Asian Food Science Journal

Volume 23, Issue 11, Page 10-23, 2024; Article no.AFSJ.125590
ISSN: 2581-7752

Gelatin, Chitosan, and Beeswax Based Edible Packaging for Food Product: A Review

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Authors' contributions

This work was carried out in collaboration between all authors. Author NSN collected the literature sources and wrote the first draft of the manuscript, author ER, IR, and RIP conceptualized the idea and performed critical reviews on manuscript. All authors read and approved the final manuscript.

Article Information

DOI: https://doi.org/10.9734/afsj/2024/v23i11750

Open Peer Review History:
This journal follows the Advanced Open Peer Review policy. Identity of the Reviewers, Editor(s) and additional Reviewers, peer review comments, different versions of the manuscript, comments of the editors, etc are available here: https://www.sdiarticle5.com/review-history/125590

Review Article

Received: 10/09/2024
Accepted: 13/11/2024
Published: 18/11/2024

ABSTRACT

The widespread use of petroleum-based plastic packaging as food packaging has raised many concerns regarding the negative impact on the environment. The increase of public awareness on environmental problems and the importance of food safety has encouraged a lot of research regarding the development of environmentally friendly food packaging that is safe for food products, such as edible packaging. Gelatin, chitosan, and beeswax have attracted attention in edible packaging research due to their biodegradability and good film-forming characteristics. Chitosan and beeswax have also been reported to have antimicrobial properties that can improve the

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Cite as: *Nurrahmah, Nabila Syifa, Emma Rochima, Iis Rostini, and Rusky Intan Pratama. 2024. "Gelatin, Chitosan, and Beeswax Based Edible Packaging for Food Product: A Review". Asian Food Science Journal 23 (11):10-23. https://doi.org/10.9734/afsj/2024/v23i11750.*

functional properties of edible packaging. Various studies have been carried out to obtain alternative packaging from a combination of these materials. This article reviews the potential application of edible packaging made from gelatin, chitosan, beeswax and their composites as packaging for food products.

Keywords: Edible packaging; biopolymer; gelatin; chitosan; beeswax.

1. INTRODUCTION

Packaging is an important factor in food product safety. Packaging functions as a protector of food products from external factors such as gas/air, water, chemicals, microorganisms and other foreign objects which can cause a decrease in product quality (Kumar et al. 2020, Widiati 2019). Ideal food packaging must have several key characteristics, such as protecting food products for a long time, being easy to use and carry, cheap, and not causing waste (Priyadarshi and Rhim 2020). Plastic packaging made from petroleum is the closest type of packaging to these ideal properties. Apart from that, other advantages of plastic packaging include flexibility in shape, light in weight, good barrier properties, transparency, and mechanical properties (Muller et al. 2017, Park et al. 2017).

Plastic packaging is still the most widely used packaging for food products (Kumar et al. 2020). Globally, the production of plastic packaging is estimated to reach 320 million tons per year [6]. The massive use of petroleum-based plastics has raised concerns due to the environmental issues it causes. This is due to petroleum-based plastic packaging are difficult to decompose naturally and trigger the accumulation of carbon dioxide and methane gas in nature (Jain and Tiwari 2015). The environmental problems caused by single-use plastic packaging have led to the need in research on the development of environmentally friendly packaging.

The environmentally friendly packaging, such as edible packaging, has received a lot of attention in the food packaging industry. The differences between edible packaging and conventional plastic packaging are the constituent materials. Edible packaging is made from biopolymers such as proteins, polysaccharides, and lipids, while plastic packaging is made from synthetic polymers such as polyethylene (PE), polypropylene (PP) and polyvinyl chloride (PVC). The advantages of using biopolymers compared to synthetic polymers is that biopolymers are safe for food products and extracted from renewable resources (Said et al. 2023, Shaikh et al. 2021).

Gelatin, chitosan, and beeswax are among the types of materials that are widely used as ingredients for edible packaging. While chitosan and gelatin are used as materials for edible packaging because of their good film-forming abilities, beeswax is widely used as material for edible packaging because it has good moisture barrier capabilities and hydrophobic properties (Diyana et al. 2021, Wang et al. 2019). Several studies have also reported that chitosan and beeswax have antimicrobial properties which can improve the functional properties of packaging and prevent deterioration in the quality of the packaged food products (Fratini et al. 2016, Priyadarshi and Rhim 2020). The utilization of natural polymers such as chitosan, gelatin, and beeswax as edible packaging materials are considered more sustainable and environmentally friendly because these materials are made from the by-products of livestock, fisheries, and beekeeping (Pari et al. 2022). The utilization of marine-based gelatin and chitosan also considered to have great potential, especially in countries with abundant marine products such as Indonesia. This paper will discuss the use of gelatin, chitosan, beeswax, and their composites as edible packaging materials and their impact on the food.

2. EDIBLE PACKAGING

The design for developing edible packaging was initially inspired by fruit and vegetable skins (Zhao et al. 2021). The use of edible packaging as food packaging has been around for several centuries. China has historically known the technique of preserving citrus fruit by coating the surface with wax since the 12th century (Kumar and Neeraj 2019). The making of edible films from boiled soybean juice which was then dried were also recorded in the early 15th century in Japan (Erkmen and Barazi 2018).

Edible packaging can be interpreted as packaging that has biodegradable properties, is safe for food products, and safe for human consumption (Petkoska et al. 2021, Saklani et al. 2019). Biodegradable packaging is defined as packaging that can be decomposed and destroyed through natural processes (Iversen et al. 2022). Apart from the high level of public concern about environmental issues caused by plastic waste, the high level of public awareness and the need for food safety has also encouraged the development of edible packaging in the food industry (Saklani et al. 2019). Edible packaging is also considered to have economic efficiency because it can maintain quality and extend the shelf life of food products (Arismendi et al. 2013). Although edible packaging is generally not intended as a complete replacement for traditional packaging, the combination of the use of edible packaging with non-edible secondary packaging can increase the protection of the food product being packaged (de Azeredo et al. 2011).

Based on the form and application, edible packaging can be grouped into two, namely edible coating and edible film. Edible coating is defined as packaging in the form of a thin layer that is generally formed and applied directly to the surface of the food product which functions as a coating, while edible film is packaging in the form of a thin sheet which is processed separately and is generally applied as packaging, pouches, bags, capsules and casings (de Azeredo et al. 2011, Nowzari et al. 2013, Petkoska et al. 2021). In general, there are two methods for making edible film, namely solution casting and extrusion. Solution casting is the most widely used method of making edible film. This method is carried out by evaporating the film solution at a certain temperature and time until a film is formed. The extrusion method is generally used to produce commercial plastic packaging (Lu et al. 2022). This method is carried out by adding dry materials to the feeding zone which will then be compressed using a revolving screw and given heat treatment and formed into a film with an extruder [Prakoso et al. 2023]. The difference between edible film and other edible coatings is the method of application to food. Edible film is applied to food by wrapping it around the product, while edible coating can be applied directly to the food surface using several methods, such as dipping, spraying, brushing, panning, and fluidized bed processing method (Kumar et al. 2022).

