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Review Article

Edible coating for different types of cheeses: A review

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ABSTRACT

Edible coatings are biodegradable and environment-friendly, used for reduce of plastic packaging. The prolonging of shelf life of food products is very important as even a few days extension of shelf life could represent a significant economic advantage for food companies. Cheese, in particular, is undoubtedly the most diversified and challenging group of dairy products and an excellent source of proteins, lipids, essential minerals (such as calcium, magnesium, and phosphorus), and vitamins. The packaging materials of cheese should be designed and developed to improve cheese quality and preventing damage and spoilage. This review focuses on edible coating and their application on different cheese varieties to improve its shelf life as a substitute for non-biodegradable polymers, and the methods of preparation of edible coating (dipping, spraying, fluidization and Panning) has been discussed.

Keywords: Edible coating; Packaging; Cheese; Shelf life

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1. Introduction

Food packaging has grown significantly in recent years to include new functionalities and meet the demands in markets that constantly challenge the development of stable and fresh food products. The goal of packaging is to enable the food to be transported safely over long distances, protect the food from external factors and contamination, ensure the nutritional value and health during consumption, and provide consumers with information about the contents (Kandasamy et al., 2021). The properties and functionality required for edible coatings must be developed mainly in relation to the deterioration pathways of each food product, so they depend on the composition of individual foods; for example, it may be necessary to decrease oxygen permeability to protect products that are sensitive to oxidation, or reduce respiration rates and the production of ethylene in fruits, or prevent weight loss. In addition, edible coatings must be compatible—both organoleptically and functionally—with the specific food involved (Zambrano-Zaragoza et al., 2018).

A biodegradable film can be defined as a packaging material or thin layer of edible material placed on or between food components, while an edible coating (EC) is a thin layer of edible material formed as a coating on a food product (Alizadeh-Sani et al., 2019). Nowadays, edible coatings are strongly impacting food processing due to their advantages over synthetic films. Edible coatings can be used to physically protect food, prevent drain of liquid, and control the physical, chemical and microbiological activities of products. In addition to being edible, they constitute a barrier for gases and water vapor, and can function as carriers of bioactive substances with antioxidant and antimicrobial properties, as well as dyes, flavorings, prebiotics and probiotics, among other important compounds (González-Reza et al., 2018). Edible coatings have the capacity to carry bioactive compounds, such as phenolic compounds, vitamins, nutraceuticals and probiotics, which improve food quality and, at the same time, provide additional health properties to the consumer after food consumption. All these characteristics contribute to shelf-life increase and a reduction in the use of additives (Pedreiro et al., 2021).

Cheese is an ancient food product that can be prepared from different types of milk. It is very diverse in textures, aromas, flavors and shapes, and often makes part of humans' regular diet, due to its composition (high amount of protein, calcium, minerals and vitamins) (Costa et al., 2018). Although cheese is a fundamental source of proteins considered to have high biological value and high digestibility, its nutritional and physicochemical characteristics is favor for the growth of microorganisms, leading to reducing its shelf life (Lima et al., 2021). Yeasts, molds and bacteria may occur on cheese surface due to the external environmental conditions, which considerably reduce cheese

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quality and demands for the development of tailored packaging materials to avoid spoilage (Ulusoy et al., 2018). Edible coating has been used to prolong the shelf life of cheeses for several years. They are mainly prepared by edible biopolymers and food-grade additives. Edible coatings, which add antimicrobials on to the surface of cheeses, are gaining a great deal of attention since they contain a high level of active ingredients in necessary targeted areas (Bagheripoor et al., 2018).

2. Suitable features of edible coatings

This protective layer results in improvement of gas and moisture barrier properties, mechanical properties, sensory quality and even the nutritional characteristics of coated/ wrapped food (Dhaka & Upadhyay, 2018). Edible coating properties primarily depend upon the coating's molecular structure rather than its chemical constitution and molecular size. Specific requirements associated with edible coatings are:

• The edible coating needs to be water-resistant and impervious to water vapors for keeping the product intact and making a covering that covers the product adequately.

