www.ThePharmaJournal.com

The Pharma Innovation

ISSN (E): 2277-7695
ISSN (P): 2349-8242
NAAS Rating: 5.23
TPI 2022; SP-11(12): 182-193

www.thepharmajournal.com
Received: 15-10-2022
Accepted: 18-11-2022

Vinoth Kumar M
M.sc, Food Science and Technology, Lovely Professional University, Punjab, India

Neha Sharma
M.sc, Food Science and Technology, Lovely Professional University, Punjab, India

Ranjith S
M.sc, Food Science and Technology, Lovely Professional University, Punjab, India

Corresponding Author:
Vinoth Kumar M
M.sc, Food Science and Technology, Lovely Professional University, Punjab, India

Trends in edible packaging of bakery products: A review

Vinoth Kumar M, Neha Sharma and Ranjith S

Abstract
As bakery products are developing as major entity of the global market, the baking enterprise is undergoing a period of rapid change. Approximately 1.3 million tons of bakery products are manufactured in about 2000 organized or semi-organized units, further to 1.7 million tons in about 10000 unorganized small-scale units. Bakery products are the third largest segment of the packaged and convenience market (ready-to-eat and ready-to-cook products). Fungi are the most spoilage causing microorganisms of baked products. Except the unpleasant appearance of visible increase, fungi also are responsible for off flavor formation and the possible production of mycotoxins and allergenic compounds which may be present even earlier than increase is seen. The development and application of bakery edible films is one of the most promising fields in food science due to their versatility, ability to be made from a variety of materials, and as carriers of various active substances such as antioxidant and/or antimicrobial agents. Bakery Edible packaging is regarded as a sustainable and biodegradable alternative in the active food packaging field, and it improves bakery product quality when compared to traditional packaging. I believe that by publishing this review, more people will become aware of bakery edible packaging and its methods of preparation of edible film and edible coating, which have the potential to be used in the trends of bakery edible packaging for the prevention of spoilage in bakery products.

Keywords: Trends, edible packaging, bakery products

Introduction
Bakery merchandise and their derivatives have an important section inside the food consumption all over the international markets. As per the records of IMARC (International Market Analysis Research and Consulting Group), the worldwide bakery products market has already attained a share of 478.4 US$ billion in 2021. And they are estimating the market to achieve a growth of 612.4 US$ billion by 2027 depicting an overall CAGR of 4.0% throughout 2022-2027 (IMARC, 2021). India is the world's second largest food producer, edging less then China, and has the potential to be the largest in terms of food and farming land (Deshmukh s *et al.* 2019) [19]. The Indian bread sector is possibly the largest segment of the country's prepared food industry. Bakery items, which include bread and rolls, comprise the majority of prepared foods, accounting for more than 82 percent of all bakery products produced in the United States (Deshmukh s *et al.* 2019) [19]. It has a near-favored position in manufacturing, with a bountiful flexibly of vital fixes required by the industry, and is the third-largest bread producing nation (after the United States and China) (Deshmukh s *et al.* 2019) [19]. In India, the bakery business is divided into three broad categories: bread, rolls, and cakes (Deshmukh s *et al.* 2019) [19]. The composed bakery industry in India produces around 1.3 million tonnes of bakery items (out of a total of 3,000,000 tonnes), while the equalisation is delivered by chaotic, small-scale neighborhood manufacturers (Deshmukh s *et al.* 2019) [19]. As bakery products are developing as major entity of the global grocery store, the baking enterprise is undergoing a period of rapid change. Bakery enterprise has to undergo continuous efforts to satisfy the healthful eating developments and the patron demands for clean products (Smtth J P *et al.*, 2018) [66]. The World Health Organization (WHO) has commenced a series of initiatives to assist governments in eliminating industrially produced Trans Fatty Acids (TFAs) from the global food supply by 2023. The guidelines urge to replace TFAs in oils and fats through rules and laws (WHO, 2019). Currently, the main lipid source used in margarines is interesterified fat. However, there are several fat adjustments for margarines that try to make the product healthier (Silva TJ *et al.* 2021) [46]. Bakery products are the third largest segment of the packaged and convenience market (ready-to-eat and ready-to-cook products).

Bread and bakery are the most popular bakery items in India. Approximately 1.3 million tons of bakery products are manufactured in about 2000 organized or semi-organized units, further to 1.7 million tons in about 10000 unorganized small-scale units (Kumar S *et al.*, 2020) [33]. Edible packaging is regarded as a sustainable and biodegradable alternative in the active food packaging field, and it improves food quality when compared to conventional packaging (Petkoska, A. T *et al.* 2021) [44]. The usefulness of edible packaging can be seen in its ability to maintain food quality, extend shelf life, reduce waste, and contribute to the economic efficiency of packaging materials (Petkoska, A. T *et al.* 2021) [44]. The development and application of edible films is one of the most promising fields in food science due to their versatility, ability to be made from a variety of materials, and as carriers of various active substances such as antioxidant and/or antimicrobial agent's g (Petkoska, A. T *et al.* 2021) [44]. Over the last decade, there has been a significant increase in research activities in this area, with several issues identified for consideration before adequate and safe industrial scale-up of edible food packaging (Petkoska, A. T *et al.* 2021) [44]. The materials used in food packaging are derived from edible ingredients such as natural polymers, which can be consumed directly by humans without posing any health risks (Petkoska, A. T *et al.* 2021) [44]. These materials can be transformed into different types of films and coatings through changes in thickness rather than differences in composition (Petkoska, A. T *et al.* 2021) [44]. Films are commonly used to make wraps, pouches, bags, capsules, and casings, whereas coatings are applied directly to the food surface (Petkoska, A. T *et al.* 2021) [44]. A definition for edible films and coatings is that they may be a primary packaging made from edible substances also, it is viable to use a thin layer of edible packaging directly within the food by using immersion, spraying, and drenching (coating) or by being formerly shaped into a film and after are used as a food wrap without converting the process method of the coating and the ingredients (Aguirre-Joya JA *et al.*, 2018) [1]. The difference between an edible film and coating is that coatings are applied in liquid forms a same time as films are received as stable laminates and then implemented to food stuff (Aguirre-Joya JA *et al.*, 2018) [1].

Advantage and disadvantage of edible packaging

Edible packaging eliminates the everyday waste cycle and does not require any recycling. On account that most edible packaging may be eaten or composted and biodegradable, will not refill landfills or recycling centers, or destroy down into micro plastics in our soil. Customers have now become more environmentally aware and with this drift on board, they without a doubt need to be aware about the waste that their purchases are accounting for. On the other side, edible food packaging quashes off the typical waste cycle and doesn't entail any recycling. Edible packaging is meant to be biodegradable and therefore, there's no danger that it might end up filling up recycling facilities or landfills The edible films protect consumable food products from deterioration by slowing the moisture loss and supplying selective barriers to moisture, breathing inhibition, gases such as oxygen and carbon dioxide, enhancing texture, aiding in the retention of volatile compounds, and preventing microbial growth on food surfaces. It has been demonstrated that the use of edible films and food coatings improves food quality and safety, adds value to edible polymer products, and reduces the use of non-biodegradable packaging materials such as plastics. During the food production and manufacturing processes, edible film is processed from food products (Atta OM *et al.* 2021) [2]. Recent decades, edible wrapping has provided a replacement and/or fortification of the natural layers at the outer surfaces of products to prevent moisture losses, gas aromas, and solvent movements out of the food, while carefully allowing for controlled exchange of essential gases involved in food product respiration, such as carbon dioxide, oxygen, and ethylene. Besides, the materials used for this purpose can be used to extensively coat the food or as a continuous layer between food components (Saklani *et al*., 2019) [45]. Excellent sensory qualities, high barrier properties, high mechanical strength, high microbial stability, free of toxics, safe for health, simple to produce, non-polluting, and low cost are all requirements for a good edible film. The processing of edible films is still in laboratory scale. There are numerous issues that must be resolved before edible films can be financially viable. When compared to synthetic plastics, edible films have lower tensile stability (particularly elongation), poor resistance to gases and liquids, a lack of evaluation on edibility and biodegradability, processing scale-up difficulties, and so on. It is therefore critical to overcome these challenges in order for the edible films to be financially viable (Jeevahan JJ *et al.* 2020) [28]. Milk and lactose allergies are extremely common, which would be a concern for packaging made from milk proteins. Those with gluten allergies should also be cautious of edible packaging, as some can be made with gluten-containing ingredients. Because the packaging is too water soluble, it will not withstand humid conditions. It would also degrade faster if it was kept cold and then exposed to condensation effects after being removed from the refrigerator. Edible films have a limited application in general due to their poor physical properties. Single, lipid-based films, for example, have good moisture barrier properties but no mechanical strength. As a result, laminated films were created by bonding two or more biopolymer films together (Wang L *et al.* 2018) [74]. Despite the use of edible packaging, non-edible materials may still be required depending on the products, negating some of the environmental benefits. Furthermore, because edible packaging is more sensitive to changes in temperature and heat, much more care is required during the shipping process, which may be costly for some businesses to establish. While there has been a lot of research and development to show that it is safe and effective, it may be difficult to gain customer trust in packaging that they can eat. People are so accustomed to discarding packaging or viewing it as a disposable item that it will take time for the culture to shift toward packaging that can be eaten. It may be difficult to change customer attitudes about whether it is hygienic or protective enough against contamination (Iverson J *et al.* 2021) [75].