The dipping and spraying method are most often used in applying edible coating. The dipping method is carried out by immersing the product in an edible coating solution for some time, while the spraying method is carried out by changing the solution into droplets through a spraying technique so that the solution covers the surface of the food product (Kumar et al. 2022). The application of edible coatings and edible films to food products also has different main purposes. Edible film functions to protect food products from mass transfer (water vapor, gas and solutes) which aims to improve product quality and extend the storage period (Bizymis and Tzia 2022). Edible coatings, on the other hand, function as carriers for additional ingredients such as anti-browning, antimicrobial and antioxidant agents, colorings, flavors, and seasonings, thereby aiming to increase the organoleptic value of the product (Kumar et al. 2020, Saklani et al. 2019).

3. EDIBLE PACKAGING MATERIALS

The main requirements for a material to be used in making edible packaging include that the material must be safe for consumption and can form good layers and films. Therefore, edible packaging is generally made from biopolymers, where the polymers are generally extracted from plant or animal parts (Kumar et al. 2022, Pereda et al. 2011). Apart from being safe for consumption and having good film-forming capabilities, the use of biopolymers as basic materials for edible packaging has great potential for developing packaging with functional properties that can guarantee food safety (Chawla et al. 2021, Umaraw and Verma 2015).

Using biopolymers as ingredients for edible packaging has several advantages and disadvantages compared to using synthetic polymers. The advantages of using biopolymers for edible packaging include that biopolymer come from renewable resources, are safe for consumption, can be degraded naturally, have environmentally safe characteristics, are non-toxic, and have quite good mechanical properties, while the disadvantages of using biopolymers include the high production costs is still quite expensive compared to using synthetic polymers (Khaneghah et al. 2018, Singh et al. 2021). The use of biopolymers as ingredients for edible packaging also has a positive impact on the utilization of waste food products because some polymers are extracted from by-products from plantations, livestock, and fisheries such as bones. shell, to hump (Hamed et al. 2022).

Based on the ingredients used, edible packaging is grouped into three categories, namely hydrocolloid (protein and polysaccharide), lipid, and composite (a combination of hydrocolloid and lipid). Each of these materials has several unique properties as materials for making edible packaging. The selection of materials that will be used in edible packaging usually depends on the type of food that will be packaged, because each product has its own need of protection and there are differences in the properties of each polymer (Chen et al. 2019, Jeevahan et al.2020). Polysaccharides generally have good oxygen barrier properties but poor moisture barrier properties (Iversen et al. 2022). Protein has good mechanical strength and promising nutritional value. Lipids have low water vapor permeability, hydrophobicity, and good moisture barrier properties but have poor mechanical strength and quite high oxygen permeability (Bharti et al. 2020). In contrast to the hydrophobic nature of lipids, polysaccharides and proteins have hydrophilic properties, causing low moisture resistance and barrier properties (Petkoska et al. 2021).

Apart from being composed of biopolymers, edible packaging also generally has the addition of plasticizers. The function of this plasticizer is to maintain the integrity of film and coating packaging which is still fragile due to extensive interactions between polymer chains (Hamed et al. 2022). Edible packaging can also include the addition of active compounds. The addition of this active compound can function to increase the shelf life, quality and safety of food by inhibiting oxidation and the growth of microorganisms that cause food spoilage (Vilela et al. 2018). The addition of active compounds to edible packaging compared to food products directly is considered more effective (Valdés et al. 2017). This is because the addition of this active compound is able to maintain the activity of the active compound for a longer time due to its periodic release on the surface of the product. The effect of applying edible packaging made from gelatin, chitosan, and beeswax can be seen in Table 2.

3.1 Gelatin

Gelatin is a natural water-soluble protein obtained through the hydrolysis process of the fibrous protein collagen which is generally found in skin, bones and white fiber tissue and tendons of animals through an acid or alkaline process (Pertiwi et al. 2018, Shankar et al. 2016). Gelatin can be produced from mammals, fish and insects (Mariod and Adam 2013). Gelatin which is commonly commercialized generally comes from pork by-products and has been popularly produced since the 1930s (Ramos et al. 2016). Apart from being obtained from mammals, gelatin can also be obtained from marine by-products. The development of marine-based gelatin could also be an alternative for several religious groups, such as Jews and Muslims, who cannot consume pork-based products. However, one of the weaknesses of gelatin derived from marine by-products is that it has less stable rheological properties compared to gelatin obtained from mammalian sources (Alfaro et al. 2015).

Gelatin has a wide range of uses, from the food industry, pharmaceuticals, photography, to packaging (Lu et al. 2022). The properties of gelatin are generally influenced by the characteristics of the collagen used and the extraction process (Ramos et al. 2016). Based on the production method used, gelatin can be classified into two types, namely type A and type B. Type A gelatin is gelatin that has an isoelectronic point at pH 8-9 obtained through an acid process, while type B gelatin is gelatin that has an isoelectronic point. at pH 4-5 obtained through an alkaline process (Shankar et al. 2016, Suryati et al. 2015).

Gelatin has the ability to form a physical gel. This gel-forming ability is obtained from the activity of rearranging the protein structure, namely breaking down the triple helix structure of collagen into single-chain molecules (Ramos et al. 2016). The availability of gelatin and its good mechanical qualities made gelatin frequently used as edible packaging material (Prakoso et al. 2023). In general, making gelatin-based edible packaging has advantages in terms of biodegradability, polymerization, hygroscopic, flexibility, strong gas barrier properties, and low cost, while the disadvantages are its water vapor permeability properties and poor mechanical properties, which limits its application as food packaging (Alves et al. 2018, Lu et al. 2022). The more gelatin concentration added to edible packaging, the greater the film thickness and improved mechanical properties, but will worsen water vapor permeability (Song et al. 2021). The advantages and disadvantages of using gelatin as a basic packaging material edible can be seen in Table 1.

Gelatin has been used together with chitosan as an edible coating ingredient to reduce color deterioration in meat (Ramos et al. 2016). The combination of gelatin and chitosan in edible packaging is also reported to exhibit antioxidant properties (Nowzari et al. 2013). The addition of essential oils to gelatin and chitosan-based edible packaging has also been proven to have good antimicrobial activity and can extend the shelf life of fish fillets (Kakaei and Shahbazi 2016). The addition of additives and agents in edible packaging can help improve the packaging properties. The development of active packaging also received a lot of attention because the incorporated of specific component in the packaging polymers has result in the enhance of physical, chemical, or biological properties and change the interaction within the package, product, and/or space within the food packaging (Said et al. 2023). The effect of applying gelatin-based edible packaging on the food products it is packaged in can be seen in Table 2.

