Al Ulum: Jurnal Sains dan Teknologi (e-ISSN 2477-4731) Vol. 9, No. 3, 2023
DOI: http://dx.doi.org/10.31602/jst.v9i3.12639

AL ULUM: JOURNAL OF SCIENCE AND TECHNOLOGY

REVIEW ARTICLE

EDIBLE FILM FOR FOOD PACKAGING

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Received: 21 September 2023 | Accepted: 25 November 2023 | Published online: 15 December 2023
UPT Publication and Journal Management Uniska-JST 2023

Abstract The purpose of this review article is to provide information about edible film, materials used, manufacturing methods, application for food packaging, and opportunities for future benefits of edible film. The method used by the author in reviewing this article, is by reading various journals from other authors and write the conclude using author own language. The conclusion is, edible film has potential to replace plastics (synthetic polymers) as food packaging. The ingredients used for edible film production are hydrocolloid (protein, polysaccharides, and alginates), lipid (polysaccharides, and alginates) and composite (mix of hydrocolloid and lipid). The methods for edible film production are wet process and dry process. Edible film can be used as food packaging, including cheese, meat, fish, vegetables, and fruit. Prospect of edible film has the potential to increase in the future because people are realizing the importance of reducing food waste with ecofriendly material as food packaging.

Keywords: Edible film · Material · Natural · Environment · Packaging

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Introduction

Food packaging has many benefits and was created to make life easier for humans. The benefits of food packaging include being able to delay the decay of food, so that the food can be stored for a longer time and and can reduce food waste thrown away, food packaging must also be able to provide better safety than unpackaged food, and the last, food packaging is a source of information for consumers who want to buy these food products (eg: nutritional value, ingredient composition, halal and information, rules of use, etc.) (Linus and Mditshwa, 2013). The materials used as food packaging also need to be considered, so the nutritional value of food is not reduced, does not cause disease, and does not pollute the environment. Currently, food packaging is mainly made of plastic materials (synthetic polymers). Based on data (*OECD*, 2022) in 2019, plastic waste reached 353 million tons, 40% came from food packaging. Plastic is commonly utilized as a primary material for food packaging because it is lightweight, heat-resistant, and low in price (Kirwan et al., 2011). In fact, the use of plastic as food packaging can cause a risk of particle transfer from solvent or plastic packaging ink to food packaged using plastic (Alamri et al., 2021). Plastic is also a problem for the environment because plastic is a petroleum derivative that cannot (difficult) be decomposed by microorganisms (Kibria et al., 2023).

Recognizing the adverse effects of continued use of plastic materials for food packaging (on both human health and the environment), the food industry began to innovate and develop new safety materials to package foods if they are to be consumed by humans long-term and with minimal harm. environmental impact. One of the innovations in food packaging that is safe for consumption and environmentally friendly is edible film. Edible film is a protective sheet for food which is thin, clear, transparent, odorless, tasteless, and edible film is needed to extend the shelf life of the product (Layuk et al., 2019).

The main function of edible film is to control moisture in food, so the food does not dry out easily, regulate gases around food (oxygen, carbon dioxide, ethylene) so that food products are not easily discolored or change their texture, keep food sterile, keep important components contained in a food (V et al., 2022).

This article will present a comprehensive overview of edible films in food packaging. It will include the materials utilized, the techniques employed for their production, and the various applications within the food industry. Additionally, it will discuss about the current trends, obstacles, and potential prospects for the future utilization of edible films too.

Materials and Methods

The article review was written using a systematic approach for choosing the topic to be examined. Author will identify, assess, and combine research articles and their findings published by researchers on international journal websites, which relate to the specific topic chosen by the author. Examining and rewriting the text using the author own words. The article review was prepared using various literature sources obtained from International Journal Websites like Google Scholar, PubMeds, Wiley, Science Direct, Scopus, and Elsevier.

Results and Discussion

From the result of reading various articles from other authors in the internet, the author found about material of edible film, method of edible film production, application of edible film for food packaging, and opportunities for future benefits of edible film.