Various types of polymers included in edible packaging

Plant sources

Gums

The term "gum" refers to a class of naturally occurring polysaccharides that can either create gels or viscous solutions with water or stabilise the emulsion system (Saha A *et al.* 2017) [52]. Natural gums are polysaccharides made up of sugars other than glucose that can increase the viscosity of a solution even at low concentrations (Saha A *et al.* 2017) [52]. They are chemically inert, cheaper, biodegradable, nontoxic, odourless, and widely available. These guys are also known as hydrocolloids since they are water soluble (Saha A *et al.* 2017) [52]. Plant-based gums are most commonly found in the woody portions of plants or within seed coverings. They are occasionally discovered in plant cell walls, tree exudates, and tuber/roots. Several plants created these gums as a defense mechanism against mechanical or microbiological degradation (Saha A *et al.* 2017) [52]. The combination of 20% glycerol (w/w) to edible coatings solutions containing 1% gum was sufficient to achieve a significant reduction in fruit and vegetable weight loss. (Salehi, F. 2020) [62]. The potato slices were coated with guar gum at a concentration of 1% and glycerol of 8% concentration is used as plasticizer (Yu, L *et al.* 2009) [65]. Coating fried potato chips with guar gum and glycerol could effectively inhibit oil absorption while having no bad impacts on breaking force (Yu, L *et al.* 2009) [65]. As a result, future research should concentrate on improving the organoleptic qualities and nutritional value of fruits and vegetables through the use of appropriate combinations of edible coating materials (Tahir, H. E. *et al.* 2019) [67].

Xanthan

The FDA approved xanthan gum as a food additive in 1969, and the European Union acknowledged it as a stabilising and thickening agent under the code E415 in 1980. Furthermore, in addition to being utilised as a stabiliser and thickening in the food sector, xanthan gum is also employed as a gel, emulsifier, and glue to prevent the development of ice crystals. Furthermore, the EFSA re-evaluated the safety of xanthan gum as a food additive in 2017, and this ingredient was deemed safe for human consumption (Pedreiro, s *et al.* 2021**)** [46]. Xanthan gum, a Generally Recognized as Safe (GRAS) chemical, is an exopolysaccharide generated by the bacteria Xanthomonas campestris during fermentation under adverse conditions. Xanthan gum is an anionic polymer composed of the base framework -(1/4)-Dglucopyranose glucan (similar to cellulose) and the residues -(3/1) - D-mannopyranose-(2/1)-D-glucuronic acid-(4/1)-D-mannopyranose (Pedreiro, s *et al.* 2021**)** [46]. At low concentrations, xanthan gum displays strong viscosity, and it is soluble in water, stable at a wide range of pH and temperature and has resistance to enzymatic destruction (Pedreiro s *et al.* 2021**)** [46].

Alginate

Dr. E.C.C. Stanford discovered and isolated alginic acid in 1881. Alginates are monovalent salts of alginic acid (E400), which include sodium alginate (E401), potassium alginate (E402), ammonium alginate (E403), and calcium alginate (E404). Water does not dissolve alginic acid or calcium alginate, whereas sodium alginate, potassium alginate, and ammonium alginate are water-soluble polymers (Parreidt TS *et al.* 2018) [53]. At low pH levels, they have a limited solubility. Kimica Corporation listed the solubility of various types of alginates in various solvents and solutions. Alginates are indigestible polysaccharides produced and refined by many brown algae genera (primarily *Laminaria hyperborean*, *Macrocystis pyrifera*, *Ascophyllum nodosum*; to a lesser extent *Laminaria digitate*, *Laminaria japonica*, *Eclonia maxima*, *Lesonia negrescens*, *Sargassum* sp.) (Parreidt TS *et al.* 2018) [53]. some bacteria, such as *Azotobacter vinelandii* and *Pseudomonas aeruginosa* mucoid strains, manufacture alginate-like polymers as exopolysaccharide (extracellular polymeric substances, EPSs) (Parreidt TS *et al.* 2018) [53]. Alginate production from marine algae and *A. vinelandii* is discussed in more detail elsewhere (Parreidt TS *et al.* 2018) [53]. Alginate is frequently employed as a thickening agent, stabiliser, emulsifier, chelating agent, encapsulating, swelling, a suspending agent, or to make gels, films, and membranes in a variety of sectors including food, beverage, textile, printing, and pharmaceutical. The most common alginate salt is sodium alginate (Parreidt TS *et al.* 2018) [53].

Pectin

Pectin is a readily available biopolymer that is non-toxic, biodegradable, and edible, and it is regarded as a good matrix for the manufacture of edible films due to its gelification potential (González CMO *et al.* 2021) [42]. The addition of fibres, vitamins, colours, and tastes to pectin films confers antibacterial, nutritional, and antioxidant benefits (González CMO *et al.* 2021) [42]. Pectins are important anionic heteropolysaccharides found in higher plant cell walls, consisting primarily of polymeric regions with an average degree of polymerization, DP, of 50–100 of -D-GalpA residues rich in D-galacturonic acid (GalA) units, as a homogalacturonan (HG) backbone segment; these -(1,4) interlinked residues are partly methyl esterified at C-6 and/ or O-acetylated at O-2 or O-3 of the GalA units (Lazaridou A *et al.* 2020) [34]. Analysis of the structural integrity and usability of commercial pectin-based edible films containing beets, orange peel, rice flour, and corn flour (15–17% amylose) (Rai, S. K *et al.* 2019) [76]. The results showed that the mechanical, structural, thermal, or microscopic behaviour of composite edible films were significantly improved by the incorporation of starch in pectin-based film formulations in the ratios of 1:1 or 60:40 (Rai, S. K *et al.* 2019) [76].

Cellulose

Cellulose (C6H10O5) n is one of most naturally occurring organic materials on the planet, with an appealing combination of different properties (Tajeddin B *et al.* 2017) [58]. Although cellulose has been known to mankind for a long time, its application in industries such as packaging is still relatively new and warrants further investigation (Tajeddin B *et al.* 2017) [58]. Cellulosic fibers are available in all natural fibers, whether wood or non-wood. This means that cellulose is a naturally occurring polymer found in the cell walls of all plants, edible and inedible (Tajeddin B *et al.* 2017) [58]. Cellulosic fibres derived from both hard and soft woods, as well as other cellulosic materials (Tajeddin B *et al.* 2017) [58]. Plants contain holocellulose (hemicellulose and cellulose), lignin, and inorganic materials in general ash (Tajeddin B *et al.* 2017)) [58]. Cellulose is not plastic in its natural state, but it can be converted into plastic using a variety of methods (Tajeddin B *et al.* 2017) [58]. To use cellulose as a polymeric material, however, it is frequently necessary to extract it from various plants (Tajeddin B *et al.* 2017) [58].

Soya Protein

Soy protein has attracted the attentions of researchers in the development of environmentally friendly protein materials with potentially beneficial properties such as regeneration, biocompatibility, biodegradability, and so on (Deepmala K *et al.* 2017) [68]. Soy proteins are made up of albumins and globulins, with 90% of them being storage proteins with globular structures, primarily 7S (b -conglycinin) and 11S (glycinin) globulins (Assad I *et al.* 2020) [3]. Soy protein is a byproduct of soybeans, which are used to produce soy oil. Soy protein concentrates (SPCs) and soy protein isolates

(SPIs) offer promising future opportunities for the development of improved packaging materials (Assad I *et al.* 2020) [3]. Nonfood applications of soy protein as polymeric materials have received increasing attention in recent years, in addition to its use as a food ingredient (Deepmala K *et al.* 2017) [68]. Soy protein resins have been used to make green composites for a variety of applications, including hydrogels, adhesives, plastics, films, coatings, and emulsifiers, and it has also been reported as a promising material for biotechnological and biomedical use (Deepmala K *et al.* 2017) [68]. Because soy proteins have both polar and non-polar side chains, strong intra- and inter-molecular interactions such as hydrogen bonding, dipole–dipole, charge–charge, and hydrophobic interactions exist (Deepmala K *et al.* 2017) [68]. The strong charge and polar interactions between soy protein side chains limit segment rotation and molecular mobility, increasing the stiffness, yield point, and impact resistance of soy protein films (Deepmala K *et al.* 2017) [68].