3.2 Chitosan

Chitosan is a compound derived from the deacetylation process of chitin through a hydrolysis process using strong acids or bases, which is often contained in the exoskeletons of marine animals such as shrimp and crabs [46]. Although in general chitosan is mostly obtained from the exoskeletons of aquatic crustaceans, chitosan can also be obtained from groups of insects and fungi (Hamed et al. 2016). The abundance of these resources makes chitin and chitosan the biopolymers that are most widely available in nature after cellulose. Chemically, chitosan is composed of the monomer (1-4)-linked 2-amino-2-deoxy- β-D-glucose (Priyadarshi and Rhim 2020). Chitosan has a solid phase in semi-crystalline form and is generally soluble in organic acids such as acetic, citric, formic, lactic, malic, or tartaric (Cazón and Vázquez 2019).

The process of producing chitosan from chitin goes through three main stages, namely deproteination, demineralization, and deacetylation. The purpose of demineralization is to remove minerals contained in raw materials. Generally, the material used in this stage is acid. Deproteinization is carried out to remove protein residues that are still present in the raw material, the materials used are generally alkaline. The conversion of chitin to chitosan occurs in the deacetylation process where in this process the group ($COCH_3$) is released from the chitin structure which can be carried out through alkaline or enzymatic processes (Abdulkarim et al. 2013).

Chitosan has very wide range of uses in the biomedical, pharmaceutical, and food sectors. The great potential for the use of chitosan is because chitosan has non-antigenic, non-toxic, biodegradable, biocompatible, and biofunctional properties, with film-forming capabilities and antimicrobial properties (Caballero-Flores et al. 2021). The functional properties of chitosan are caused by the presence of amine groups (Priyadarshi and Rhim 2020). The good film-forming properties of chitosan make it very potential as a material for making edible packaging. Edible packaging made from chitosan is also reported to show good mechanical properties, has good strength and toughness, does not tear easily, and has antimicrobial properties (Alves et al. 2018). Packaging made from chitosan is reported to have good mechanical, permeability to CO_2 and O_2, and antimicrobial properties (Cazón and Vázquez 2019).

The antimicrobial activity of chitosan is reported to be effective against yeast, mold and bacteria [88]. The antimicrobial effectiveness of chitosan as a food packaging material can be influenced by various parameters, such as the degree of deacetylation, concentration, exposure period, molecular weight, pH, temperature, and type of test organism (Caballero-Flores et al. 2021). According to Riaz et al. (2018), chitosan is able to prevent the growth of various types of fungi and bacteria and is generally very good at preventing the growth of gram-positive bacteria. The antimicrobial properties of chitosan are caused by the interaction between the amino group ($-NH_3$) in chitosan which is positively charged with a negatively charged carboxylic group (-COO-) in the bacterial cell wall (Bravo-Anaya et al. 2016). The interaction between these two charged ions will cause damage to microorganisms, resulting in the inhibition of microbial polygalacturonase secretion (Hernández-Muñoz et al. 2008). Another opinion states that the antimicrobial mechanism of action of chitosan is due to chitosan's ability to form a protective layer such as cellophane on the surface of food products so that it is able to prevent bacterial contamination and is able to inhibit gas exchange between food products and the environment which can prevent bacterial growth (Dotto et al. 2015).

Currently, the use of chitosan in the packaging industry is being developed in nano form. Nanochitosan is a form of physical modification by reducing the size of chitosan particles to nano size. The making of nanochitosan can be done using various methods, including the method of beads-mill and ionic gelation (Arsyi et al. 2018, Rochima et al. 2018). Methods for producing nanochitosan vary, depending on the desired characteristics, such as particle size, chemical and thermal stability of the particles, kinetic profile, and residual toxicity (Rochima et al. 2018). The ionic gelation method is the method most widely used in making nanochitosan because the process is relatively simple, namely by adding sodium tripolyphosphate (Na TPP) solution to the chitosan solution and then homogenizing it by constant stirring (Arsyi et al. 2018). The utilization of nanochitosan in making edible films is generally used as an antimicrobial agent and filler. Nano chitosan also can be produced through beads milling process (Rochima et al. 2017).

Reducing the size of chitosan particles to nanoscale as a material *nanofiller* Packaging is believed to be able to increase the properties of the packaging surface area by creating an interfacial area between the nanofiller with a biopolymer matrix. The large distance between these interfacial areas can facilitate the movement of molecules so that it can improve the thermal, barrier, and mechanical characteristics of the packaging (Unalan et al. 2014). The effect of applying edible packaging made from chitosan can be seen in Table 2.

3.3 Beeswax

Beeswax is generally produced by worker honey bee species *Apis mellifera* and *Apis cerana* (Fratini et al. 2016). Beeswax is a complex chemical mixture of free fatty acids, hydrocarbons, free fatty alcohols, and monoesters secreted from the beeswax glands (Sun et al. 2021, Zambrano-Zaragoza et al. 2020). The use of beeswax as a coating has been widely applied in the food industry. This is because beeswax has the characteristics of being waterproof, moisture resistant, antioxidant properties, and able to release active ingredients (Chaireh et al. 2020). As an edible packaging material, beeswax is also reported to have good water vapor permeability properties.

The hydrophobic nature of natural lipids makes edible film packaging made from beeswax have good water vapor permeability (Iversen et al. 2022). Beeswax is also reported to have antimicrobial properties. The antimicrobial effect of beeswax is caused by the presence of propolis, which is a sticky substance that bees use to cover holes and cracks in the nest (Pinto et al. 2017). This propolis is obtained from the resin that bees obtain when collecting pollen from plants (Wilson et al. 2013). The advantage of beeswax as a raw material is because it is a lipid compound *food grade*, its availability throughout the year, its utilization is still limited, and the price is relatively cheap. Beeswax has anti-inflammatory, wound healing, antioxidant, and antimicrobial activities (Fratini et al. 2016). Beeswax is also considered suitable as a packaging material *edible* because it has hydrophobic properties that function to inhibit water vapor. However, edible packaging made from beeswax is reported to have poor optical properties and fragile (Bizymis et al. 2022, Fabra et al. 2012).

The addition of beeswax to the chitosan edible coating was reported to be able to inhibit the rate of respiration and transpiration, as well as suppress weight loss in guava fruit (Yolanda et al. 2021). The combination of beeswax and chitosan is also able to maintain the firmness and skin color of sapodilla fruit (Velickova et al. 2013). Edible film beeswax able to extend the shelf life of Naem fermented sausage without major changes in color change, low lipid oxidation, and is able to suppress microbial growth for up to 15 days (Bui et al. 2024). The effect of applying beeswax to food products can be seen in Table 2.

3.4 Composite Edible Films and Coatings

Currently, the development of edible packaging is starting to focus on composite films or multi-component films to take advantage of the superior properties of individual materials and minimize their disadvantages (Bizymis and Tzia 2022). This is because the use of just one type of biopolymer as a material for making edible packaging can generally produce several unfavorable packaging properties (Chawla et al. 2021). For example, edible films composed of chitosan alone generally have poor mechanical and water vapor barrier properties, and edible films composed of gelatin alone generally have poor mechanical and thermal properties (Cao et al. 2020, Shankar et al. 2019). Combining two or more different polymers as materials for making edible packaging can improve the properties of the resulting packaging (Bizymis and Tzia 2022). The combination of two different polymers is called a composite (Milani and Nemati 2022).