• The covering should not degrade a higher level of oxygen or accumulate elevated carbon dioxide inside the package. As at least 1–3% amount of oxygen is required surrounding a product for avoiding anaerobic respiration.

• The coating should maintain structural integrity, enhance appearance, improve mechanical handling properties.

• The coating material should be non-sticky, easily emulsifiable.

• The coating should not impart unwanted odor and should never interfere with the quality of fresh commodities (Mahela et al., 2020).

3. Methods of preparation of edible coating

The effectiveness of applied coating materials on food products such as fruits, vegetables, meat, etc., is influenced by the various applied techniques such as dipping, spraying, fluidized-bed, and panning. These deposition methods of coating on food products are dependent on the nature of food that should be coated, the surface attributes and the primary objective of the coating (Suhag et al., 2020).

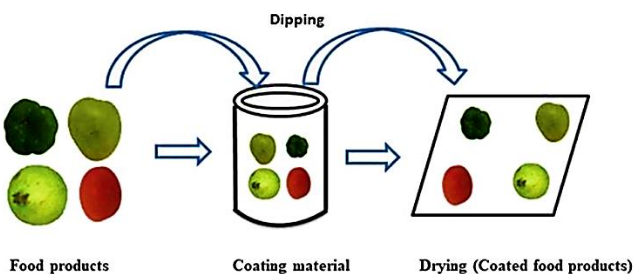

Fig. 1. Dipping application methods of edible coating for fruits & vegetables and other food products.

3.1. Dipping

Dipping is done by immersing food products into the coating-forming solution for a given time, followed by draining and drying before the coated products are ready to be stored. This technique is more appropriate for irregularly shaped products (Hamed et al., 2022) (Fig. 1). Dipping has proven less effective in direct applications on food surfaces of antimicrobial agents, as the loss of activity is caused by leaching on the food, enzymatic activity and the reaction with additional food constituents. Due to its simplicity and low cost, the dipping method is the main laboratory coating method (Atieno et al., 2019).

3.2. Spray-coating

The spray-coating process has been reported to form a thin film on food surfaces and can be well controlled despite the need to carefully modify the viscosity of the coating solutions for application with a specific spray-gum application (Fig. 2). Spraying enables thin or thick layers of suspensions of aqueous solution and molten lipids or chocolate to be deposited. Spraying technique (electrostatics) of application of edible coating on food products enhancing the food quality and appearance (Zhong et al., 2019). Some coating applications, using spray system, are common in several processes such as to coat beef tenderloins, pork loins, salmon fillets, chicken breasts, bakery products, and fruit-based salads (Silva-Vera et al., 2018).

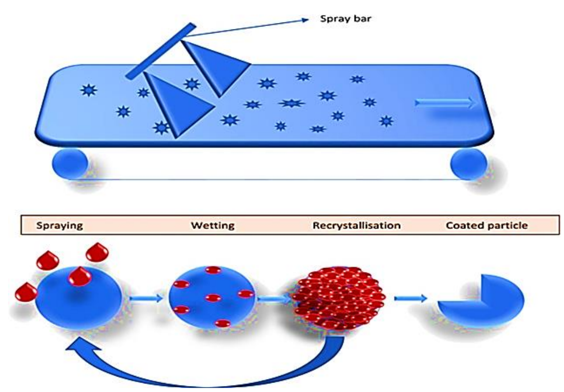

Fig. 2. Spraying application methods of edible coating.

3.3. Fluidization process

In a fluidization process, granular material is subjected as a solid state to behave like a fluid (Fig. 3). In addition, atomizing air also facilitates the evaporation of the solvent coating. Such evaporation increases the viscosity of the droplets and reduces the spread and coalescence when the core material interacts (Zhalehrajabi et al., 2019). The coating solution and suspension are sprayed onto the fluidized powder surface via a number of nozzles to form a shell-like structure in a fluidized coating process. However, it requires shorter processing time, provides complete coverage, and minimizes cluster formation (Bertuzzi & Slavutsky, 2016).