Wheat gluten

Wheat gluten protein (WGP) is the gluten powder that remains after washing out the starch and other soluble substances from wheat flour. WGP, as a byproduct of cereal crops, is a low-cost, abundant, and renewable resource suitable for edible packaging films (Chavoshizadeh, Pirsa, & Mohtarami, 2020) [9]. It has excellent film-forming and gas barrier properties. WG (wheat Gluten)-abased films have good heat-sealing properties as well as good oxygen and oil resistance (Dong M *et al.* 2022) [20]. However, the mechanical and water barrier properties of WG-based films are poor, severely limiting their applications (Dong M *et al.* 2022) [20]. High levels of water and oxygen inside the food package are the primary factors that can affect food quality and shelf-life, as moisture can alter food quality by increasing chemical reactions and microbial spoilage (Dong M *et al.* 2022) [20]. As a result, the mechanical and water barrier properties of WG films should be improved in order to broaden their applications (Dong M *et al.* 2022) [20].

Corn zein

Zein is a generic term for plant-based alcohol-soluble proteins derived from corn endosperm tissue that are produced as a byproduct of bioethanol production in industry. In 1821, John Gorham was the first to coin the term (Bayer LS *et al.* 2021) [8]. Zein's chemical amino acid composition analysis reveals that it contains a high concentration of hydrophobic amino acid residues, which make it soluble in a variety of organic solvents or blends and render it hydrophobic (Bayer LS *et al.* 2021) [8]. When solvent-casted from ethanol solutions, zein forms a film and can also be extruded (Bayer LS *et al.* 2021) [8]. As a result, it is a highly sought-after biopolymer for packaging. Because of its renewability and biodegradability, protein-based food packaging derived from bio-based sources has advanced significantly in recent years and has become an alternative to conventional oil-derived polymer packaging (Bayer LS *et al.* 2021) [8]. Corn zein edible film on intermediate moisture apricots quality (Baysal, T. *et al.* 2010) [69]. Corn zein film is prepared by 6.75 g of zein in 40.6 ml of 95% ethanol and 1.9 ml of glycerin as a plasticizer, potassium sorbate(0.1%) and ascorbic acid (1%) are used to make different formulation corn zein edible film (Baysal, T. et., al 2010) [69]. The apricot with intermediate moisture content had a corn-zein film coating that prevented microbial growth (Baysal, T. *et al.* 2010) [69]. The barrier effect and advantageous internal oxygen composition of the corn zein film coating helped to prevent the growth of microorganisms (Baysal, T. *et al.* 2010) [69]. At high storage temperatures, the coating treatment had an impact on the moisture content of the control samples, but at low temperatures, no discernible moisture loss was observed between samples (Baysal, T. *et al.* 2010) [69]. Novel corn starch/orange-peel oil/zein nanocapsules (OZN) bio-active food packaging materials were produced using zein, corn starch (CS), and orange-peel oil (OPO) extracted from orange peels (Wang, Y *et al.* 2019) [77]. Zein and orange peel oil were weighed in the following proportions: 1/10, 2/10, 3/10, 4/10, and 5/10 (Wang, Y *et al.* 2019) [77]. Zein was then dissolved in 50 ml of 80% ethanol and developed into microcapsules (Wang, Y *et al.* 2019) [77]. Orange peel oil and zein microcapsules were combined to create a film-forming solution, which was then turned into an edible composite film (Wang, Y *et al.* 2019) [77]. The composite film was found to have good apparent performance (Wang, Y *et al.* 2019) [77]. Composite films' mechanical characteristics and barrier performance significantly improved while their light transmittance was significantly reduced (Wang, Y *et al.* 2019) [77].

Animal source

Collagen

Collagen is the most abundant protein in vertebrate extracellular matrix, accounting for approximately 30% of total body protein mass. It is absent in plants and unicellular organisms, where polysaccharides and cellulose play the role. Invertebrates have collagen in their body walls and cuticle, whereas mammals have collagen in their cornea, bones, blood vessels, cartilage, dentin of teeth, and so on. Because of its mechanical properties (Dong, C *et al.* 2016) [21], collagen can be used to produce edible films in the meat industry, such as sausages, salami, and snacks. Collagen films can be embedded/edible in meat products to provide safety benefits, control quality changes, and reduce shrinkage loss of meat and meat-based products during storage, thereby extending shelf life and maintaining product visual appeal for a long time (Holman, B.W.B *et al.* 2018) [78]. Water-soluble collagen accounts for a small proportion of total collagen. Collagen solubility n varies with tissue type and age (Lisitsyn A *et al.* 2021) [36]. The most commonly used solvents for collagen extraction are a neutral salt solution or dilute acetic acid. To break down the additional cross-linked bonds, strong alkali or enzymes are used to extract the insoluble collagen (Lisitsyn A *et al.* 2021) [36]. The effectiveness of edible coatings made of collagen and lysozyme (CL1, 0.1% lysozyme to 4% collagen; CL2, 0.3% lysozyme to 4% collagen; CL3, 0.5% lysozyme to 4% collagen; and CL4, 0.7% lysozyme to 4% collagen, w/v) in preserving fresh salmon fillets (Salmo salar) (Wang, Z et., al 2017) [79]. Results showed that all treatments significantly enhance the fresh salmon fillets' ability to be preserved (P 0.05). Particularly, CL4 reduced the total volatile basic nitrogen (TVB-N) values and inhibited bacterial growth more effectively than other treatments, but it had adverse effects on the samples' general acceptability (Wang, Z *et al.* 2017) [79]. The samples' weight loss was least affected by CL3, which had the greatest impact (Wang, Z *et al.* 2017) [79]. Collagen from fish skins is extracted, and the physical characteristics of the biodegradable films produced from the fish collagen are examined (O'Sullivan, A *et al.* 2006) [70]. A collagen substance that could be used to create biodegradable collagen films was successfully obtained through an acetic acid extraction process (O'Sullivan, A *et al.* 2006) [70]. For each film, 40 g of an aqueous solution of acid extracted fish collagen (1% w/w) was poured onto a level circular perspex plate and allowed to dry for 48 hours to a constant weight at a temperature of 15± 2ºC and a relative humidity of 50± 5% (O'Sullivan, A *et al.* 2006) [70]. As a plasticizer, glycerol (0.08 percent, w/w) was added. Before testing, films were peeled from the plates and kept at 50± 5% RH and 15± 2ºC for 48 hours (O'Sullivan, A *et al.* 2006) [70]. Water vapour permeability (WVP) decreased when plasticizer was added to collagen films, which may be related to a change in collagen structure brought on by the plasticizer (O'Sullivan, A *et al.* 2006) [70].

Casein

Milk protein is a component of two proteins: whey protein and casein protein (kumar L *et al.* 2021) [31]. The majority of milk protein is found in the form of casein protein (kumar L *et al.* 2021) [31]. Casein is made up of four different components: S1-, S2-, -, and -casein, which combine to form colloidal micelles in milk that are stabilised by casein arrangements and calcium phosphate bridges (Chevalier E *et al.* 2018) [14]. Depending on the coagulation method, different types of casein with distinct properties are obtained; the most common types are rennet and acid casein (Chevalier E *et al.* 2018) [14]. Acid casein is precipitated casein obtained by acidifying milk pH to 4.6 (casein's isoelectric point) with mineral acids or lactic acid (produced by lactic acid bacteria) (Chevalier E *et al.* 2018) [14]. During the coagulation process, acid casein colloidal calcium phosphates are solubilized and lost. Acid casein is insoluble in water and has a pH of about 4.6 (Chevalier E *et al.* 2018) [14]. In the case of rennet casein, coagulation is achieved through the action of enzymes, chymosin (rennet), which cleaves a chemical bound in k-casein. Chymosin cleaves the k-casein tail, also known as glycomacropetide, causing casein micelles to destabilize (Chevalier E *et al.* 2018) [14]. Rennet casein obtained is insoluble in water, retains colloidal calcium phosphates, and has a pH of around 7.5 (Chevalier E *et al.* 2018) [14]. Lactic acid and rennet precipitated casein edible films are used to perform the mechanical and barrier properties of edible film. The edible film composition is distilled water, sorbitol or glycerol was combined with lactic acid or rennet casein at concentrations of 3, 5, or 7 percent by weight, and the pH was raised to 10 with 1M NaOH (Chick, J., & Ustunol, Z, 1998) [71]. Similar to other protein-based edible films, films made from these two caseins had good mechanical and oxygen barrier properties, but they weren't very good moisture barriers (Chick, J., & Ustunol, Z, 1998) [71]. Overall, the most effective mechanical and barrier properties were found in lactic acid casein films plasticized with sorbitol (Chick, J., & Ustunol, Z, 1998) [71].