The effect of combining two different types of polymers has been proven to be able to improve several properties of edible packaging. Edible packaging based on gelatin alone is reported to have almost no antibacterial effect (Wu et al. 2023). However, when gelatin-based edible packaging is combined with other substances such as chitosan, essential oils, and silver nanoparticles, the antimicrobial effect of edible packaging can increase (Shankar et al. 2016). The addition of gelatin to chitosan edible films shows an increase in firmness and carbon dioxide barrier properties (Poverenov et al. 2014). Gelatin-chitosan edible films show a relatively flat and homogeneous surface, and have excellent physical properties (Wang et al. 2021, Xu et al. 2020). The addition of chitosan to edible coating beeswax shows an increase in texture, retention of color, visual appearance, and antimicrobial activity. The addition of beeswax to chitosan edible film can reduce water vapor permeability (Velickova et al. 2013).

Table 1. Advantages and disadvantages of gelatin, chitosan, and beeswax as edible packaging materials

Material	Advantage	Disadvantage
Gelatin	Good film-forming ability (Lu et al. 2022) Water-binding ability and emulsifying tendency (Ahmad et al. 2017)	Fragile under specific drying condition (Andreuccetti et al. 2017) Weak water vapor barrier property (Hoque et al. 2011)
Chitosan	Good antibacterial properties (Kerch 2015) Good gas barrier properties (Bolívar-Monsalve et al. 2019) Produce transparent film (Alves et al. 2018)	Poor flexibility and extensibility (Prateepchanachai et al. 2017) Possibility to cause allergies (Velickova et al. 2013)
Beeswax	Good hydrophobicity (Kowalczyk and Baraniak 2014) Good water vapor permeability (Iversen et al. 2022)	Poor optical properties (Fabra et al. 2012) Fragile, lack of homogeneity, and presence of holes and crack on coating surface (Bizymis and Tzia 2022)
Gelatin-Chitosan	Good optical properties (Chawla et al. 2021) Good surface morphology dan good inhibitory effect (>80%) against spoilage bacteria growth (Xu et al. 2020)	Poor water vapor permeability (Shankar et al. 2019, Supeni and Irawan 2012)

Table 2. Effect of gelatin, chitosan, and beeswax based edible packaging on food

Film/Coating biopolymer-based material	Packaged food and storage condition	Reported effects	Reference
Beeswax and Chitosan Coating	Crystal Guava (*Psidium guajava L. Var. Crystals*)	Beeswax coating (4%) gives the best effect on fruit quality based on weight loss, texture, color, taste, and aroma parameter.	(Yolanda et al. 2021)
Gelatin-Beeswax and Gelatin-Chitosan-Nanochitin	Jelly Candy (*Kappaphycus alvarezii*)	Gelatin-Chitosan-Nanochitin gives the best effect on the candy quality based on microbial activity, appearance and aroma properties	(Naiu et al. 2021)
Chitosan and Beeswax Coating	Strawberry	Combination of Chitosan 2% and Beeswax 4% gives the best effect on fruit quality based on weight loss, water content, and microbial activity.	(Nurmala et al. 2018)
Beeswax Film	Naem fermented sausage	Low lipid oxidation, few color changes, fewer microbial growth	(Bui et al. 2024)

Film/Coating biopolymer-based material	**Packaged food and storage condition**	**Reported effects**	**Reference**
Chitosan Film	Sea bream (*Sparus aurata*) fillets vacuum packed at 4 ± 1 ℃ for 20 days	Inhibited the spoilage bacteria Good quality indication during storage especially the TVB-N value	(Izci et al. 2017)
Gelatin-Propolis extract Film	Rainbow trout (*Oncorhynchus mykiss*) fillets stored at 4 ± 1℃ for 10 days	The addition of garlic peel extract enhanced in antimicrobial and antioxidant properties, good sensory results	(Ucak et al. 2020)
Chitosan-Gelatin Film	Alaskan Pollock Sausages	Inhibited microbial growth in the sausages during storage (until 42 days)	(Alemán et al. 2016)
Chitosan-Beeswax Coating	Sapodilla (*Achras zapota*) fruit	Slowed down microbial population growth over the period of 17 days, slowed down weight loss, retain firmness and skin colour	(Foo et al. 2019)
Chitosan-beeswax coating	Strawberry	Decreasing the senescence and weight loss, good protective effect of the overall fruit quality	(Velickova et al. 2013)
Chitosan and beeswax-pollen grain coating and films	Le Conte pear in cold storage	Beeswax addition lowers WVTR value, reduced elongation% at break, and increase film stiffness. Decrease fruit weight loss, decay, and rate of softening.	(Sultan et al. 2021)
Chitosan-aloe vera-beeswax coating	Mango	Beeswax addition reduced emulsions particle size and coating water vapor permeability. Increase antimicrobial properties. Reduced fruit weight loss, delayed firmness loss, minimized pH change, and retained free radical scavenging activity.	(Amin et al. 2021)
Chitosan-beeswax bilayer coating	Ginger stored at 18℃ and 25℃ for 6 months	Chitosan-beeswax coating reduced weight loss, slowed down physicochemical properties changes, and increases total soluble solid.	(Hernani et al. 2024)

5. CONCLUSION

Currently, the development of edible packaging is driven by the great demand for environmentally friendly and safe packaging for food products. Gelatin, chitosan and beeswax are natural ingredients that have great potential as the materials for producing edible packaging because they are safe to consumed and come from renewable resources. The good mechanical properties of gelatin, the antimicrobial ability of chitosan, and the good water vapor properties of beeswax are good characteristics in making edible packaging. The combination of these materials with additional materials is expected to produce composite edible packaging with the best protection for food products.

DISCLAIMER (ARTIFICIAL INTELLIGENCE)

Authors hereby declare that NO generative AI technologies such as Large Language Models (ChatGPT, COPILOT, etc.) and text-to-image generators have been used during the writing or editing of this manuscript.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

REFERENCES

Abdulkarim, A., Isa, M. T., Abdulsalam, S., Muhammad, A. J., & Ameh, A. O. (2013). Extraction and characterisation of chitin and chitosan from mussel shell. *Civil and Environmental Research*, *3*(2), 108–114.