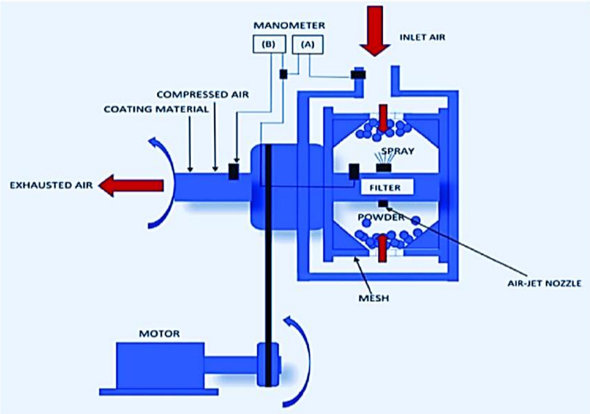

Fig. 3. Rotating fluidized-bed application method of edible coating.

3.4. Panning

Panning is a suitable coating method for food and confectionary items (Fig. 4). Plenty of round or oval shape food products can be coated in a single batch in this method. A big round ball known as a pan is rotated, and food products are rotated inside it. The coating forming solution is sprayed on the surface of food product, while the pan keeps spinning (Kumar et al., 2021).

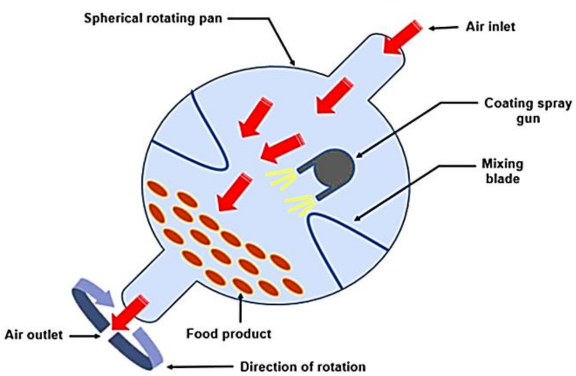

Fig. 4. Panning method for edible coating formation with the help of air circulation, the air from the inlet to rotating pan evaporates the solvent used for coating, leaving the coating formation on food products.

4. Edible coating based on polysaccharides, lipids and proteins

Biopolymers, such as polysaccharides and proteins, or lipids, can be used to prepare edible films and coatings for cheese, carrying antifungal agents encapsulated in the polymer matrix that should limit the compound migration within the cheese matrix, making the antifungal action more effective on the cheese surface (Ordoñez et al., 2021). Biopolymers have several advantages, such as biodegradability, recyclability, and sustainability; there are certain limitations due to their poor mechanical and barrier properties (Singh et al., 2021). To obtain highly effective coatings, solution is synthesized and dried at a precise temperature and relative humidity. Adjusting the pH or heating the solutions can be accomplished for the particular polymer to enable dispersion (Hassan et al., 2018).

4.1. Polysaccharide based coatings

The main polysaccharide component used for edible coating are the followed: starch, chitosan, pullulan, alginate, carragennan, modified cellulose, pectin, gellan gum, xanthan gum, etc. The polysaccharides properties are such as biodegradable, nontoxic, antibacterial, biocompatible, transparent, antifungal, good mechanical properties, high water vapor permeability, and a barrier to gases usually blended with other polymers (Kumar, 2019).The most used biopolymers in the production of edible films and coatings are starch and Alginate. Starch is considered the universal biopolymer for bio-packaging, which has been widely used for decades, due to its characteristics and gelatinization properties. Alginate is another important biopolymer that displays the ability to form hydrogels and encapsulation barriers (Díaz-Montes & Castro-Muñoz, 2021). Chitosan is a natural polysaccharide which is composed of a linear (1-4) linked 2- amino-2-deoxy-D glucan, can be chemically made from naturally existing chitin by treatment with alkali at the high temperatures. Chitosan extensively existing in the nature and has antibacterial effects (Bakhy et al., 2018). Since polysaccharides are hydrophilic, the integrity of packaging reduces in highly humid conditions. This hydrophilicity can be reduced by adding lipophilic substances, for instance, wax and oil. The addition of antimicrobial agents and antioxidants to the packaging materials may reduce food products' ripening process and increase shelf life (Pooja Saklani et al., 2019).