Chitosan

Chitosan is a polysaccharide that is produced through the deacetylation of chitin (Wankhade V *et al.* 2020) [60]. Chitin is a cellulose-like biopolymer found in the exoskeletons of crustaceans and insects, as well as the cell walls of fungi and yeast. Chitin, like cellulose, serves as a structural material in plant cells (Wankhade V *et al.* 2020) [60]. It is a polymer composed primarily of (1 -4) -linked 2 -acetamido - 2 -deoxy - D -glucose monomers and is produced in massive quantities of 10 metric tonnes per year (Wankhade V *et al.* 2020) [60]. Chitosan can be used in food packaging applications as packaging films or as coatings directly on food material (Priyadarshi R *et al.* 2020) [47]. Various researchers from around the world have looked into both approaches (Priyadarshi R *et al.* 2020) [47]. The fabrication methods of chitosan films and coatings have been discussed in this section (Priyadarshi R *et al.* 2020) [47]. Furthermore, some research works on formulations and applications of pure chitosan films without any other polymer/biopolymer, as well as chitosan films blended with other polymers/biopolymers such as polysaccharides, proteins, and synthetic plastics, have been discussed (Priyadarshi R *et al.* 2020) [47].

Chitin

Chitin is the second most abundant biopolymer in nature. Chitin, like cellulose, is an N-acetyl glucosamine homopolymer (Yu Z *et al.* 2020) [64]. Chitin is found primarily in the exoskeletons of shellfish and insects, as well as in the cell walls of mushrooms, with a biosynthesis rate of 10^{10}–10^{11} t per year (Yu Z *et al.* 2020) [64]. Chitin is primarily found in the cuticles of crustaceans such as crabs, shrimp, and lobster, as well as fish scales (Kumari, S *et al.* 2020) [33]. Crustaceans have an exoskeleton made up of proteins, chitin, and calcium carbonate that combine to form an external shell (Kumari, S *et al.* 2020) [33]. Protein and chitosan bind, and a small amount of protein is present in the polymer complex. As a result, chitin separation from the shell necessitates the removal of two major constituents, protein and minerals (Kumari, S *et al.* 2020) [33]. A deproteinization process removes protein, and a demineralization process removes minerals (Kumari, S *et al.* 2020) [33].

Keratin

Keratin is naturally non-burning, water - soluble, biocompatible, and biodegradable, and it can be used in a variety of ways through chemical processing (Ramakrishnan, N *et al.* 2018) [48]. Keratin protein isolated from chicken feathers can be used in a variety of biotechnological applications, including sponges, films, and fibres, either alone or in combination with other natural or synthetic polymers (Ramakrishnan, N *et al.* 2018) [48]. Feather contains 90% protein, known as keratin, which is abundantly produced by the poultry industry worldwide (Ramakrishnan, N *et al.* 2018) [48]. The 60 ml of keratin solution was mixed with different concentrations of (2, 5, 10 wt percent) glycerol to make the keratin edible film (Ramakrishnan, N *et al.* 2018) [48]. The mixture was then mixed for 5 hours at 60 °C with constant magnetic stirring. The aliquot was spread over a circular aluminium weighing boat with a top diameter of 43 mm and placed in a 60 oC oven for 24 hours (Ramakrishnan, N *et al.* 2018) [48]. After 24 hours, the mixture was checked to ensure that it was completely dry and allowed to cool (Ramakrishnan, N *et al.* 2018) [48]. The aluminium weighing boat was then torn apart in order to separate the edible film from the weighing boat (Ramakrishnan, N *et al.* 2018) [48]. After that, the edible film was labelled and stored for analysis. This procedure was repeated with each glycerol concentration (Ramakrishnan, N *et al.* 2018) [48].

Gelatin

Gelatin is one of the most commonly used animal-derived proteins in the production of edible films (Liu, J *et al.* 2020) [37]. Gelatin, a partially denatured derivative of insoluble fibrous collagen, can be extracted from the skins, bones, and tissues of various animal sources (cows, pigs, fish, chickens, and goats) and is easily soluble in hot water (Liu, J *et al.* 2020). Regardless of its origin, gelatin's remarkable film-forming ability, biocompatibility, nontoxicity, and biodegradability make it ideal for food applications (Liu, J *et al.* 2020) [37]. Gelatin is classified into two types based on the extraction method: gelatin obtained through acidic treatment of collagen, with an isoelectronic point of pH =8–9, known as "Type A, and gelatin obtained through alkaline treatment, which converts glutamine and asparagine remains into their respective acids, resulting in increased viscosity and an isoelectronic point of pH = 4-5, known as "Type B" (Milani, Jafar M *et al.* 2020) [40]. Gelatin films outperformed other protein-based films in terms of mechanical strength, thermal resistance, and oxygen permeability (Milani, Jafar M *et al.* 2020) [40]. Other advantages of gelatin-based film included good elasticity, transparency, and negligible wettability. However, low water vapour resistance is a major drawback of this film, and several efforts have been made to improve it over the last decade (Milani, Jafar M *et al.* 2020) [40].

Methods of preparation of edible packaging

To create functional and effective protective structures, edible films and coatings must go through several physical and chemical processes during manufacturing (Marisa Ribeiro A *et al.* 2020) [72]. The precipitation or phase change of the polymeric complex can occur via three different mechanisms during their manufacturing process: simple coacervation, complex coacervation, and gelation or thermal coagulation (Marisa Ribeiro A *et al.* 2020) [72]. During a simple coacervation, precipitation occurs following solvent evaporation, followed by the incorporation of a non-electrolyte compound and an electrolyte, respectively, the latter being added to adjust the pH of the solution, which in turn promotes cross-linking (Marisa Ribeiro A *et al.* 2020) [72]. In contrast, precipitation in a complex coacervation is achieved by mixing two hydrocolloid solutions with opposing electron charges. Precipitation of biopolymers during coagulation can be achieved by heating or cooling the film solution, causing its degradation (Marisa Ribeiro A *et al.* 2020) [72]. Prior to the formation of the film and coating, the base biopolymer must be dissolved in a solvent such as water, alcohol, or a combination of the two (Marisa Ribeiro A *et al.* 2020) [72]. Various active agents (e.g., antioxidants, antimicrobials, colourants, flavours, plasticizers) can be added to the previous solution at this stage to improve the final product's properties (Marisa Ribeiro A *et al.* 2020) [72]. The method by which this mother solution is transformed into the final conformation is determined by the type of packaging desired because, while films and coatings serve the same final function, their production methods are quite different (Marisa Ribeiro A *et al.* 2020) [72]. The most common method used in edible packaging industry is casting and extrusion method.

Casting method

Casting is a simple wet process for producing edible films, but it is a batch procedure used on a very small scale (Aguirre-Joya, Jorge A *et al.* 2018) [1]. However, because the film-forming suspension is prepared on continuous carrier tapes with controlled thickness, a continuous casting method can be used on an industrial scale (Aguirre-Joya, Jorge A *et al.* 2018) [1]. During the casting process, equipment, atmosphere, time, and temperature can all have a significant impact on the final film's performance (wang H *et al.* 2021) [61]. Pouring, drying, and balanced storage are standard techniques in the casting process (wang H *et al.* 2021) [61]. Casting entails three steps in the preparation of a biopolymer film: Solubilization of biopolymer in a suitable solvent, casting of the solution in the mould, and drying of the casted solution (fig 1) (suhag R *et al.* 2020) [56]. The selection of the polymer or polymer mixture that will form the basic film is the first step in the production of edible films (suhag R *et al.* 2020) [56]. Solubilisation occurs when the chosen polymer is dissolved or dispersed in a suitable solvent; for example, ethanol is used to dissolve soy protein isolate polymer (suhag R *et al.* 2020) [56]. In solvent casting, film formation is determined by the polymer's solubility rather than melting (suhag R *et al.* 2020) [56]. The obtained solution is poured into a predefined mould or teflon-coated glass plates during the casting process (suhag R *et al.* 2020) [56]. The drying process allows enough time for the solvent to evaporate, resulting in a polymer film that adheres to the mould (suhag R *et al.* 2020) [56]. Air driers such as hot air ovens, tray dryers, microwaves, and vacuum driers are used in the casting of films to facilitate the removal of solvents and film peel (suhag R *et al.* 2020) [56]. The air-drying procedure for edible film casting is a critical step in improving the intra-molecular relationship between the polymer chains and obtaining a suitable microstructure of the film (suhag R *et al.* 2020) [56]. The use of quick-drying methods for casting the film has had a negative impact on its physical and structural properties (suhag R *et al.* 2020) [56]. Several studies have been conducted to compare drying temperature and air-drying methods for the production of edible films (suhag R *et al.* 2020) [56].

