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Review Article

An Overview on Antioxidants Activity of Polysaccharide Edible Films and Coatings Contains Essential Oils and Herb Extracts in Meat and Meat Products

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Abstract | According to the environmental problems that plastic packaging was made in recent decades, edible film/coating have been drawn attention due to their beneficial properties. Alginate, chitosan, starch, CMC and etc. are of the most common edible films/coatings. On the other hand, the meat and meat products are vulnerable to oxidative reactions that reduce their quality and also lose nutrients and risk consumers health and safety. A strategy to limit this, is use of a wide range of antioxidants. Nowadays, consumers tend to use natural antioxidants due to the complication of synthetic antioxidants. Essential oil and herbal extracts are among natural compounds with high functional properties but they had undesirable effects on sensorial quality of meat and meat products in high doses. An interesting strategy to overcome this limitation is application of polysaccharide edible film/coating as carrier of these compounds. Natural antioxidants in edible films/coatings improve the film matrix and cause an increase in meat shelf-life, benefits sensorial quality and also enhance nutritional value of meat. This paper discusses the combining of natural antioxidants with polysaccharide film and coating in meat and meat products.

Keywords | Edible film and coating, Polysaccharide, Essential oil and extracts, Antioxidants, Meat and meat product, Shelf-life

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INTRODUCTION

Meat is a known source of protein and due to its valuable proteins, essential amino acids, vitamins, minerals and fat, meat is an important part of a balanced diet. During the storage and processing of meat and meat products oxidative reactions can occur (Stadnik and Kęska, 2015) (Domínguez et al., 2016). Oxidation of lipids is one of the most important reaction in meat products which cause rancidity, reduce in quality, nutritional value, and taste. It could even produce toxic compounds which could be risky for human health. The application of antioxidants is of the best solutions to prevent oxidation and protect meat against oxidative damage. Complications of synthetic antioxidants in foods and consumers demand for natural preservative leads to utilization of natural antioxidants in food products. Therefore, due to high bioactive contents of essential oils and plant extracts, scientists and industries made an effort to add them in meat and meat products to prevent oxidative reactions (Domínguez et al., 2014) (Nićiforović et al., 2010).

Food packaging prevents the entry of external agents such as microorganisms. It also protects food against color changes and undesirable tastes. Meat and meat productions are not exceptions and their quality and safety depend on the packaging technology. Today, a series of new packaging technologies such as intelligent and/or active packaging, and using edible films and coatings have been developed. These technologies support quality and safety of the food products and they also attracts consumers (Fang et al., 2017).

Biodegradable edible films and coatings are of the new approaches in order to reduce food destruction. They also create a barrier against external factors such as oxygen, moisture, light and etc. which could lead to improvement of quality and shelf life of food products. Application of antioxidants in biodegradable edible films and coatings improved properties and preservation of food (Sánchez-González et al., 2011). Among various edible films/coatings, polysaccharide biopolymers were used in a wide range in foods because of their desirable properties, margin of safety, and structure diversity (Tomé et al., 2015). This overview discusses the rationale of using edible film/coatings for polysaccharides contains essential oils and plant extracts in food products.

Natural and common antioxidants in the meat industry

Natural antioxidants and their benefits for human health were reported by many researchers including desirable effects on cardiovascular diseases (Kashino et al., 2019), fatty liver (Shahmohammadi et al., 2017), cancers (Parohan et al., 2019), inflammation (Zilaee et al., 2019) and even improvement of obesity parameters (Shirali et al., 2016) and aging-associated diseases (Conti et al., 2016).

Food additives includes six groups: colorants, flavoring agents, ingredient materials, nutritional supplements, texturizers and preservatives. The latter group includes antioxidants which is important in meat due to high content of fat (Santos-Sánchez et al., 2017; Aminzare et al., 2017).

Properties of antioxidants is critical. Because not only they should be colored and flavored but also, they must be food grade, stable, non-toxic and economical (dos Santos et al., 2015). Antioxidants are bioactive compounds that in low concentrations can retard oxidation changes in foods including meat products. Antioxidants prevent negative effects of oxidative reactions quality degradation, sensory changes and it also benefits nutritional attributes and increase the shelf-life of products (Mallick et al., 2016) (Shah et al., 2014).

Antioxidants donate hydrogen atoms to free radicals and cause neutralization free radicals, decomposition of peroxides, and decrease the concentration of dissolved oxygen (Rather et al., 2016). Antioxidants could be obtained synthetically or naturally. Butylated hydroxyanisole (Reshi et al., 2017) and Butylated hydroxytoluene (BHT) are of the most synthetic antioxidants which were used as food additive. But utilization of synthetic antioxidants in foods is limited due to their toxicity, carcinogenesis and malnutrition effects (ŞİMŞEK et al., 2017). Therefore, natural antioxidants such as essential oils and plant extracts are being studied as alternatives for synthetic antioxidants which can be used with edible films/coatings due to their phenolic contents (Ehsani et al., 2020). Phenolic compounds have the ability to give hydrogen atoms to free radicals and present in all parts of plants (stems, heaves, root, pollen and seeds) (de Almeida et al., 2015).