Ahmad, T., Ismail, A., Ahmad, S. A., Khalil, K. A., Kumar, Y., Adeyemi, K. D., & Sazili, A. Q. (2017). Recent advances on the role of process variables affecting gelatin yield and characteristics with special reference to enzymatic extraction: A review. *Food Hydrocolloids*, *63*, 85–96. https://doi.org/10.1016/j.foodhyd.2016.08.007

Alemán, A., González, F., Arancibia, M. Y., López-Caballero, M. E., Montero, P., & Gómez-Guillén, M. C. (2016). Comparative study between film and coating packaging based on shrimp concentrate obtained from marine industrial waste for fish sausage preservation. *Food Control*, *70*, 325–332. https://doi.org/10.1016/j.foodcont.2016.06.007

Alfaro, A. da T., Balbinot, E., Weber, C. I., Tonial, I. B., & Machado-Lunkes, A. (2015). Fish Gelatin: Characteristics, Functional Properties, Applications and Future Potentials. *Food Engineering Reviews*, *7*(1), 33–44. https://doi.org/10.1007/s12393-014-9096-5

Alves, V. L. C. D., Rico, B. P. M., Cruz, R. M. S., Vicente, A. A., Khmelinskii, I., & Vieira, M. C. (2018). Preparation and characterization of a chitosan film with grape seed extract-carvacrol microcapsules and its effect on the shelf-life of refrigerated Salmon (*Salmo salar*). *LWT*, *89*, 525–534. https://doi.org/10.1016/j.lwt.2017.11.013

Amin, U., Khan, M. K. I., Khan, M. U., Akram, M. E., Pateiro, M., Lorenzo, J. M., & Maan, A. A. (2021). Improvement of the Performance of Chitosan — Aloe vera Coatings by Adding Beeswax on Postharvest Quality of Mango Fruit. *Foods*, *10*(2240), 1–12. https://doi.org/https://doi.org/10.3390/foods10102240

Andreuccetti, C., Galicia-García, T., González-Nuñez, R., Martínez-Bustos, F., & Grosso, C. R. F. (2017). Native and Modified Gelatin Films Produced by Casting, Extrusion, and Blowing Extrusion Processes. *Polymers from Renewable Resources*, *8*(1), 11–26. https://doi.org/10.1177/204124791700800102

Arismendi, C., Chillo, S., Conte, A., Del Nobile, M. A., Flores, S., & Gerschenson, L. N. (2013). Optimization of physical properties of xanthan gum/tapioca starch edible matrices containing potassium sorbate and evaluation of its antimicrobial effectiveness. *LWT - Food Science and Technology*, *53*(1), 290–296. https://doi.org/10.1016/j.lwt.2013.01.022

Arsyi, N. Z., Nurjannah, E., Ahlina, D. N., & Budiyati, E. (2018). Karakterisasi Nano Kitosan dari Cangkang Kerang Hijau dengan Metode Gelasi Ionik. *Jurnal Teknologi Bahan Alam*, *2*(2), 106–111.

Bizymis, A.-P., & Tzia, C. (2022). Edible films and coatings: properties for the selection of the components, evolution through composites and nanomaterials, and safety issues. *Critical Reviews in Food Science and Nutrition*, *62*(31), 8777–8792. https://doi.org/10.1080/10408398.2021.1934652

Bolívar-Monsalve, J., Ramírez-Toro, C., Bolívar, G., & Ceballos-González, C. (2019). Mechanisms of action of novel ingredients used in edible films to preserve microbial quality and oxidative stability in sausages - A review. *Trends in Food Science & Technology*, *89*, 100–109. https://doi.org/10.1016/j.tifs.2019.05.011

Bravo-Anaya, L. M., Soltero, J. F. A., & Rinaudo, M. (2016). DNA/Chitosan Electrostatic Complex. *International Journal of Biological Macromolecules*, *88*, 345–353. https://doi.org/https://doi.org/10.1016/j.ijbiomac.2016.03.035

Bui, D., Tangkham, W., LeMieux, F., Vuong, O., Priyanwiwatkul, W., & Xu, Z. (2024). Effect of beeswax edible film on preservation of Naem product quality during storage. *Agriculture and Natural Resources*, *58*(1), 129–138. https://doi.org/10.34044/j.anres.2024.58.1.13

Caballero-Flores, H., Nabeshima, C. K., Sarra, G., Moreira, M. S., Arana-Chavez, V. E., Marques, M. M., & Machado, M. E. de L. (2021). Development and Characterization of a New Chitosan-Based Scaffold Associated with Gelatin, Microparticulate Dentin and Genipin for Endodontic Regeneration. *Dental Materials*, *37*(7), 1–12. https://doi.org/10.1016/j.dental.2021.03.016

Cao, C., Wang, Y., Zheng, S., Zhang, J., Li, W., Li, B., Guo, R., & Yu, J. (2020). Poly (butylene adipate-co-terephthalate)/titanium dioxide/silver composite biofilms for food packaging application. *LWT*, *132*, 109874. https://doi.org/10.1016/j.lwt.2020.109874

Cazón, P., & Vázquez, M. (2019). Applications of Chitosan as Food Packaging Materials. In G. Crini & E. Lichtfouse (Eds.), *Sustainable Agriculture Reviews 36* (pp. 81–123). Springer Cham. https://doi.org/10.1007/978-3-030-16581-9

Chaireh, S., Ngasatool, P., & Kaewtatip, K. (2020). Novel Composite Foam Made from Starch and Water Hyacinth with Beeswax Coating for Food Packaging Applications. *International Journal of Biological Macromolecules*, *165*, 1382–1391. https://doi.org/10.1016/j.ijbiomac.2020.10.007

Chawla, R., Sivakumar, S., Kaur, H., & Kumar, S. (2021). Effect of Starch Based Edible Antimicrobial Films and Modified Atmospheric Packaging (MAP) on Extended Life of Composite Sweetmeat. *Carbohydrate Polymer Technologies and Applications*, *2*, 1–10. https://doi.org/10.1016/j.carpta.2021.100055

Chen, H., Wang, J., Cheng, Y., Wang, C., Liu, H., Bian, H., Pan, Y., Sun, J., & Han, W. (2019). Application of Protein-Based Films and Coatings for Food Packaging: A Review. *Polymers*, *11*(12), 2039. https://doi.org/10.3390/polym11122039

de Azeredo, H. M. C., Capparelli Mattoso, L. H., & Habig, T. (2011). Nanocomposites in Food Packaging – A Review. In *Advances in Diverse Industrial Applications of Nanocomposites*. InTech. https://doi.org/10.5772/14437

Diyana, Z. N., Jumaidin, R., Selamat, M. Z., & Suan, M. S. M. (2021). Thermoplastic Starch/Beeswax Blend: Characterization on Thermal Mechanical and Moisture Absorption Properties. *International Journal of Biological Macromolecules*, *190*, 224–232. https://doi.org/10.1016/j.ijbiomac.2021.08.201

Dotto, G. L., Vieira, M. L. G., & Pinto, L. A. A. (2015). LWT - Food Science and Technology Use of chitosan solutions for the microbiological shelf life extension of papaya fruits during storage at room temperature. *LWT - Food Science and Technology*, *64*(1), 126–130. https://doi.org/10.1016/j.lwt.2015.05.042

Erkmen, O., & Barazi, A. O. (2018). General Characteristic of Edible Films. *Journal of Food Biotechnology Research*, *2*(1), 1–4.