4.2. Lipid based coatings

Fats and oils have the capability to form a thin coat with unique sealable nature on the surface of the food thus forming a barrier between the food and its external environment (Bhagath & Manjula, 2019). Lipid compounds exploited as edible polymers consist of acetylated monoglycerides, paraffin wax, beeswax and surfactants. The main function of a lipid-based coating is to block passage of moisture since they display a relative low polarity. Lipid-based coatings are characterized by highly satisfactory moisture barrier properties during handling and serving, but usually form relatively low elastic surfaces. Coatings made by lipids are shiny and lose less humidity. The main ingredients of these materials are extracted from plant and animal fats. The other materials in the lipids category are essential oils. These materials are hydrophobic and some of them have antibacterial characteristics due to the presence of terpenoids as well as terpens (Paidari et al., 2021). Essential oils contain a complex mixture of different constituents (non-volatile and volatile), whose composition is highly variable. In particular, oregano essential oil (OEO) has been previously utilized to control the microbial growth in foods. Its active compound carvacrol presents strong antifungal capacity and high inhibitory effect against *Listeria monocytogenes*, *Salmonella*, *Escherichia coli* and *Staphylococcus aureus* (Artiga-Artigas et al., 2017). The essential oil of *Pimpinella saxifraga* (PSEO), as a novel natural bioactive compound, was successfully incorporated in sodium alginate coating for cheese preservation. PSEO, mainly composed of anethole, exhibited potent antioxidant and antibacterial abilities (Ksouda et al., 2019).

4.3. Protein based coatings

Proteins used for edible packaging (EP) have mostly animal origin (gelatin, casein, whey proteins, collagen or egg albumin). However, plant-derived proteins (e.g., corn, soybean, wheat, cottonseed, peanut, and rice) are also appreciated and compatible with the vegetarian diet (Pop et al., 2019). For the preparation of functionalized (edible) films and coatings, the most utilized proteins are casein, gelatin, wheat gluten, soy protein or zein. Regarding the biodegradability, protein-based food packages are among the most feasible ones. Low price and sustainability are the most important aspects from the industrial point of view (Mihalca et al., 2021). Many proteins have been widely used as coating agents due to their properties that act as a good barrier against the O_2 and CO_2 permeability. Each protein has an unique set of physicochemical properties. Its particular sequence of amino acids allows a wide variety of both intra- and intermolecular interactions and with other material participating in the formation of the edible matrix (Pech-Canul et al., 2020). Proteins can be found naturally, as fibrous proteins or globular proteins; globular are rolled over their selves, and the fibrous ones are bonded to each other on parallel (Mohamed et al., 2020). The coatings which are composed of protein are inherently hydrophilic and thus they do not provide the resistance from the water vapor but they consist of good organoleptic and mechanical properties (Singh et al., 2020).

5. Edible coating for different types of cheeses

Cheese is the most varied group of all foodstuffs. Its short shelf life is associated with the uncontrolled growth of microorganisms on their surface (Mahcene et al., 2021). Recently, advances in dairy process engineering and technology have made it possible to move from traditional cheese making operations to a modern industrial process in which researchs are important for increasing shelf life and promoting quality and the safety of cheese products (Mahcene et al., 2021). Although edible packaging can be potentially applied into the entire range of dairy commodities, to date the majority of the dairy-related applications of edible films and coatings is related to cheese products. This is since the cheese quality is jointly driven by a plethora of biochemical, physical, chemical, microbiological and sensory changes occurring during the ripening process. Depending on the moisture content of the cheese (hard, semi-hard, or soft), different requirements as concerns the edible packaging form (e.g. coating or pre-casted edible film) and its technical aspects (e.g. water vapor or gases permeability, level of opaqueness, easiness to conveying natural flavoring or coloring agents, etc.) need to be considered (Hellebois et al., 2020).