Various materials of edible film

The main elements of edible films are classified into three types, which are hydrocolloids (plant or animal proteins, polysaccharides, and alginates), lipids (fatty acids, glycerol, waxes) and composites (mixtures of hydrocolloids and lipids) (Galus et al., 2020). According to data from (Market Research Future, 2023) it is estimated that the demand for edible films as food packaging will continue to grow and increase from 2022 to 2023, with a growth rate (CAGR) of about 8.5% and market revenue increasing in 2022 worth 2.1 billion USD to 4.4 billion USD in 2032. (Reportlinker, 2022) reported that the largest edible film market segmentation is in North America, Europe, Asia Pacific, Latin America, Middle East, and Africa, and in 2021, the most significant edible film market revenue is in the Asia Pacific region (China and Japan). Some researchers make edible film formulations from various kinds of vegetable and animal proteins, then formulate various kinds of polysaccharides, and formulate lipids. Below are some edible film formulations that have been produced by several researchers.

Edible film made from protein

Edible films made from proteins have advantages over edible films made from polysaccharides and lipids, including that edible films crafted from proteins show superior gases barrier and mechanical properties compared edible films made from polysaccharides or lipids (Wittaya, 2012). Common proteins used to create edible films are collagen, gelatin, corn zein, wheat gluten, soy, casein and mungbean (Chiralt et al., 2017).

Collagen

Collagen is an abundant protein found in mammalian connective tissue (ligaments, tendons, bones, cartilage) and the amount of protein is about 25% of the total amount of protein in the mammalian body (Shenoy et al., 2022). Collagen has several advantages, including: collagen is acceptable and suitable for the human body; non-toxic; has elemental, physical and chemical properties, as well as a good immune system for humans; easily separated and purified in large quantities to be produced as edible films (Wittaya, 2012).

Gelatin

Gelatin is a substance produced by separate the protein collagen, which is naturally found in the skin, bones, and connective tissues of animals (Radhakrishnan et al., 2016). The use of gelatin in the edible film production has its advantages, including low production costs (Coronado et al., 2015). The composition of the amino acids that are the constituents of gelatin is not precisely known, but it is estimated that nearly 60% of the hydroxyproline, followed proline and glycine contained in collagen are extracted from gelatin (note: composition and presentation of total amino acids depends on the gelatin raw material) (Rehman et al., 2016).

Corn Zein

Protein in corn is called zein, zein content is about 45-50% of the total protein in corn (Shukla and Cheryan, 2001). Zein is a by-product of corn protein starch processing, produced by food industry corn gluten meal (CGM) and corn gluten feed (CGF) (Sun et al., 2018). Because zein ability to prevent water vapor is very good compared to other materials, zein has the potential to be used as edible film (Bayer, 2021).

Wheat Gluten

Wheat gluten is a protein found in the endosperm of wheat, which plays a role in thickening food products made from wheat (Xu and Li, 2023). Wheat gluten has excellent properties in oxygen barrier, low price compared to other plant protein raw materials, good viscosity, strong tensile strength, and effective prevent water capability, so wheat gluten allows it to be used as an edible film material (Mojumdar et al., 2011).

Soy

Soy protein is derived from the leftover materials of producing soybean oil (Rhim et al., 2000). The protein content contained in soybeans ranges from 38-44% (Wittaya, 2012). The type of amino acids contained in soy protein is 7S globulin (conglycinin) as much as 37% and 11S globulin (glycinin) as much as 31% of the total amino acids in soy protein (Soliman et al., 2007). Soy protein has excellent properties in prevent oxygen and oil in food, inexpensive, easily found in the market, and rich in nutrients (Perera et al., 2023).

Cassein

Milk contains three levels of nitrogen, namely: casein, whey protein, and non-protein nitrogen (Alichanidis et al., 2016). The amount of protein in casein makes up around 75-80% of the overall protein found in milk (Bhat et al., 2016). Casein is obtained by precipitating skim milk and acidified to pH 4.6 at 20°C (Nakano et al., 2017). Casein-based edible films have a better ability to prevent oxygen (Bonnaillie et al., 2014).

Mung Bean

It has been studied that the protein content in mung beans is quite high, ranging from 25- 28% (Khaket et al., 2015). It was reported that edible films made from mung bean have better mechanical properties such as tensile strength and elongation at break, and can prevent water vapor better when looking at other edible films made from different proteins (casein, soy protein, wheat gluten, peanut (Wittaya, 2013).

Edible film made from polysaccharide

The polysaccharide-based food industry has shown an increasing trend in the use of edible films over the past few years (Lagarón et al., 2016). Polysaccharide made from starch, alginate, cellulose and its derivatives, chitosan, carrageenan, and pectins are used as thickener, adding adhesion to the edible film (Dhanapal et al., 2012). Polysaccharide edible film has good properties in control gas in food (vegetables, fruit (Zhang et al., 2013).