Fabra, M. J., Talens, P., Gavara, R., & Chiralt, A. (2012). Barrier properties of sodium caseinate films as affected by lipid composition and moisture content. *Journal of Food Engineering*, *109*(3), 372–379. https://doi.org/10.1016/j.jfoodeng.2011.11.019

Foo, S. Y., Hanani, Z. A. N., Rozzamri, A., Ibadullah, W. Z. W., & Ismail-Fitry, M. R. (2019). Effect of Chitosan–Beeswax Edible Coatings on the Shelf-life of Sapodilla (Achras zapota) Fruit. *Journal of Packaging Technology and Research*, *3*(1), 27–34. https://doi.org/10.1007/s41783-018-0047-0

Fratini, F., Cilia, G., Turchi, B., & Felicioli, A. (2016). Beeswax : A Minireview of Its Antimicrobial Activity and Its Application in Medicine. *Asian Pacific Journal of Tropical Medicine*, *9*(9), 839–843. https://doi.org/10.1016/j.apjtm.2016.07.003

Hamed, I., Jakobsen, A. N., & Lerfall, J. (2022). Sustainable edible packaging systems based on active compounds from food processing byproducts: A review. *Comprehensive Reviews in Food Science and Food Safety*, *21*(1), 198–226. https://doi.org/10.1111/1541-4337.12870

Hamed, I., Özogul, F., & Regenstein, J. M. (2016). Industrial applications of crustacean by-products (chitin, chitosan, and chitooligosaccharides): A review. *Trends in Food Science & Technology*, *48*, 40–50. https://doi.org/10.1016/j.tifs.2015.11.007

Hernández-Muñoz, P., Almenar, E., Valle, V. Del, Velez, D., & Gavara, R. (2008). Effect of Chitosan Coating Combined with Postharvest Calcium Treatment on Strawberry (Fragaria ananassa) Quality During Refrigerated Storage. *Food Chemistry*, *110*(2), 428–432. https://doi.org/10.1016/j.foodchem.2008.02.020

Hernani, Winarti, C., Hidayat, T., Bin Arif, A., & Yuliani, S. (2024). Physicochemical Evaluation of Coated Ginger during Long-Term Storage: Impact of Chitosan and Beeswax Bilayer Coatings at Different Temperatures. *Scientifica*, *2024*, 1–8. https://doi.org/10.1155/2024/2054943

Hoque, M. S., Benjakul, S., & Prodpran, T. (2011). Effects of partial hydrolysis and plasticizer content on the properties of film from cuttlefish (Sepia pharaonis) skin gelatin. *Food Hydrocolloids*, *25*(1), 82–90.

https://doi.org/10.1016/j.foodhyd.2010.05.008

Iversen, L. J. L., Rovina, K., Vonnie, J. M., Matanjun, P., Erna, K. H., 'Aqilah, N. M. N., Felicia, W. X. L., & Funk, A. A. (2022). The Emergence of Edible and Food-Application Coatings for Food Packaging: A Review. *Molecules*, *27*(17), 5604. https://doi.org/10.3390/molecules27175604

Izci, L., Ekici, F., & Gunlu, A. (2017). Coating with chitosan film of sea bream (Sparus aurata) fillets: determining shelf life in refrigerator conditions. *Food Science and Technology*, *38*(1), 54–59. https://doi.org/10.1590/1678-457x.38416

Jain, R., & Tiwari, A. (2015). Biosynthesis of planet friendly bioplastics using renewable carbon source. *Journal of Environmental Health Science and Engineering*, *13*(1), 11. https://doi.org/10.1186/s40201-015-0165-3

Jeevahan, J. J., Chandrasekaran, M., Venkatesan, S. P., Sriram, V., Britto Joseph, G., Mageshwaran, G., & Durairaj, R. B. (2020). Scaling up difficulties and commercial aspects of edible films for food packaging: A review. *Trends in Food Science & Technology*, *100*, 210–222. https://doi.org/10.1016/j.tifs.2020.04.014

Kakaei, S., & Shahbazi, Y. (2016). Effect of chitosan-gelatin film incorporated with ethanolic red grape seed extract and Ziziphora clinopodioides essential oil on survival of Listeria monocytogenes and chemical, microbial and sensory properties of minced trout fillet. *LWT - Food Science and Technology*, *72*, 432–438. https://doi.org/10.1016/j.lwt.2016.05.021

Kerch, G. (2015). Chitosan Films and Coatings Prevent Losses of Fresh Fruit Nutritional Quality : A review. *Trends in Food Science & Technology*, *46*(2), 159–166. https://doi.org/10.1016/j.tifs.2015.10.010

Kowalczyk, D., & Baraniak, B. (2014). Effect of candelilla wax on functional properties of biopolymer emulsion films – A comparative study. *Food Hydrocolloids*, *41*, 195–209. https://doi.org/10.1016/j.foodhyd.2014.04.004

Kumar, L., Ramakanth, D., Akhila, K., & Gaikwad, K. K. (2022). Edible films and coatings for food packaging applications: a review. *Environmental Chemistry Letters*, *20*(1), 875–900. https://doi.org/10.1007/s10311-021-01339-z

Kumar, N., & Neeraj. (2019). Polysaccharide-Based Component and Their Relevance in Edible Film/Coating: A Review. *Nutrition & Food Science*, *49*(5), 793–823. https://doi.org/10.1108/NFS-10-2018-0294

Kumar, S., Mukherjee, A., & Dutta, J. (2020). Chitosan Based Nanocomposite Films and Coatings : Emerging Antimicrobial Food Packaging Alternatives. *Trends in Food Science & Technology*, *97*, 196–209. https://doi.org/10.1016/j.tifs.2020.01.002

Lu, Y., Luo, Q., Chu, Y., Tao, N., Deng, S., Wang, L., & Li, L. (2022). Application of Gelatin in Food Packaging: A Review. *Polymers*, *14*(3), 436. https://doi.org/10.3390/polym14030436

Mariod, A. A., & Adam, H. F. (2013). Review: Gelatin, Source, Extraction and Industrial Applications. *Acta Scientiarum Polonorum, Technologia Alimentaria*, *12*(2), 135–147.

Milani, J. M., & Nemati, A. (2022). Lipid-Based Edible Films and Coatings: A Review of Recent Advances and Applications. *Journal of Packaging Technology and Research*, *6*(1), 11–22. https://doi.org/10.1007/s41783-021-00130-3

Mousavi Khaneghah, A., Hashemi, S. M. B., & Limbo, S. (2018). Antimicrobial agents and packaging systems in antimicrobial active food packaging: An overview of approaches and interactions. *Food and Bioproducts Processing*, *111*, 1–19. https://doi.org/10.1016/j.fbp.2018.05.001

Muller, J., González-Martínez, C., & Chiralt, A. (2017). Combination of Poly(lactic) Acid and Starch for Biodegradable Food Packaging. *Materials*, *10*(8), 952. https://doi.org/10.3390/ma10080952

Naiu, A. S., Yusuf, N., Yusuf, S. C., & Hudongi, Y. S. (2021). Perbedaan Mutu Perman Jeli Kappaphycus alvarezii yang Dikemas Edible Film Berbasis Gelatin-CMC-Lilin Lebah dan Gelatin-Kitosan-Nanokitin. *Jurnal Pengolahan Hasil Perikanan Indonesia*, *24*(3), 358–369.