5.1. Soft cheese

It is known that the shelf-life of cheeses, especially in the case of soft and spread cheeses, can be affected by several types of spoilage bacteria, yeasts, and molds that may occur on the cheese surface during storage. Thus, currently, active cheese packaging has been utilized in soft and fresh cheese to avoid damage and spoilage. The application of WPC-based films incorporated with rosemary and sage infusion as packaging material of soft cheese was able to protect the soft cheese from spoilage or pathogenic bacteria (Kontogianni et al., 2022). According to the results, edible coating based on sodium alginate and carboxymethyl cellulose, containing the wild garlic extract, can be used to increase the shelf life of cheese (Mousavi et al., 2020).

- Fresh unripened curd cheese has long been a well-known Eastern European artisanal dairy product; however, due to possible cross-contamination from manual production steps, high moisture content (50–60%), and metabolic activity of present lactic acid bacteria, the shelf life of curd cheese is short (10–20 d). The edible coating based on liquid whey protein concentrate with the incorporation of cinnamon extract was demonstrated to efficiently extend the shelf life of perishable fresh curd cheese, enhance its functional value, and contribute to a more sustainable production process (Mileriene et al., 2021). Findings indicate that alginate-maltodextrin-glycerol formulation provided an excellent matrix to support *Lactococcus* cells viability and bacteriocin production. This bioactive coating can act as protective antimicrobial barrier in fresh cheeses by reducing bacterial contamination after processing (Silva et al., 2022). The use of edible coatings supplemented with essential oils is an important viable alternative for the technological improvement of fresh cheese processing (Pieretti et al., 2019).
- Panela cheese is a type of fresh cheese made from pasteurized cow's milk very popular in Mexico, where its production accounted for 418,560 tons in 2018 (Ríos-de-Benito et al., 2021). It is white, with a porous, soft and fluffy texture with low fat content. The shelf life of fresh cheeses is about 15–18 days, due to its high moisture content and nutrients availability. The coating on Panela cheese delayed acidification and moisture loss. Therefore, SC:CH (sodium caseinate-chitosan) coating added with MSN-OEO (mesoporous silica nanoparticles filled with oregano essential oil) may be successfully used to increase Panela cheese shelf life (Ríos-de-Benito et al., 2021).
- Karish cheese is very popular soft cheese consumed in Egypt and usually made of low fat milk and coagulate agent of mixed culture of lactic acid bacteria. Karish cheese can stand only for two weeks or less, stored at 4℃, before undesirable microbial growth observed on the surface. The short shelf life of Karish cheese is mainly because of its high moisture content and low salt concentration. Karish cheese preserved under edible coatings made of liposomal chitosan emulsion loaded with thyme essential oil (TEO) showed antimicrobial activities lasts over 4 weeks of storage (Al-Moghazy et al., 2021). The quality of Karish cheese is significantly affected by the addition of essential oils such as rosemary oil which are identified as the major chemicals components responsible for extending antimicrobial activity.
- The use of coatings containing garlic or oregano oil prevented the growth of pathogenic or contaminating microorganisms on the product during 42-day storage. The results indicated that the use of edible coatings incorporating garlic or oregano oil as antimicrobial compounds are an alternative to extend the shelf life of double cream cheese (Molina-Hernández et al., 2020).
- Iranian Ultra-filtered (UF) cheese is high perishable due to growth of both pathogens and spoiling microorganisms such as, Pseudomonas aeruginosa and some penicillium species on its surface. Therefore, cheese has low shelf life and its lower pH with addition salt help to increase shelf life up to 1 month in the refrigerator temperature. Obtained results indicated that the prepared coating (edible coating based on chitosan and Natamycin, as antibacterial and antifungal agents) significantly inhibited the growth of the cheese spoilage microorganisms without negative effects on starter cultures which play important role in cheese ripening and quality (Nottagh et al., 2020). Based