Extract plants

Herbal extracts have antioxidant activity due to their polyphenolic, phenolic acids, biological and anticoagulant compounds. These constituents have made it possible to replace chemical preservatives with them. They also adequate for daily consumption. Method of extraction and solvent affects their properties (Rather et al., 2016).

Essential oils

Essential oils are volatile and aromatic liquids which extracted from various parts plants (seeds, buds, leaves, flowers, stems, and bark). They were also recognized as alternatives for chemical preservatives to protects foods. They were also applied in food industry cosmetic and pharmaceutical industries. Antimicrobial and antioxidative effects are the most important properties of Essential oils. They also have insecticidal and herbicidal effects (Aminzare et al., 2017).

Essential oils constituents can be classified according to their chemical structure including: terpenes (hydrocarbons have several isoprene units), terpenoids (thymol, carvacrol, linalool, linalyl acetate, and etc.), and phenylpropanoides (cinnamaldehyde and eugenol). Thymol, carvacrol and eugenol effects as food preservatives have been evaluated before (Raeisi et al., 2016; Amiri et al., 2019; Raeisi et al., 2017).

It has been shown that direct application of essential oils with high doses had undesirable effects on organoleptic properties in food products. Therefore, administering them to packaging materials is an excellent approach that has recently been considered in food packaging industry (Reshi et al., 2017; Atarés and Chiralt, 2016).

Due to the lipid nature of the essential oils, it is expected to help reduce the water vapor permeability of hydrophilic films and positive effects on physical and microstructure properties of used films in food packaging (Sánchez-González et al., 2011).

There are challenges in usage of essential oils in food due to their weak solubility in water, high volatility, and low sustainability during the processing of food. Reaction between essential oils and food ingredients should be avoided to maintain biological activity and reduce sensory changes in food. Encapsulation of essential oils particularly on the nanoscale (size less than 100nm), can solve this problem (Sharma et al., 2017; Gahruie et al., 2017).

Improving the quality and shelf life of meat products is possible with regard to the effects of nanoscale materials on coatings and edible films. Edible coatings with active nano-capsules can actively enhance chemical properties of films and preserve the food product (Gahruie et al., 2017).

Edible film and coating

Application of plastic materials is common in food packaging and they have high resistance to long-term maintenance. But because plastics are not degradable, they are one of the environmental concerns. In addition, their ingredients immigrate into the food which a risk for consumers safety. Common practices like burning and burial are not suitable and result in entering toxic gases and materials to the atmosphere and soil. Moreover, they have high manufacturing cost, no positive impact on food, food safety and hygiene issues. Hence, recently the use of natural compounds to produce active packaging, replacing plastic materials has been drawn attention in research studies (Campos et al., 2011; Ezeoha and Ezenwanne, 2013; Tajik et al., 2015; Aminzare et al., 2017).

Edible films and coatings have low cost, prevents the loss of moisture, gases, and lipids and also preserve the nutritional properties of food. They are not affect the flavor, color, and taste (Wang et al., 2015). Various edible films and coatings exist based on their production method, application, size, and food combination. Films are a thin layer used to preserve the food while the coatings are directly added as liquid by different way (spray, immersion, etc.) to the outer surface of the food product (Pascall and Lin, 2013).

Edible films and coatings can be used to improve the quality of fresh produce foods such as meat products (fresh, freeze, processed) without altering essential ingredients and processing methods because of their desirable properties including prevention of gases and moisture loss, reduction of oxidative reactions, preservation of taste, improving the appearance of the product, prevention of color changes and oxymyoglobin formation, prevention of liquid loss from lean meat tissue, reduction of oil absorption during frying, ability to add various additives to their matrix (antioxidants, antimicrobials, vitamins, minerals, flavors, pigments, spices and etc.), maintain nutritional value and improving sensory properties of food (Milani and Sahraee, 2015).

Development of biodegradable packaging system is considered to provide functional food products and health of consumers.

Polysaccharides, proteins and lipids are used to make biodegradable edible films and coatings. Polysaccharides has unique properties that distinguish them from other biopolymers including low cost, water-solubility, no need for solvent, appropriate chemical structure for coating, easy to work, thermostability and etc. Polysaccharides are divided into different types by weight and structure (Zheng et al., 2015; Arnon et al., 2015).

Four Polysaccharides films and coating

Starch film and coating

Starch polymer is considered as an alternative to plastics in the food packaging industry. Biodegradation, easy access, low cost, low permeability to oxygen, odorless, tasteless, colorless, high resolution and clarity are the suitable characteristics of this polymer but due to weak mechanical properties, some strategies need to be considered to improve these defects such as combination with antimicrobial polymers, active nanoparticles, antioxidant and antimicrobial compounds (essential oil, phenolic extract) (Jiang et al., 2016; Sánchez et al., 2015). The type of starch, amylose/amylopectin ratio affects, thickness, color, moisture, accumulation, heat, surface and mechanical properties. Higher amount of amylose causes greater plasticity, thickness and more resistance of films which also depend on the water amount. Because of hydrophobicity of starch films they can be used in food products with high water activity such as vegetable, cheese, meat and etc (Basiak et al., 2017).