Nowzari, F., Shábanpour, B., & Ojagh, S. M. (2013). Comparison of Chitosan-Gelatin Composite and Bilayer Coating and Film Effect on the Quality of Refrigerated Rainbow Trout. *Food Chemistry*, *141*(3), 1667–1672. https://doi.org/10.1016/j.foodchem.2013.03.022

Nurmala, N. A., Susatyo, E. B., & Mahatmanti, F. W. (2018). Sintesis Kitosan dari Cangkang Rajungan Terkomposit Lilin Lebah dan Aplikasinya sebagai Edible Coating pada

Buah Stroberi. *Indonesian Journal of Chemical Science*, *7*(3), 278–284.

Pari, R. F., Mayangsari, D., & Hardiningtyas, S. D. (2022). Depolymerization of Chitosan from Shrimp Shell Using Papain Enzyme and Ultraviolet Light Irradiation. *Jurnal Pengolahan Hasil Perikanan Indonesia*, *25*(1), 118–131. https://doi.org/10.17844/jphpi.v25i1.40311

Park, J. H., Koo, M. S., Cho, S. H., & Lyu, M.Y. (2017). Comparison of thermal and optical properties and flowability of fossil-based and bio-based polycarbonate. *Macromolecular Research*, *25*(11), 1135–1144. https://doi.org/10.1007/s13233-017-5153-2

Pertiwi, M., Atma, Y., Mustopa, A. Z., & Maisarah, R. (2018). Karakteristik Fisik dan Kimia Gelatin dari Tulang Ikan Patin dengan Pre-Treatment Asam Sitrat. *Jurnal Aplikasi Teknologi Pangan*, *7*(2), 83–91. https://doi.org/https://doi.org/10.17728/jatp.2470

Petkoska, A. T., Daniloski, D., D'Cunha, N. M., Naumovski, N., & Broach, A. T. (2021). Edible packaging : Sustainable Solutions and Novel Trends in Food Packaging. *Food Research International*, *140*, 1–15. https://doi.org/10.1016/j.foodres.2020.109981

Pinto, C. T., Pankowski, J. A., & Nano, F. E. (2017). The Anti-Microbial Effect of Food Wrap Containing Beeswax Products. *Journal of Microbiology, Biotechnology and Food Science*, *7*(2), 145–148. https://doi.org/10.15414/jmbfs.2017.7.2.145-148

Poverenov, E., Zaitsev, Y., Arnon, H., Granit, R., Alkalai-Tuvia, S., Perzelan, Y., Weinberg, T., & Fallik, E. (2014). Effects of a Composite Chitosan-Gelatin Edible Coating on Postharvest Quality and Storability of Red Bell Peppers. *Postharvest Biology and Technology*, *96*, 106–109. https://doi.org/10.1016/j.postharvbio.2014.05.015

Prakoso, F. A. H., Indiarto, R., & Utama, G. L. (2023). Edible Film Casting Techniques and Materials and Their Utilization for Meat-Based Product Packaging. *Polymers*, *15*(13), 2800. https://doi.org/10.3390/polym15132800

Prateepchanachai, S., Thakhiew, W., Devahastin, S., & Soponronnarit, S. (2017). Mechanical properties improvement of chitosan films via the use of plasticizer, charge modifying agent and film solution homogenization. *Carbohydrate Polymers*, *174*, 253–261. https://doi.org/10.1016/j.carbpol.2017.06.069

Priyadarshi, R., & Rhim, J.-W. (2020). Chitosan-Based Biodegradable Functional Films for Food Packaging Applications. *Innovative Food Science & Emerging Technologies*, *62*, 1–20. https://doi.org/10.1016/j.ifset.2020.102346

Ramos, M., Valdés, A., Beltrán, A., & Garrigós, M. C. (2016). Gelatin-Based Films and Coatings for Food Packaging Applications. *Coatings*, *6*(4), 1–20. https://doi.org/10.3390/coatings6040041

Riaz, A., Lei, S., Akhtar, H. M. S., Wan, P., Chen, D., Jabbar, S., Abid, M., Hashim, M. M., & Zeng, X. (2018). Preparation and Characterization of Chitosan-Based Antimicrobial Active Food Packaging Film Incorporated with Apple Peel Polyphenols. *International Journal of Biological Macromolecules*, *114*, 547–555. https://doi.org/10.1016/j.ijbiomac.2018.03.126

Rochima, E., Azhary, S. Y., Pratama, R. I., Panatarani, C., & Joni, I. M. (2017). Preparation and Characterization of Nano Chitosan from Crab Shell Waste by Beads-Milling Method. *IOP Conference Series: Materials Science and Engineering*, *193*(1), 1–6. https://doi.org/10.1088/1757-899X/193/1/012043

Rochima, E., Fiyanih, E., Afrianto, E., Joni, I. M., Subhan, U., & Panatarani, C. (2018). Efek Penambahan Suspensi Nanokitosan pada Edible Coating terhadap Aktivitas Antibakteri. *Jurnal Pengolahan Hasil Perikanan Indonesia*, *21*(1), 127–136. https://doi.org/10.17844/jphpi.v21i1.21461

Said, N. S., Howell, N. K., & Sarbon, N. . (2023). A Review on Potential Use of Gelatin-based Film as Active and Smart Biodegradable Films for Food Packaging Application. *Food Reviews International*, *39*(2), 1063–1085. https://doi.org/10.1080/87559129.2021.1929298

Saklani, P., Siddhnath, Das, S. K., & Singh, S. M. (2019). A Review of Edible Packaging for Foods. *International Journal of Current Microbiology and Applied Sciences*, *8*(7), 2885–2895. https://doi.org/10.20546/ijcmas.2019.807.359

Shaikh, S., Yaqoob, M., & Aggarwal, P. (2021). An Overview of Biodegradable Packaging in Food Industry. *Current Research in Food Science*, *4*, 503–520. https://doi.org/10.1016/j.crfs.2021.07.005

Shankar, S., Jaiswal, L., Selvakannan, P. R., Ham, K. S., & Rhim, J. W. (2016). Gelatin-Based Dissolvable Antibacterial Films Reinforced with Metallic Nanoparticles. *RSC Advances*, *6*(71), 67340–67352. https://doi.org/10.1039/C6RA10620J

Shankar, S., Wang, L. F., & Rhim, J. W. (2019). Effect of Melanin Nanoparticles on the Mechanical, Water Vapor Barrier, and Antioxidant Properties of Gelatin-Based Films for Food Packaging Application. *Food Packaging and Shelf Life*, *21*, 1–7. https://doi.org/10.1016/j.fpsl.2019.100363