Starch

Starch is a complex carbohydrate made by plants (Apriyanto et al., 2022). Starch is made up of two polymers, amylose, and amylopectin (Delcour and Hoseney, n.d.). Amylose is considered as a polymer of α-D-glucose connected with α-1,4 bonds, while amylopectin consists of α-D-glucose connected with α-1,4 and α-1,6 bonds (Delcour and Hoseney, n.d.). Because of these two polymers, edible starch-based films have good oxygen barrier properties (Cazón et al., 2017).

Alginate

Alginate is a biopolymer that occurs naturally and is extracted from brown algae, commonly known as kelp (Abka-khajouei et al., 2022). Alginate is composed of 1,4'-linked β-D-mannuronic acid (M) and α-L-guluronic acid (G) (Bhatia and Bera, 2015). Alginate is produced by *Laminaria hyperborean, Macrocystis pyrifera, Ascophyllum nodosum, Laminaria digitata, Laminaria japonica, Eclonia maxima, Lesonia negrescens, Sargassum sp* (Kaidi et al., 2022).

Cellulose and derivatives

Cellulose is the most common biopolymer made from natural sources (Khandelwal and Windle, 2013). The primary element found in the cell walls of green plants is referred to as the main component (Kumar-Gupta et al., 2019). Cellulose is made of α-D-glucopyranose units (AGU) that are connected to β-glucosidic bond (Mehandzhiyski and Zozoulenko, 2021). Four types of cellulose derivatives that can be used as edible films include carboxymethyl cellulose (CMC), methyl cellulose (MC), hydroxypropyl cellulose (HPMC), and hydropropyl cellulose (HPC) (Bourtoom, 2008). Edible films made from CMC, MC, HPMC, HPC have the advantages of being resistant to oil and fat, flexible, moderate oxygen barrier properties (Shit and Shah, 2014).

Chitosan

Chitosan is an abundant chitin derivative and is found in crustacean exoskeletons, fungal cell walls, and others (Elsabee and Abdou, 2013). Chitosan is obtained by deacetylation using alkaline media (predominantly) or acid treatment (Abdou et al., 2008). Chitosan consists of linear amino polysaccharides with D-glucosamine and N-acetyl-D-glucosamine (Wang et al., 2018). Edible films created from chitosan have the advantage of being very good at prevent gases (CO_2 and O_2) in food (Domard and Domard, 2002).

Carrageenan

Carrageenan is a substance made from extracting the polysaccharide found in red algae, especially *Euchema cottonii* (Ili-Balqis et al., 2017), *Mastocarpus stellatus* (Torres et al., 2017), *Hypnea musciformis* (Rafiquzzaman et al., 2016). Carrageenan consists of D-galactose and 3,6-anhydro-ga-lactose (3,6-AG) which binds to α-1,3 and β-1,4-glycosidic acids (Necas and Bartosikova, 2013). It is reported that edible films made from carrageenan have a good ability to prevent O_2 and CO_2 (Alves et al., 2011).

Pectins

Pectins are complex polysaccharides that exist in nature and are contained in plant cell walls (Jolie et al., 2010). Pectin is widely obtained from apples and citrus fruits (Stephen et al., 2006). Pectins consist of poly α 1-4-galacturonic acids with methylation of carboxylic acid residues or polygalacturonic acids (Mishra et al., 2012).

Edible film made from lipid

Lipids are natural compounds derived from plants, animals, and insects (Mohamed et al., 2020; Pardede et al., 2013). The main components of lipids are derivatives of fatty acids, small components of lipids in the form of amides (Belitz et al., 2009). The advantage of edible films made from lipids is that they are very good at prevent water vapor and gas compared to other materials (Rhim and Shellhammer, 2005).

Edible Film made from Composite

Composite edible film is a combination of hydrophobic and hydrophilic compounds to obtain better properties of each compound (V et al., 2022). Hydrocolloid edible films have excellent properties in prevent oxygen and carbon dioxide gases (even better than plastic) (Erkmen and Barazi, 2018). While lipid edible films have good properties in prevent water vapor (hydrophobic) (Janjarasskul and Krochta, 2010). Composite edible films have advantages over layered films, as layered films require more pouring and drying process (Galus and Kadzińska, 2015).