Extrusion method

The extrusion process is used to make edible films, and it has the potential to increase commercial production (Kumar L *et al.* 2021) [31]. Extrusion is a dry process because it requires little or no solvent (Kumar L *et al.* 2021) [31]. Because there is little or no solvent, we do not need to wait for the solvent to evaporate, and the drying time is eliminated (Kumar L *et al.* 2021) [31]. The extruder is divided into three zones (Kumar L *et al.* 2021) [31]. The feeding zone is where biopolymer and additives are introduced into the extruder (Kumar L *et al.* 2021) [31]. Following that is the kneading zone, where ingredients are properly mixed with the help of an extruder screw, and the final zone is the heating zone, where some heat is provided with the help of the oven (Kumar L *et al.* 2021) [31]. Melting and mixing of biopolymer and additives takes place here (Kumar L *et al.* 2021) [31]. A die is fixed at the extruder's end, determining the shape and thickness of the extruded film (Kumar L *et al.* 2021) [31]. High temperatures alter the structure of the biopolymer, improving its overall properties. The temperature-sensitive biopolymer cannot be extruded because high temperatures degrade it (Kumar L *et al.* 2021) [31]. Extruder screw speed, heat amount, heating zone length, and solvent content, if present, are all critical parameters (Kumar L *et al.* 2021) [31]. They are crucial in determining the mechanical and optical properties of the film (Kumar L *et al.* 2021) [31]. When compared to a single screw extruder, a twin screw extruder improves feed mixing (Kumar L *et al.* 2021) [31]. We can produce a multilayered film with improved overall properties by using more than one extruder (Kumar L *et al.* 2021) [31]. This is referred to as co-extrusion. The final co-extruded film will have enhanced properties over single-layer extruded film (Kumar L *et al.* 2021) [31]. The drawback of this type is that only temperature or heat tolerate biopolymer can be used as the mixture of biopolymer and additives flows forward and the extruder temperature rises (Kumar L *et al.* 2021) [31]. Heat-sensitive materials will deteriorate as a result of the temperature zone. Because extruder equipment has a high initial cost, the total manufacturing cost is higher than with casting (Kumar L *et al.* 2021) [31].

Methods of edible coating

As the principal edible packaging, edible coating is directly put to the surface of fruits, vegetables, and other food products (Kumar L *et al.* 2021) [31]. Dipping, spraying, fluidized bed, and panning for coating are the four basic coating processes (Kumar L *et al.* 2021) [31]. The coating method used is determined by various aspects, including the surface qualities of the food product and the function of the coating layer (Kumar L *et al.* 2021) [31]. Coating formation begins with the components being diffused over the food surface, followed by adhesion between the coating material and the food surface (Kumar L *et al.* 2021) [31]. This section provides a quick overview of the primary coating methods (Kumar L *et al.* 2021) [31]. Edible coatings operate as an additional layer that covers the stomata, lowering transpiration and, as a result, weight loss; this is the fundamental beneficial impact of edible coatings, as seen in a variety of fruits and vegetables (Salehi F *et al.* 2020) [62]. The addition of glycerol as a plasticizer to the edible coating produced good results in terms of reducing fruit and vegetable moisture loss, which was consistent with previous reports in which the addition of 20% glycerol (w/w) to edible coating solutions containing 1% gum was sufficient to achieve the high reduction of weight loss (Salehi F *et al.* 2020) [62].

Dipping method

Dipping is most typically done with fruits and vegetables (Kumar L *et al.* 2021) [31]. This procedure may be broken down into three phases (Kumar L *et al.* 2021) [31]. The first step is to completely immerse the food product in the coating-forming fluid. The coating substance is then put on the surface of the food product (Kumar L *et al.* 2021) [31]. The solvent evaporates from the coating in the final phase, generating a solution and leaving a thin coating on the product's surface (Kumar L *et al.* 2021) [31]. Edible coating has comparable features to modified environment packaging in that it protects food goods from oxygen, light, microbes, and moisture, hence extending their shelf life (Tripath A,D *et al.* 2021) [73]. Water vapor permeability and oxygen permeability tests can be used to measure the barrier qualities of edible coatings (Tripath A, D *et al.* 2021) [73]. The protective role of edible coatings, on the other hand, may be identified by their tensile characteristics, which include Young's Modulus, tensile strength, and elongation at break (Tripath A,D *et al.* 2021) [73] (fig 3). Chitosan is one of the few cationic polysaccharides found in crustaceans and fungus. Because of its antibacterial characteristics against germs, moulds, and yeasts, chitosan is a highly appealing material for food coating (Costa M,J *et al.* 2018) [15]. Chitosan-based coatings and films were tested on many varieties of cheeses depending on this and their coating and film forming capabilities, with the goal of reducing microbial development and thereby extending cheese shelf life (Costa M,J *et al.* 2018) [15]. It was also employed as a carrier for other antibacterial chemicals. Inoculated ready-to-eat Emmental cheese with Listeria innocua and employed a 1 percent (v/v) chitosan-based coating to function as an antibacterial and prevent pathogen development (Costa M,J *et al.* 2018) [15]. This method resulted in the 100% suppression of L. innocua for 132 hours when the coating was applied to 1 cm^3 cheese samples and incubated at 37 C (Costa M,J *et al.* 2018) [15]. Chitosan coating with 60% lysozyme to an aged, low moisture, sliced mozzarella cheese (Costa M,J *et al.* 2018) [15].

Spraying method

The liquid solution is sprayed on the food product in this approach. The liquid solution is converted into small droplets when sprayed (Suhag, R *et al.* 2020) [56]. These droplets will have larger surface area for the same volume of liquid solution. As a result, droplets will cover a larger area of the substance (Suhag, R *et al.* 2020) [56]. This procedure is classified into two types based on how the droplets form: air spray atomization and pressure atomization (Suhag, R *et al.* 2020) [56]. High-speed air is used in air spray atomization to convert the liquid into droplets, whereas high pressure is used in pressure atomization to convert the liquid into droplets (Suhag, R *et al.* 2020) [56]. Figure 4 depicts the spraying procedure for covering Valencia oranges with edible coating (Suhag, R *et al.* 2020) [56]. A xanthin gum-based edible coating, as well as citric acid and glycerol as plasticizers, was sprayed over the lotus root until it reached a thickness of 5 mm (Lara, G *et al.* 2020) [35]. This coating prevents colour change and inhibits Bacillus subtilis microbe development, extending the shelf life of lotus roots (Lara, G *et al.* 2020) [35]. Since the coating solution is not viscous, spraying may be performed (García A, V *et al.* 2015) [26]. The food product is delivered into the coating system and sprayed by managing the ultimate drop size of the spray solution, which is determined by spray gun thickness, nozzle temperature, air and liquid flow rates, incoming air and polymer solution humidity, drying time and temperature (García A,V *et al.* 2015) [26]. In this application, the typical spraying device may create fine sprays with drop-size distributions of up to 20 µm (García A, V *et al.* 2015) [26]

Panning method

Panning involves keeping food in a big rotating basin called a pan, into which layering solution is poured by sprinkling and drizzling (Valdes, A *et al.* 2017) [80]. To cover the product uniformly, the product and solution were tossed together (Valdes, A *et al.* 2017) [80]. This process has been classified into three varieties based on the qualities of the food products: soft panning, hard panning, and chocolate panning (Tiwari, S *et al.* 2020) [57]. This procedure is appropriate for extruded food items with fixed sizes and a round or oval shape, producing an exceptionally clear coating with improved elasticity and a polished look (Dhumal, C. V., & Sarkar, P *et al.* 2018) [18]. A pan, a large round ball, is turned, and food ingredients are rotated inside it. While the pan is rotating, the coating forming solution is sprayed on the surface of the food product (Campos, C. A *et al.* 2011) [16]. The thickness of the final coating on the food product is determined by the volume of solution sprayed (Campos, C. A *et al.* 2011) [16]. Figure 5 depicts the panning coating production process, in which the coating spray cannon deposits the edible coating ingredient on the food product (Campos, C. A *et al.* 2011) [16].