Singh, G., Singh, S., Kumar, B., & Gaikwad, K. K. (2021). Active barrier chitosan films containing gallic acid based oxygen scavenger. *Journal of Food Measurement and Characterization*, *15*(1), 585–593. https://doi.org/10.1007/s11694-020-00669-w

Song, D.-H., Hoa, V. B., Kim, H. W., Khang, S. M., Cho, S.-H., Ham, J.-S., & Seol, K.-H. (2021). Edible Films on Meat and Meat Products. *Coatings*, *11*(11), 1344. https://doi.org/10.3390/coatings11111344

Sultan, M., Hafez, O. M., Saleh, A., & Youssef, A. M. (2021). Smart Edible Coating Films Based on Chitosan and Beeswax–Pollen Grains for the Postharvest Preservation of Le Conte Pear. *RSC Advances*, *11*, 9572–9585. https://doi.org/10.1039/d0ra10671b

Sun, R., Song, G., Zhang, H., Zhang, H., Chi, Y., Ma, Y., Li, H., Bai, S., & Zhang, X. (2021). Effect of Basil Essential Oil and Beeswax Incorporation on the Physical, Structural , and Antibacterial Properties of Chitosan Emulsion based Coating for Eggs Preservation. *LWT - Food Science and Technology*, *150*, 1–11. https://doi.org/10.1016/j.lwt.2021.112020

Supeni, G., & Irawan, S. (2012). Pengaruh Penggunaan Kitosan Terhadap Sifat Barrier Edible Film Tapioka Termodifikasi. *Jurnal Kimia Kemasan*, *34*(1), 199–206.

Suryati, S., ZA, N., Meriatna, M., & Suryani, S. (2015). Pembuatan dan Karakterisasi Gelatin dari Ceker Ayam dengan Proses Hidrolisis. *Jurnal Teknologi Kimia Unimal*, *4*(2), 66–79. https://doi.org/10.29103/jtku.v4i2.74

Ucak, I., Khalily, R., Carrillo, C., Tomasevic, I., & Barba, F. J. (2020). Potential of Propolis Extract as a Natural Antioxidant and Antimicrobial in Gelatin Films Applied to Rainbow Trout (Oncorhynchus mykiss) Fillets. *Foods*, *9*(11), 1584. https://doi.org/10.3390/foods9111584

Unalan, I. U., Cerri, G., Marcuzzo, E., Cozzolino, C. A., & Farris, S. (2014). Nanocomposite Films and Coatings Using Inorganic Nanobuilding Blocks (NBB): Current Applications and Future Opportunities in the Food Packaging Sector. *RSC Advances*, *4*(56), 29393–29428. https://doi.org/10.1039/c4ra01778a

Valdés, A., Ramos, M., Beltrán, A., Jiménez, A., & Garrigós, M. (2017). State of the Art of Antimicrobial Edible Coatings for Food Packaging Applications. *Coatings*, *7*(56), 1–23. https://doi.org/10.3390/coatings7040056

Velickova, E., Winkelhausen, E., Kuzmanova, S., Alves, V. D., & Moldão-Martins, M. (2013). Impact of chitosan-beeswax edible coatings on the quality of fresh strawberries (Fragaria ananassa cv Camarosa) under commercial storage conditions. *LWT - Food Science and Technology*, *52*(2), 80–92. https://doi.org/10.1016/j.lwt.2013.02.004

Vilela, C., Kurek, M., Hayouka, Z., Röcker, B., Yildirim, S., Antunes, M. D. C., Nilsen-Nygaard, J., Pettersen, M. K., & Freire, C. S. R. (2018). A concise guide to active agents for active food packaging. *Trends in Food Science & Technology*, *80*, 212–222. https://doi.org/10.1016/j.tifs.2018.08.006

Wang, H., Ding, F., Ma, L., & Zhang, Y. (2021). Edible Films from Chitosan-Gelatin : Physical Properties and Food Packaging Application. *Food Bioscience*, *40*, 1–17. https://doi.org/10.1016/j.fbio.2020.100871

Wang, H., Liao, Y., Wu, A., Li, B., Qian, J., & Ding, F. (2019). Effect of sodium trimetaphosphate on chitosan-methylcellulose composite films: Physicochemical properties and food packaging application. *Polymers*, *11*(2), 1–15. https://doi.org/10.3390/POLYM11020368

Widiati, A. (2019). Peranan Kemasan (Packaging) Dalam Meningkatkan Pemasaran Produk Usaha Mikro Kecil Menengah (Umkm) Di “Mas Pack” Terminal Kemasan Pontianak. *JAAKFE UNTAN (Jurnal Audit Dan Akuntansi Fakultas Ekonomi Universitas Tanjungpura)*, *8*(2), 67–76. https://doi.org/10.26418/jaakfe.v8i2.40670

Wilson, M. B., Spivak, M., Hegeman, A. D., Rendahl, A., & Cohen, J. D. (2013). Metabolomics Reveals the Origins of

Antimicrobial Plant Resins Collected by Honey Bees. *PLOS ONE*, *8*(10), 1–13. https://doi.org/10.1371/journal.pone.0077512

Wu, H., Li, T., Peng, L., Wang, J., Lei, Y., Li, S., Li, Q., Yuan, X., Zhou, M., & Zhang, Z. (2023). Development and characterization of antioxidant composite films based on starch and gelatin incorporating resveratrol fabricated by extrusion compression moulding. *Food Hydrocolloids*, *139*, 108509. https://doi.org/10.1016/j.foodhyd.2023.108509

Xu, J., Wei, R., Jia, Z., & Song, R. (2020). Characteristics and bioactive functions of chitosan/gelatin-based film incorporated with ε-polylysine and astaxanthin extracts derived from by-products of shrimp (Litopenaeus vannamei). *Food Hydrocolloids*, *100*, 105436. https://doi.org/10.1016/j.foodhyd.2019.105436

Yolanda, N., Khamidah, N., & Rizali, A. (2021). Teknologi Edible Coating Menggunakan Lilin Lebah (Beeswax) dan Kitosan terhadap Mutu Buah Jambu Kristal (Psidium guajava Var.Kristal). *Agrotek View*, *4*(2), 114–124.

Zambrano-Zaragoza, M. L., Quintanar-Guerrero, D., Del Real, A., González-Reza, R. M., Cornejo-Villegas, M. A., & Gutiérrez-Cortez, E. (2020). Effect of Nano-Edible Coating Based on Beeswax Solid Lipid Nanoparticles on Strawberry's Preservation. *Coatings*, *10*(3), 253. https://doi.org/10.3390/coatings10030253

Zhao, Y., Li, B., Li, C., Xu, Y., Luo, Y., Liang, D., & Huang, C. (2021). Comprehensive Review of Polysaccharide-Based Materials in Edible Packaging: A Sustainable Approach. *Foods*, *10*(8), 1845. https://doi.org/10.3390/foods10081845

Peer-review history:
The peer review history for this paper can be accessed here:
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