on researches, it can be concluded that RSM (Response surface methodology) could be an attractive method in order to predict, model and optimize the physico-chemical and biological characteristics of the coated cheese as function of the concentration of chitosan and Natamycin (Nottagh et al., 2018). Another work evaluate the efficiency of novel antimicrobial edible coatings based on chitosan (CH), sodium alginate (SA), and carboxymethyl cellulose (CMC) with an eco-friendly antimicrobial microcrystalline cellulose (AMCC) and probiotic strains (*Bifidobacterium lactis*, *Lactobacillus acidophilus*, and *Lactobacillus casei*). These edible films were applied for preservation of UF soft cheese for 45 days, instead of using traditional plastic sheet. Therefore, the formulation of the antimicrobial edible coating can be applied for soft cheese to control the spoilage and maintain the stability of products (El-Sayed et al., 2021). The results showed that whey protein based edible coating can be used as a carrier of natamycin and lysozyme-xanthan to increase the shelf life of ultrafiltrtated cheese. Coatings incorporating natamycin and lysozyme-xanthan gum conjugate significantly inhibited the growth of *Penicillium Chrysogenum*, *Escherichia coli* O157:H7 and *Staphylococcus aureus* compared to uncoated cheese, and consequently extended the shelf life of samples (Jalilzadeh et al., 2020).

- Mozarella is a type of soft cheese that can be easily contaminated by microorganisms and spoil. Furthermore, it is usually sold in vacuum cleaner plastic wrap for storage. The plastic used for the wrapping is usually polyethylene, polyamide, or polypropylene, which are non-biodegradable and can cause environmental pollution. Chitosan edible film with purslane extract can be used as a substitute for plastic packaging to preserve mozzarella cheese during storage at room temperature or in the refrigerator (Pratiwi et al., 2021). Findings indicate that natamycin-containing hydroxyethylcellulose films may be used on Mozzarella cheese rather than direct applications, as a biodegradable antifungal system, without sacrificing food safety (Torrijos et al., 2022). The applications of pectin over mozzarella cheese significantly increase the shelf life from 7 to 21 days at 5℃. Pectin aqueous extract has good antioxidant activity and antibacterial properties against Escherichia coli is 15 mm, for Staphylococcus aureus is 19.6 mm, and for Salmonella Enteritidis is 12 mm. According to obtained results, it was concluded that the addition of linalool and thymol active components to polyethylene film (PE) had a positive effect on the extension of the mozzarella cheese shelf life. Both thymol and linalool showed good antimicrobial activity in PE films and significantly reduced the growth and proliferation rate of the microorganisms (Chang et al., 2021). Results suggest that biodegradable films produced by nisin Z addition into HPMC (hydroxypropylmethylcellulose) matrix are an excellent biomaterial for mozzarella cheese preservation. From the SEM images, it was possible to observe the presence of nisin Z on the film surfaces, which indicates direct contact with the medium and explains the antimicrobial activity in vitro of films in contact with mozzarella cheese (Freitas et al., 2020).

5.2. Semi hard cheese

- White brined cheese is a semi-hard, unfermented traditional cheese popular in the Mediterranean region. While it is mostly produced from pasteurized milk and is normally a low safety risk, post-process contamination with foodborne pathogens may result from mishandling of cheese during processing or repeated opening of cheese packs during storage. Results indicated that the novel bionanocomposite of chitosan-ZnO nanoparticles coating can be successfully used as an active, smart packaging material for white brined cheese (Al-Nabulsi et al., 2020).
- Swiss cheese is a medium, hard, yellow-color cheese that originated in Emmental, Switzerland. One of the main problems in storage of Swiss cheese is high moisture loss. In addition, Swiss cheese is prone to contamination by bacteria, molds, and yeasts, particularly when stored without packaging. An edible coating was developed to improve the physicochemical, microbiological, and sensory attributes of Swiss cheese using sweet whey as the main ingredient throughout 60 days of storage, as a substitute for commercial nonedible paraffin coatings. Use of sweet whey provided an antibacterial function due to the presence of lactic acid (Siriwardana & Wijesekara, 2021).
- Lighvan cheese is an Iranian semi-hard traditional cheese. It is produced from Ewe milk without a starter in the village of Lighvan. The results of study showed that alginate-collagen films containing betanin and cumin essential oils, by preventing tissue changes and oxidation of lipids, increased the quality of the Lighvan cheese during storage at 4°C (Ahmadimaram et al., 2021).