Fluidized bed processing method

This method is useful for applying a thin layer of coating to the surface of a very tiny dry food product, such as wheat or almonds (Chawla, R *et al.* 2021) [11]. The coating solution is sprayed using nozzles, which aids in the flow of the sprayed solution over the smaller size food (Chawla, R *et al*. 2021) [11]. The solution begins to build a shell on the food, which gradually transforms into the coating. Following that, drying is carried out (Chawla, R *et al*. 2021) [11]. This process is more expensive than other coating methods (Chawla, R *et al*. 2021) [11]. This procedure is utilized in the food sector to create a wide variety of encapsulated foods and additives such as cereals, almonds, peanuts, and so on (Debeaufort, F., & Voilley, A. *et al*. 2009) [17]. The use of the fluidized bed technology for particle coating always attempts to produce a product of uniform quality and morphology batch after batch. This is mostly governed by the physical condition of the droplets. The process of applying a film on a solid is truly complicated. A layer of coating does not form in a single pass through the coating zone, but rather requires several such passes to cover the whole surface. Binary or pneumatic nozzles are commonly employed in fluidized bed coating: liquid is fed at a low pressure and sheared into droplets by air. Droplet size and distribution are more controlled than with a hydraulic nozzle, particularly at low liquid flow rates. Furthermore, the atomization air adds to the evaporation of the coating solvent. This evaporation raises the viscosity of the droplets, preventing them from spreading and coalescing when they come into contact with the core substance. Figure 6 is a conventional top-spray method evolved from fluidized bed dryer.

Bakery edible packaging

Edible films and coatings have emerged as a viable alternative to plastic packaging for a variety of food product uses, including fruits and vegetables, dairy goods, nutritious items, meat and meat products, and so on. Bakery edible packaging made from films and coating are according several research paper (Table 1). The conceivable use for edible coatings in bakery and confectionery items is an essential quality factor that influences purchasers' visual judgments and prospective purchase of the product. The packaging of the product is a crucial influence to the look and attractiveness of the product.

Table 1: Bakery edible packaging made from films and coating are according several research paper

Bakery Item	Coating composition	Major findings	Reference
Muffins	Triticale flour (4%) +Glycerol	Coated muffins were reported to be softer on storage for 10 days. Hardening of muffins was diminished. Retardation in staling process decreased K value (0.2407) & slower crumb firmness kinetics. Higher time constant values (31%) than in control.	Bartolozzo, J *et al.* 2016 [5]
	Cinnamon oil-based nano emulsion (1.5% v/v soy lecithin) + clove oil-based nano emulsion (2% v/v soy lecithin)	Increased antioxidant and antimicrobial activity of essential oil-based Nano emulsions coated muffins. Shelf life of muffins was improved. Coated muffins were observed with softer texture, reduced weight loss, density, and moisture content. Clove oil nano emulsion coated muffins had higher total plate count.	Kaur, G., & Singh, A, *et al.* 2022 [29]
	Cassava starch (50%) +Inverted sugar (1.4%) +Sucrose (0.7%) + Natural additives [Soluble coffee (0.0-2.0%), Cocoa powder, Propolis extract (0.0-2.0%)]	Mould and yeast development on the muffins without the use of synthetic additives. Active edible coating had a shelf life of 87 days. Color of edible coated muffins was significantly improved.	Luana, D. O. M. N *et al.* 2019 [37]
	Sodium alginate (0.4% & 1.0%) +Glycerol (25%) +Carboxymethyl cellulose (0.05% & 0.1%) +Glycerol (25%)	Low concentrations of coating were found to be effective in reducing syneresis in raspberries during muffin baking. The edible coating used in this process was beneficial in the development of baking-stable red raspberry incorporated muffins. Sodium alginate coating on red raspberries resulted in 13.9 percent syneresis in baked muffins. Edible coating improved mechanical properties and reduced drip loss in muffin (1.26%).	Quintanilla, A *et al.* 2021 [63]
Cookies	Whey (8%), glycerol (6%) +Inulin (4% & 2%) +gelatine (5%, 3.5% & 2%) +*Lactobacillus casei shirota* (1% & 2%)	Colour loss in cracker cookies had a shelf life of 20 days was observed. The coating of Inulin 4%, gelatine 3.5%, LBC (lactobacillus casei Shirota) 2% maintained good quality of cracker cookies with better acceptance by consumers. No difference in texture and moisture after coating. As a result, by supplementing these cookies with probiotic bacteria, they can be used to add functional food value.	García-Argueta, I *et al.* 2015 [26]
Crackers	Corn starch (27% amylose) + Methylcellulose (27.5 – 32%) + Soyabean oil (1.45 g) +Glycerol (1.16 g)	Edible coating in crackers induced low water activity. Loss of crispness resulted in shorter shelf life. Optimum edible coating to crackers was atomization pressure of two bar and film thickness of 30µm. Decrease in relative humidity% as when there is increase in the hours of shelf life of coated crackers.	Bravin, B *et al.* 2006 [7]
cake	Methylcellulose (1.44g) + Corn starch (3.19g)+Glycerol (1.16g) + Cinnamon oil (1.45ml)	Lower total count of bacteria and yeasts when compared to the control sample improved the rheological properties of dough. Acid value and peroxide value of edible coated cake was reduced while in storage condition. Improved the specific volume and firmness of the cake.	El-Zainy, A. R. M *et al.* 2014 [23]

Gingerbread cake	Corn starch or potato starch (2-10%) +Gelatin (5-25%) +Plasticizer [urea (1-5%)] +Hydrophobic component [paraffin or linseed oil (1-10%)] + Solvent (water)	Maintained freshness of gingerbread cakes during storage without altering their organoleptic and physical and chemical quality parameters. Slight difference in friability of edible coated gingerbread cake when compared to the coating of synthetic material and sugar syrup. Intensive staling of edible coated gingerbread cake was reduced. Better moisture retention properties.	Shulga, O *et al.* 2016 [54]
Mini panettone (cake)	Potato starch [amylose (220g/kg) & amylopectin (780g/kg)] +Inverted sugar (76-78% brix, 90% inversion and PH 4.5-5)	Mold/yeast was not detected after 48 days when potassium sorbate was used. Safety and quality of mini panettone cake is improved. 130% increase in shelf life of mini panettone cake with the addition of antimicrobial compounds.	Saraiva, L. E. F *et al.* 2016 [50]
Biscuits	Okra mucilage gum (4g) +Ethanol 95%	Reduced the loss of crispness during storage. Improved the moisture barrier properties of biscuits.	Nayanakanthi, T. P *et al.* 2021 [41]
Bread	Pectin, alginate and whey protein concentrate (1.5 w/w) +Glycerol (33%)	The hardness of bread increased in the study for 24 hrs. When compared to commercial bread. Moisture and textural quality of bread retained during storage. No effect on mechanical characteristics of fresh bread.	Chakravartula, S. S. N *et al.* 2019 [10]
Traditional bulk bread	*Lactobacillus rhamnosus* GG (1%) + Methyl cellulose (2%) + Corn starch (1%) + Whey protein concentrate (2%) +Soybean oil (2%, 4%, and 6%)	Probiotic component in the coating enhanced the viability throughout the shelf-life. Soybean oil improved texture, sensory properties and image index during storage. Stable values of lightness (L⋆), redness (a⋆) and yellowness (b⋆) were observed in the bread prepared with soybean oil.	Qandashtant, R. A *et al.* 2020 [62]
	Wax-based coating (20%) +HPMC (Hydroxypropyl methyl cellulose) oleogel coating (0.8% in 38.6% of distilled water) + Ethyl cellulose oleogel coating (20%)	Minimized water migration (12.5%). The bread retain moisture during ambient storage. When compared to bread stored for five days in plastic bags. 20% candelilla wax coating had the highest moisture barrier efficiency.	Chen, Y *et al.* 2021[13]
Rye wheat bread	Potato starch – (5%) +Gelatin – (15%) +Urea – (3%) +Flaxseed oil – (5%) +water – (72%)	The moisture content of synthetic packaging and edible packaging are in same level of 43.8% to 43.3%. Edible coated rye wheat bread has the properties of absorbing water crumb, structural and mechanical properties. Edible coating improves the organoleptic properties of rye wheat bread and gaining gloss. Edible coated rye wheat bread is a complete replacement of synthetic packaging for rye wheat bread.	Shulga, O *et al.* 2017 [55]
Danish and croissant	Methylcellulose (1.44g) in 75ml distilled water +Corn starch (3.19g) in 75 ml of water +Soybean oil (1.45g) +Glycerol (1.16g) +Nisin (0.1g/100ml)	The shelf life of Danish and Croissants was extended by 21 and 42 days, respectively. Water activity and staling of edible coated Danish and Croissant were significantly reduced during storage. The use of methylcellulose in combined with nisin resulted in the lowest total count, as well as mould and yeast counts. The edible coating improves storability by lowering rancidity in bakery products.	EL-DIN, AA H *et al.* 2015
Frozen dough	Tomato powder (7.5g) + Ascorbic acid 1.5ml + Corn starch (15g/L) + Glycerol (20.2%)	It improved firmness and browning of the bread when using with coated frozen dough. Shelf-life of coated frozen dough is 60 days of frozen storage. The bread prepared with coated frozen dough enhanced specific volume and less hardness. The parameters such as surface tension, viscosity and electrical conductivity increase in the independent variable.	Galvão AMMT *et al.* 2018 [25]

Conclusion

This review assembles information on the significance and functions of edible coating and film in extending the shelf life of bakery products. Edible coatings and films improve food quality by lowering microbial counts. The methods of film formation and edible coating on various food products are also discussed in this study. The review included that the edible coating of different bakery products and this review discuss about the casting method of film formation and types of coating of edible packaging. All edible coating methods improve the efficiency and longevity of the coating material or coated bakery products.