Method of edible film production

There are two methods of edible film production, it is wet process (solvent casting) and dry process (extrusion processes, compression molding, and injection molding) (Suhag et al., 2020; V et al., 2022). Wet process is most widely used in edible films production because this method is low cost (Kumar et al., 2022; V et al., 2022). Explained by (Kumar et al., 2022) that there are three steps in edible film production using solvent casting method. The first is the solubilization stage, where the biopolymer material is dissolved using a solvent that is not harmful to human consumption (mostly using ethyl alcohol and water). Next is the stage of pouring the solution on the mold. The last is the drying stage, where the solvent is evaporated from the edible film until it forms a gel and becomes an edible film. Some researchers who use the solvent casting method in making edible films include (Sandhu et al., 2020) used pearl millet starch and carrageenan gum, (Fakhreddin-Hosseini et al., 2013) made edible films from fish gelatin and chitosan, (Bharti et al., 2021) using sweet potato stach and K-Carageenan.

Kumar et al. (2022) mentioned another method of edible films production, namely dry processes (extrusion processes, compression molding, and injection molding), called dry processes because they use little or no solvent. The advantage of using the extrusion method is that it saves time because there is no solvent evaporation. There are three stages in edible film production using the extrusion method. The first is the feeding zone, where the biopolymer and additives are fed into the extruder. After being inserted, the ingredients are mixed until smooth. The last stage is heating using an oven so that the ingredients fuse together. Some researchers who use the extrusion method in edible film production are (Huntrakul et al., 2020) used acetylated cassava starch (AS) and pea protein isolate (PI), (Chevalier et al., 2018) using rennet casein native powder, waxes and casein sheet; compression molding method as done by (Ceballos et al., 2020) in the manufacture of edible films using native cassava starch and yerba mate; injection molding method in research (Cho et al., 2011) using wheat gluten protein.

Application of edible film for food packaging

The demand for edible film as food packaging will continue to increase every year if a lot of people are aware of the importance of food packaging that is environmentally friendly but still of good quality and non-toxic. Usually, edible film is widely used to coat products in the form of cheese, meat, and fish.

Cheese

Researcher (Fajardo et al., 2010) have studied that chitosan is able to maintain the quality (bacteria, O_2, CO_2, moisture) of cheese stored for one week at 25°C compared to cheese not coated by chitosan. This is because chitosan contains natamycin which is an anti-mold.

Meat

The results of research conducted by (Naseri et al. (2020) is gelatin-chitosan powder and 0.5% FAEO (Ferulago Angulate Essential Oil) can inhibit bacterial growth and increase the shelf life of turkey meat.

Fish

Researcher Castro et al. (2019) succeeded in making whey protein edible films added with two plants, namely green tea, and rosemary extract, which were able to inhibit lipid oxidation of fresh salmon for 14 days of storage and room temperature.

Vegetable and fruit

The results of research conducted by Zhang et al. (2017) stated that Chitosan-TiO_2 edible film was able to extend the storage period of red wine and was also able to inhibit the growth of E. coli bacteria (gram-negative bacteria), S. aureus (gram-positive bacteria), C. albicans (fungus), and A. niger (fungus). However, Chitosan-TiO2 edible film was best able to inhibit E. coli bacteria.

Opportunities for future benefits of edible films

Currently, research on edible film raw materials in the form of biopolymers continues to be carried out and developed to be able and equivalent in quality with polymer syntetic (plastic) packaging, so that edible films have the potential as an replacement for polymer-based food packaging (plastic). Considering that plastic food packaging waste contributes a large amount of pollution to the world (around 63%) in 2021. (Environment, 2021), then the use of edible films is very potential to be developed and become a trend in the future because it is environmentally friendly, easily available, can be an antimicrobial agent and antioxidant, safe for consumption (non-toxic) and cheap (Carpiné et al., 2015)

Conclusion

Edible film has been identified by many researchers as an alternative to plastic used for food packaging because it is safe for consumption, eco-friendly nature, and cost effectiveness. Many researchers have demonstrated that using multiple ingredients in edible film production improves the characteristic of the edible film itself compared to using a single ingredient. Prospect of edible films has the potential to increase in the future as people begin to realize the importance of reducing food waste (using alternative food packaging) without destroy the earth.

Compliance with ethical standards

Conflict of interest

The authors declare that they have no conflict of interest.

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