from chitosan exhibits antimicrobial activity. Besides that, pure chitosan films are transparent, non-toxic and protect lipid oxidations in food (Cazón and Vázquez 2019).

2.3.6 Galactomannans

Galactomannans are polysaccharides composed of galactose and mannose. These gums are extracted from the endosperm of dicotyledonous seeds of various plants. Guar gum, tara gum and locust bean gum are the most commercially important forms of galactomannans in the food industry. Galactomannans need only water for preparation and have been known to form highly viscous solutions even with very little amounts of the polysaccharide. These are used in combination with other substances such as plasticizers, biopolymers, nanoparticles, etc. in order to decrease WVP and OP, while increasing their TS and Eb% properties (Cerqueira et al. 2011).

2.3.7 Pectin

Pectins are complex polysaccharides with D-galacturonic acid as a principal constituent. It is found in the cell walls of many plants and comprises of 1,4-α-D-galacturonic acid molecules, which are linked to rhamnose residues (main chain) and arabinose, galactose and xylose (side chains). Pectin may be high methoxyl or low methoxyl. Low methoxyl pectins are the ones generally used in food coatings. Pectin forms gels when dissolved in water under suitable conditions, which is the most important property for its use as food packaging. They also provide effective barrier against oxygen, lipids and aroma. They also possess good mechanical properties, but fall short in terms of moisture protection (Valdés et al. 2015).

2.3.8 Starch and Derivatives

Starch $(C_6H_{10}O_5)n$ is a polysaccharide made up of glucose units joined by α-1,4-glycosidic linkages. It is composed of a linear amylose polymer and a branched amylopectin polymer. Starch films are tasteless, odourless, transparent and considerably less permeable to moisture, O_2, CO_2, lipids and aroma. Starch as an edible packaging is particularly promising because of its low cost and easy availability (Pelissari et al. 2019; Versino et al. 2016).

2.4 Edible Protein Packaging

Proteins are large polymers made up of one or more linear chains of amino acids. Edible packaging made from proteins can be classified as those sourced from plant proteins, such as soy protein and wheat gluten, and those sourced from animal proteins, such as casein and whey protein. Edible packaging based on proteins possesses excellent gas barrier and lipid barrier properties, which helps in the prevention of loss of flavours while also controlling the exchange of gases such as oxygen and carbon dioxide. However, protein-based packaging had weak water barrier characteristics, which requires them to be used in combination with polysaccharide derivatives, plasticizers and other substances in order to improve their packaging properties.

2.4.1 Casein

Casein is an animal protein (found in mammalian milk), and is comprised of four phosphoproteins – kappa-casein, beta-casein, alpha s1-casein and alpha s2-casein. Casein possesses excellent film-forming properties. Apart from being biodegradable, it has a high thermal stability, and is non-toxic while also being highly nutritious. However, casein-based packaging is highly sensitive to moisture and, thus, needs to be combined with substances such as plasticizers to improve WVP properties and properties like TS (Chen et al. 2019).

2.4.2 Collagen and Gelatin

Collagen is another animal protein which is popularly used to manufacture commercial edible protein film. It is the most abundant protein found in the connective tissues of mammals. Collagen is a fibrous protein and comprises of a triple helix formed by amino acids bundled together (Shoulders and Raines 2009). Collagen-based packaging exhibits exceptional barrier against oxygen at 0% relative humidity, but an increased relative humidity (RH) leads to weaker barrier properties. Their resistance to moisture is also relatively low. In order to overcome these shortcomings, collagens are combined with polysaccharide derivatives or plasticizers.

Gelatin is produced when collagen is hydrolysed. Gelatin-based packaging is transparent and has excellent oxygen barrier properties. The melting point of gelatin is 35 °C, which makes it highly desirable as an edible food packaging material. Gelatin-based films may also be incorporated with antimicrobial or antioxidant agents to improve their functionality (Chen et al. 2019).

2.4.3 Corn Zein

Zein makes up the major protein component in the endosperm of maize or corn. Alpha-, β-, γ- and δ-zein are the four molecular parts of zein. It is not soluble in water but forms a solution in alcohol. Zein has been widely used as a component of chewing gum and in the coating of various candies. Zein has excellent film-forming properties, is hydrophobic but soluble in organic solvents (e.g. ethanol) and possesses suitable gas barrier properties, which makes it an excellent contender for preparing edible food coatings and films. It is also compatible with most natural antioxidants and antimicrobial agents. However, zein-based films are brittle and do not provide a good barrier against WVP. Combination with other substances such as plasticizers and other biopolymers helps zein-based films and coatings to achieve better mechanical properties (Arcan et al. 2017).

2.4.4 Soy Proteins

Soy proteins are extracted from soybeans. They are available as soy protein isolates, soy flour and soy protein concentrates. Soy protein isolates (SPI) serve as a major source in the production of soy protein-based films. The film-forming characteristics of soy proteins have been extensively researched upon through the years. Soy proteins are usually combined with plasticizers to create edible films. The concentration of SPI and plasticizer is a major determinant of the mechanical properties of the resulting edible packaging material. A higher SPI concentration shows increased thickness with greater tensile strength, while decreasing the Eb%. On the other hand, a higher plasticizer concentration leads to a decreased thickness and lower tensile strength but results in an increase in Eb% (Nandane and Jain 2014).