Reference

1. Aguirre-Joya JA, De Leon-Zapata MA, Alvarez-Perez OB, Torres-León C, Nieto-Oropeza DE, Ventura-Sobrevilla JM, *et al.* Basic and applied concepts of edible packaging for foods. In Food packaging and preservation (pp. 1-61). Academic Press; c2018.
2. Atta OM, Manan S, Ahmed AAQ, Awad MF, Ul-Islam M, Subhan F, *et al.* Development and characterization of yeast-incorporated antimicrobial cellulose biofilms for edible food packaging application. Polymers. 2021;13(14):2310.
3. Assad I, Bhat SU, Gani A, Shah A. Protein based packaging of plant origin: Fabrication, properties, recent advances and future perspectives. International Journal of

Biological Macromolecules. 2020;164:707-716.
4. Bakery production around the world. (n.d.). International Market Analysis Research and Consulting Group. Retrieved March 28, 2022, from https://www.imarcgroup.com/bakery-products-market
5. Bartolozzo J, Borneo R, Aguirre A. Effect of triticale-based edible coating on muffin quality maintenance during storage. Journal of Food Measurement and Characterization. 2016;10(1):88-95.
6. Bilbao-Sainz C, Chiou BS, Punotai K, Olson D, Williams T, Wood D, *et al.* Layer-by-layer alginate and fungal chitosan based edible coatings applied to fruit bars. Journal of food science. 2018;83(7):1880-1887.
7. Bravin B, Peressini D, Sensidoni A. Development and application of polysaccharide–lipid edible coating to extend shelf-life of dry bakery products. Journal of Food Engineering. 2006;76(3):280-290.
8. Bayer IS. Zein in Food Packaging. Sustainable Food Packaging Technology; c2021.p. 199-224.
9. Chavoshizadeh S, Pirsa S, Mohtarami F. Conducting/smart color film based on wheat gluten/chlorophyll/polypyrrole nanocomposite. Food Packaging and Shelf Life. 2020;24:100501.
10. Chakravartula SSN, Cevoli C, Balestra F, Fabbri A, Dalla Rosa M. Evaluation of drying of edible coating on bread using NIR spectroscopy. Journal of Food Engineering. 2019;240:29-37.
11. Chawla R, Sivakumar S, Kaur H. Antimicrobial edible films in food packaging: Current scenario and recent nanotechnological advancements-a review. Carbohydrate Polymer Technologies and Applications. 2021;2:100024.
12. Chhavi DK, Singh VK, Sakshi C, Naman J. Soy protein based green composite: a review. Res Rev: J Mater Sci, 2017;5(2):66-77.
13. Chen Y, Gavaliatsis T, Kuster S, Städeli C, Fischer P, Windhab EJ. Crust treatments to reduce bread staling. Current Research in Food Science. 2021;4:182-190.
14. Chevalier E, Assezat G, Prochazka F, Oulahal N. Development and characterization of a novel edible extruded sheet based on different casein sources and influence of the glycerol concentration. Food Hydrocolloids. 2018;75:182-191.
15. Costa MJ, Maciel LC, Teixeira JA, Vicente AA, Cerqueira MA. Use of edible films and coatings in cheese preservation: Opportunities and challenges. Food Research International. 2018;107:84-92.
16. Campos CA, Gerschenson LN, Flores SK. Development of edible films and coatings with antimicrobial activity. Food and bioprocess technology. 2011;4(6):849-875.
17. Debeaufort F, Voilley A. Lipid-based edible films and coatings. In Edible films and coatings for food applications. Springer, New York, NY; c2009.p. 135-168.
18. Dhumal CV, Sarkar P. Composite edible films and coatings from food-grade biopolymers. Journal of food science and technology. 2018;55(11):4369-4383.
19. Deshmukh S. Study of Marketing Function in Bakery Industry in India. Study of Marketing Function in Bakery Industry in India. 2019;16(8):212-219. http://ignited.in/I/a/252692.
20. Dong M, Tian L, Li J, Jia J, Dong Y, Tu Y, *et al.* Improving physicochemical properties of edible wheat gluten protein films with proteins, polysaccharides and organic acid. LWT. 2022;154:112868.
21. Dong C, Lv Y. Application of collagen scaffold in tissue engineering: recent advances and new perspectives. Polymers. 2016;8(2):42.
22. El-din AAH, Khalik AMA, Asael M. Effect of using coating film in preservation of some bakery products having a functional significance value; c2016.
23. El-Zainy ARM, Aboul-Anean H, Shelbaya LA, Ramadan EMM. Effect of edible coating with cinnamon oil on the quality of cake. Middle East Journal of Applied Sciences. 2014;4(4):1171-86.
24. Eyiz V, Tontul İ, Türker S. The effect of edible coatings on physical and chemical characteristics of fruit bars. Journal of Food Measurement and Characterization. 2020;14(3):1775-1783.
25. Galvão AM, Zambelli RA, Araújo AW, Bastos MS. Edible coating based on modified corn starch/tomato powder: Effect on the quality of dough bread. LWT. 2018;89:518-524.
26. García-Argueta I, Quintero-Salazar B, Dominguez-Lopez A, Gómez-Oliván LM, Díaz-Bandera D, Dublán-García O. Effect of edible coating based on whey, inulin and gelatine with Lactobacillus casei on the textural and sensorial properties of a cracker cookie. J Prob. Health. 2015;4:153.
27. Gavahian M, Chu YH, Lorenzo JM, Mousavi Khaneghah A, Barba FJ. Essential oils as natural preservatives for bakery products: Understanding the mechanisms of action, recent findings, and applications. Critical reviews in food science and nutrition. 202060(2):310-321.
28. Jeevahan JJ, Chandrasekaran M, Venkatesan, SP, Sriram V, Joseph GB, Mageshwaran G, *et al.* Scaling up difficulties and commercial aspects of edible films for food packaging: A review. Trends in Food Science & Technology. 2020;100:210-222.
29. Kaur G, Singh A. Shelf life extension of muffins coated with cinnamon and clove oil nanoemulsions. Journal of Food Science and Technology. 2022;59(5):1878-1888.
30. Kumar S, Singh C. Productivity growth in India's bakery manufacturing industry. Journal of Agribusiness in Developing and Emerging Economies; c2020.
31. Kumar, L, Ramakanth D, Akhila K, Gaikwad KK. Edible films and coatings for food packaging applications: a review. Environmental Chemistry Letters; c2021.p. 1-26.
32. Kumari S, Kishor R. Chitin and chitosan: origin, properties, and applications. In Handbook of chitin and chitosan. Elsevier; c2020.p. 1-33.
33. Kumar L, Ramakanth D, Akhila K, Gaikwad KK. Edible films and coatings for food packaging applications: a review. Environmental Chemistry Letters; c2021.p. 1-26.
34. Lazaridou A, Biliaderis CG. Edible films and coatings with pectin. Pectin: Technological and physiological properties; c2020.p. 99-123.
35. Lara G, Yakoubi S, Villacorta CM, Uemura K, Kobayashi I, Takahashi C, *et al.* Spray technology applications of xanthan gum-based edible coatings for fresh-cut lotus root (Nelumbo nucifera). Food Research International. 2020;137:109723.
36. Lisitsyn A, Semenova A, Nasonova V, Polishchuk E, Revutskaya N, Kozyrev I, *et al.* Approaches in animal proteins and natural polysaccharides application for food packaging: Edible film production and quality estimation. Polymers. 2021;13(10):1592.
37. Luana DOMN, Bruna ASM, Luciana EFS, Samantha SC,