5.3. Hard cheese

- The use of an optimized chitosan solution containing glycerol and Tween 20 has resulted in an excellent vehicle for the incorporation of an industrial solid residue extract of S. chamaecyparissus in a coating for the preservation of Manchego cheese. This incorporation yielded a coating with enhanced antifungal and antioxidant capacities with respect to the original chitosan coating. In conclusion, the use of Santolina chamaecyparissus by-product has resulted in a prospective preservation system for its application as a coating for Manchego cheeses or other similar fatty ones (de Elguea-Culebras et al., 2019).
- The coating of Gouda cheese with gelatinized starch containing natamycin and nisin (cheese-GNANI) resulted in an improvement, compared to the direct addition of antimicrobials in aqueous suspension (cheese-CNANI), against external contamination during ripening, by a mixed culture of *S. cerevisiae* and *L. Innocua*, evidencing its capacity as a microbiological barrier (Berti et al., 2019).
- Paipa cheese is a medium fat, semi-ripened hard cheese manufactured from raw cow's milk by enzymatic coagulation which has received protected geographical indication (PGI) by Colombian regulations. After application on the Paipa cheeses, the carvacrol/starch coatings enhanced the brightness of the cheeses without significant changes in water activity, moisture content, color attributes, and mesophilic aerobic bacteria and molds/yeasts count. Moreover, edible coatings have a significant effect on the hardness, the gumminess, the springiness, and the chewiness of the Paipa cheese (López-Córdoba, 2021).
- Mongolian cheese is one of the most popular dairy products which are rich in nutrients, such as proteins, vitamins and minerals. It is also considered to be a high quality food source of calcium. However, Mongolian cheese has a short shelf life up to 5 days (store in a damp place at 25℃) owing to the growth of microorganisms, especially *Escherichia coli*, *Staphylococcus aureus*, yeasts and molds, which resulted in quality deterioration. Therefore, cheese preservation during storage has long been recognized as important treatments for the protection of the

quality and safety of the product. Edible coatings consisted of casein, chitosan and flaxseed gum were developed to extend the shelf life of Mongolian cheese by self-assembly on its surface (Lu et al., 2021). When the composite films were used for packaging Mongolian cheese to improve the preservation, the results showed that all the wrapped Mongolian cheeses reduced weight loss and delayed the growth of bacteria, yeast and mold compared with the uncoated Mongolian cheese. Also cheese packaging by cassava starch–chitosan composite film presented better treatment performance in maintaining the quality, reducing weight loss and delayering microbial growth (Ma et al., 2021).

6. Conclusion

Currently, the food industries have a duty to offer to the consumers fresh, pleasant, good quality food with beneficial properties for health. Edible coatings made from edible ingredients are an important issue due to their properties and good performance in food packaging, they also can provide safety for fresh foods. In addition, edible coatings guarantee a considerably lower packaging weight, enhance product appearance, and ensure its safety. Moreover, the simplicity and relative economy could be very beneficial and of commercial importance to the dairy industry. Appropriate biopolymer material with naturally available active agents is improving the shelf life of food products. Edible coating provided the cheese samples a good barrier that protected them against weight loss, hardness, discoloration, loss off-flavor and texture, etc.; and prevented microbial spoilage. Depending on the moisture content of the cheese (hard, semi-hard, or soft), different requirements as concerns the edible packaging need to be considered. Most of the existing studies concern semi-hard and soft cheese products as their high moisture levels render them more perishable than the hard longed aged products. In fact, our aim was to provide a thorough introduction to the recent advancements of developing edible coating for application on cheese packaging. The industrialization of edible coating requires further research that will improve the quality and reduce the cost of production.

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Conflict of interest

The authors declare that they have no known conflict of interest.

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