2.4.5 Wheat Gluten

Gluten is the major protein found in cereal grains like barley, rye and wheat. It is a protein complex comprised of two fractions – gliadin (water soluble) and glutenin (water insoluble). Gluten-based films are transparent, strong and have excellent gas barrier properties at low RH. The WVP property of gluten-based films can be improved drastically by combination with lipidic compounds (Gontard and Guilbert 1998).

2.4.6 Whey Protein

Whey protein is another protein found in mammalian milk. Whey protein comprises of α-lactalbumin, β-lactoglobulin, serum albumin and immunoglobulins. Edible films based on whey protein are transparent, have no distinct taste or smell, are flexible and possess excellent gas and lipid barrier characteristics at low RH. However, whey protein films have poor water barrier properties so they have to be used in combination with other hydrophobic substances such as lipidic compounds to reduce the WVP (Javanmard 2009).

2.5 Edible Lipid Packaging

Lipids are large biopolymers which are soluble in non-polar solvents. Lipids can be classified into fatty acids, glycerolipids, glycerophospholipids, sphignolipids, sterols, prenols, saccharolipids and polyketides. Lipids are hydrophobic in nature.

Lipid-based edible films and coatings have excellent WVP properties, which is its most desirable property in the food packaging industry. However, lipid-based films are usually opaque, inflexible and significantly brittle; thus, lipids are often used in combination with polysaccharide or protein derivatives to achieve better functionality.

2.5.1 Acetoglycerides/Acetylated Monoglycerides

Acetoglycerides constitute a class of compounds comprising of a mixture of carboxylic acid esters of glycerol. Acetylated monoglycerides are emulsifiers and are generally used for their plasticizer properties and incorporated into edible coating formulations.

2.5.2 Resins

Naturally occurring resins are secreted by plants and insects as a protective response to injury. Resins are usually mixtures of organic compounds. Shellac resin is secreted by *Laccifer lacca,* which is an insect in the *Kerriidae* family. It is soluble in alcohols and alkaline solutions and is composed of a mixture of aliphatic alicyclic hydroxyl acid polymers. It is the most commonly used resin in edible food coatings. Terpene resin is derived from wood (Hall 2011).

2.5.3 Waxes and Paraffins

Beeswax is naturally produced by honeybees, which belong to the genus *Apis*. Beeswax is composed of esters of fatty acids and long-chain alcohols. Paraffin wax is derived from crude petroleum. Candelilla is obtained from candelilla plant. Carnauba wax is extracted from the leaves of *C. cerifera* (palm tree). Mineral oil is comprised of a mixture of liquid paraffinic and naphthenic hydrocarbons.

Waxes and paraffins have been used as natural glazing agents on food items. In terms of edible packaging, these are often used in combination with polysaccharide or protein derivatives for its excellent hydrophobic properties to reduce the WVP of the edible packaging. They also possesses excellent gas barrier properties. Paraffin wax is not permitted for use on food items other than raw fruits and vegetables and cheese. If the wax or paraffin coatings on food items are thick, they are generally required to be removed before consumption of the packaged food (Trevisani et al. 2017; Bourtoom 2008).

2.5.3.1 Origin

The categorization of edible biopolymers based on their origin is shown in Fig. 2.2.

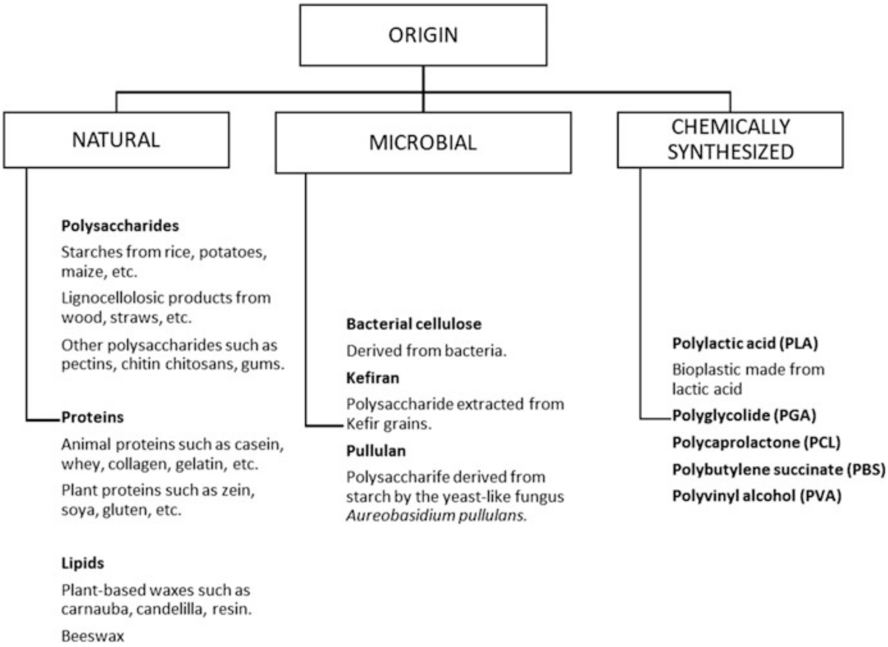

Fig. 2.2 Origin of edible biopolymers (Shankar and Rhim 2018)

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