Rejane PDS, Emanuelle AD, *et al.* Physicochemical and microbiological stability of muffins packed in actives edible coatings from cassava starch: Inverted sugar/sucrose and natural additives. African Journal of Biotechnology. 2019;18(10):206-219.
38. Liu J, Zhang L, Liu C, Zheng X, Tang K. Tuning structure and properties of gelatin edible films through pullulan dialdehyde crosslinking. Lwt. 2020;138:110607.
39. Mojumdar SC, Moresoli C, Simon LC, Legge RL. Edible wheat gluten (WG) protein films: Preparation, thermal, mechanical and spectral properties. Journal of thermal analysis and calorimetry. 2011;104(3):929-936.
40. Milani JM, Tirgarian B. An overview of edible protein-based packaging: Main sources, advantages, drawbacks, recent progressions and food applications. Journal of Packaging Technology and Research. 2020;4(1):103-115.
41. Nayanakanthi TP, Senanayake CM, Siranjiv P. Development of an Edible Coating from Okra Mucilage to Preserve the Crispiness in Soft Dough Biscuits upon Storage; c2021.
42. Otálora González CM, De Nobili MD, Rojas AM, Basanta MF, Gerschenson LN. Development of functional pectin edible films with fillers obtained from red cabbage and beetroot. International Journal of Food Science & Technology. 202156(8):3662-3669.
43. Pandhi S, Kumar A, Alam T. Probiotic edible films and coatings: Concerns, applications and future prospects. Journal of Packaging Technology and Research. 2019;3(3):261-268.
44. Petkoska AT, Daniloski DD, Cunha NM, Naumovski N, Broach AT. Edible packaging: Sustainable solutions and novel trends in food packaging. Food Research International. 2021;140:109981.
45. Pooja Saklani PS, Nath S, Kishor Das S, Singh SM. A review of edible packaging for foods. Int. J Curr. Microbiol. Appl. Sci. 2019;8:2885-2895.
46. Pedreiro S, Figueirinha A, Silva AS, Ramos F. Bioactive Edible Films and Coatings Based in Gums and Starch: Phenolic Enrichment and Foods Application. Coatings. 2021;11(11):1393.
47. Priyadarshi R, Rhim JW. Chitosan-based biodegradable functional films for food packaging applications. Innovative Food Science & Emerging Technologies. 2020;62:102346.
48. Ramakrishnan N, Sharma S, Gupta A, Alashwal BY. Keratin based bio plastic film from chicken feathers and its characterization. International journal of biological macromolecules. 2018;111:352-358.
49. Ribeiro AM, Estevinho BN, Rocha F. Edible films prepared with different biopolymers, containing polyphenols extracted from elderberry (*Sambucus nigra* L.), to protect food products and to improve food functionality. Food and Bioprocess Technology. 2020;13(10):1742-1754.
50. Saraiva LEF, Naponucena LDOM, da Silva Santos V, Silva RPD, de Souza CO, Souza IEGL, *et al.* Development and application of edible film of active potato starch to extend mini panettone shelf life. LWT. 2016;73:311-319.
51. Silva TJ, Fernandes GD, Bernardinelli OD, da Rosa Silva EC, Barrera-Arellano D, Ribeiro APB. Organogels in low-fat and high-fat margarine: A study of physical properties and shelf life. Food Research International. 2021;140:110036.
52. Saha A, Tyagi S, Gupta RK, Tyagi YK. Natural gums of plant origin as edible coatings for food industry applications. Critical reviews in biotechnology. 2017;37(8):959-973.
53. Senturk Parreidt T, Müller K, Schmid M. Alginate-based edible films and coatings for food packaging applications. Foods. 2018;7(10):170.
54. Shulga O, Chorna A, Arsenieva L. Edible coating as factor of preserving freshness and increasing biological value of gingerbread cakes; c2016.
55. Shulga O, Chorna A, Shulga S. Influence of edible coatings on rye and rye-wheat bread quality; c2017.
56. Suhag R, Kumar N, Petkoska AT, Upadhyay A. Film formation and deposition methods of edible coating on food products: A review. Food Research International. 2020;136:109582.
57. Tiwari S, Mathur G. Polymer based coating and its applications in food industry. Recent trends in biosciences and biotechnology; c2020. p. 97.
58. Tajeddin B. Cellulose-based polymers for packaging applications. Lignocellulosic polymer composites: Processing, characterization, and properties; c2017. p. 1-584.
59. Valdés A, Burgos N, Jiménez A, Garrigós MC. Natural pectin polysaccharides as edible coatings. Coatings. 2015;5(4):865-886.
60. Wankhade V. Animal-derived biopolymers in food and biomedical technology. In Biopolymer-Based Formulations. Elsevier; c2020.p. 139-152.
61. Wang H, Ding F, Ma L, Zhang Y. Edible films from chitosan-gelatin: Physical properties and food packaging application. Food Bioscience. 2021;40:100871.
62. Qandashtant RA, Salehi EA, Sani AM, Sangatash MM, Safari O. Investigation on quality properties of traditional bulk bread covered with probiotics and soybean oil edible coating. Acta Alimentaria. 2020;49(2):144-153.
63. Quintanilla A, Zhang H, Powers J, Sablani SS. Developing Baking-Stable Red Raspberries with Improved Mechanical Properties and Reduced Syneresis. Food and Bioprocess Technology. 2021;14(5):804-816.
64. Yu Z, Ji Y, Bourg V, Bilgen M, Meredith JC. Chitin-and cellulose-based sustainable barrier materials: a review. Emergent Materials. 2020;3(6):919-936.
65. Yu X, Schmidt AR, Schmidt SJ. Uncertainty analysis of hygrometer-obtained water activity measurements of saturated salt slurries and food materials. Food chemistry. 2009;115(1):214-226.
66. Smtth JP, Simpson BK. Modified atmosphere packaging of bakery and pasta products. In Principles of Modified-Atmosphere Amd Sous Vide Product Packaging. Routledge. 2018 Dec 19;207-242.
67. Tahir HE, Xiaobo Z, Mahunu GK, Arslan M, Abdalhai M, Zhihua L. Recent developments in gum edible coating applications for fruits and vegetables preservation: A review. Carbohydrate polymers. 2019 Nov 15;224:115141.
68. Kumar Nagda, J, Nishant AB, Deepmala K, Akhouri H, Dinesh K. Mitigating effect of foliar applied ascorbic acid on morpho-physiological, biochemical changes and yield attributes induced by salt stress in Vigna radiate; c2017. p. 112-116.
69. Baysal T, Bilek SE, Apaydin E. The effect of corn zein edible film coating on intermediate moisture apricot (*Prunus armenica* L.) quality. Gida. 2010 Aug

1;35(4):245-249.
70. Wallace IM, O'sullivan O, Higgins DG, Notredame C. M-Coffee: Combining multiple sequence alignment methods with T-Coffee. Nucleic acids research. 2006 Jan 1;34(6):1692-1699.
71. Chick J, Ustunol Z. Mechanical and barrier properties of lactic acid and rennet precipitated casein-based edible films. Journal of food science. 1998 Nov;63(6):1024-1027.
72. Ribeiro AM, Shahgol M, Estevinho BN, Rocha F. Microencapsulation of Vitamin A by spray-drying, using binary and ternary blends of gum arabic, starch and maltodextrin. Food Hydrocolloids. 2020 Nov 1;108:106029.
73. Vijayalakshmi D, Manimegalai CT, Ayyanar N, Nguyen TK, Kalimuthu K. Highly sensitive tri-path photonic crystal fiber plasmonic sensor based on hybrid layer of gold/platinum diselenide. Optical and Quantum Electronics. 2021 Aug;53(8):1-7.
74. Semler MW, Self WH, Wanderer JP, Ehrenfeld JM, Wang L, Byrne DW, *et al*. Balanced crystalloids versus saline in critically ill adults. New England Journal of Medicine. 2018 Mar 1;378(9):829-839.
75. Kim E, Zhang X, Ferreira VS, Banker J, Iverson JK, Sipahigil A, *et al*. Quantum electrodynamics in a topological waveguide. Physical Review X. 2021 Jan 25;11(1):011015.
76. Chen-Xu M, Yokose C, Rai SK, Pillinger MH, Choi HK. Contemporary prevalence of gout and hyperuricemia in the United States and decadal trends: the National Health and Nutrition Examination Survey, 2007–2016. Arthritis & rheumatology. 2019 Jun;71(6):991-999.
77. Wang Y, Sun Y, Liu Z, Sarma SE, Bronstein MM, Solomon JM. Dynamic graph cnn for learning on point clouds. Acm Transactions on Graphics (tog). 2019 Oct 10;38(5):1-2.
78. Holman BW, Kerry JP, Hopkins DL. Meat packaging solutions to current industry challenges: A review. Meat Science. 2018 Oct 1;144:159-168.
79. Ledig C, Theis L, Huszár F, Caballero J, Cunningham A, Acosta A, *et al*. Photo-realistic single image super-resolution using a generative adversarial network. InProceedings of the IEEE conference on computer vision and pattern recognition; c2017.p. 4681-4690.
80. Forns X, Lee SS, Valdes J, Lens S, Ghalib R, Aguilar H, *et al*. Glecaprevir plus pibrentasvir for chronic hepatitis C virus genotype 1, 2, 4, 5, or 6 infection in adults with compensated cirrhosis (Expedition-1): A single-arm, open-label, multicentre phase 3 trial. The Lancet infectious diseases. 2017 Oct 1;17(10):1062-1068.