Chitosan film and coating

Chitosan is a linear polysaccharide polymer of 1,4-linked-2-amino-deoxy-bD-glucan units which is a deacetylated derivate from natural chitin and used as natural preservative with high potential antioxidant, antimicrobial, anticancer, antidiabetic and other effects in food and health (Ngo et al., 2015).

Chitosan copolymer has some benefits that makes it adequate to produce edible films such as biodegradability, biocompatibility, cationic effect (electrostatic balance with other compounds), good barrier attribute, non-toxic polymer, antibacterial and antifungal properties (Martins et al., 2012).

Carboxymethyl cellulose (CMC)

Carboxymethyl cellulose (CMC) as a linear water-soluble biopolymer with long-chain, is an anionic polysaccharide derived from cellulose. CMC is one of the most important derivatives of cellulose and it is biocompatible, safe, thickener, viscosity creator non-allergic polymer with many applications such as in foods, coating, pesticides and etc. Thermal gelation effect, polymeric structure and high molecular weight of CMC made it possible to produce excellent films and bio-composites (Dashipour et al., 2015; Almasi et al., 2010).

Alginate

Alginate is linear and non-branched polysaccharides composed of BD-mannuronic acid and a-L-guluronic acid units and generally due to their chemical composition are raised as biocompatible, non-toxic natural biological materials which are wiedly used with particular importance (Bayer et al., 2011).

Thickening, stabilizing, suspension capability, film forming, gel production and emulsion stabilization are unique properties of alginate. Hydrogenated alginate films are poorly insulated with moisture. Adding plasticizers to the main materials of the film, reduces structural stiffness, increase the flexibility of alginate film, reduce brittleness (Koushki et al., 2015).

Essential oils and herbal extracts in films and coatings

Essential oils have been added to biodegradable food coatings and affect the continuity of the polymer matrix. They also provide antioxidant and antimicrobial properties for films and coatings depending on their composition (Galus and Kadzińska, 2015). Following studies show the application of natural edible polysaccharide films and coatings impregnated with essential oils and herbal extracts and their antioxidant effect of in meat and meat products during 2010-2018 years.

Polysaccharide films and coatings (chitosan-CMC-alginate-starch) combined with essential and extracts in meat and meat products

Alginate films and coatings

Several studies have been evaluated quality and shelf-life of foods coated with alginate films and coatings. In a study determination of antioxidant effects of sodium alginate coating containing thyme essential oil on rainbow trout fillets during refrigerated storage showed that this coating reduced effectively fish oxidation kept in cold storage (Hamzeh and Rezaei, 2011).

Evaluation of the effect of sodium alginate coating containing horsemint essential oil on quality of bighead carp fillets during storage at refrigeration temperature showed that this type of coating can reduce spoilage, increase shelf-life, reduce the TVB-N content and lipid oxidation, reduce free fatty acids, peroxide value and thiobarbituric acid in the storage period, and overall, improve the quality of food (Heydari et al., 2015).

The effects of Sodium alginate coating impregnated with calcium chloride and oregano or rosemary essential oil in beef steaks showed that coatings enriched with essential oils (especially those enriched with oregano) had a significant effect on consumer acceptance. Antioxidant activity of oregano essential oil were the best among all treatments (Vital et al., 2016).

A study conducted on the antioxidant activity of bioactive sodium alginate and galbanum gum coating incorporated with *Zizphora persica* essential oil. Their impact on chicken fillets quality showed that *Zizphora persica* and galbanum gum had high phenolic content and antioxidant activity and formation thiobarbituric acid, total volatile base nitrogen and peroxides was significantly lower in samples containing *Zizphora persica* and galbanum gum. Therefore, alginate-galbanum gum with *Zizphora persica* essential oil can be used as bioactive edible coating for preservation and shelf-life extension in chicken fillets and other food (Hamedi et al., 2017).

Another study investigated the effect of thyme essential oil as antioxidants in composition of an alginate edible coating to preserve chicken breast fillets showed that selected coatings increased food shelf life to 33% and improved the safety of chicken breast fillets (Matiacevich et al., 2015). Lu et al. 2010 evaluated the effect of calcium alginate coating impregnated with cinnamon and nisin on quality of northern snakehead fish fillets. The results showed that cinnamon was significantly lowered thiobarbitoric acid analysis athlough the color was changed due to the cinnamon color (Lu et al., 2010). The effects of edible alginate coating contain vitamin C and tea polyphenols on the shelf life span bream (*megalobramo amblycephanla*) during storage at the refrigerator temperature showed reduction of chemical in peroxide value and thiobarbitoric acid test. It also reduced the spoilage of meat and improved total sensory quality of fish (Song et al., 2011).

Chitosan films and coatings

Many studies have been conducted to evaluate and increase food quality and extending shelf-life by chitosan enriched with various bioactive components. Chicken meat is susceptible to rapid deterioration due to high protein and high moisture. A survey on coating chicken breast meat in cold temperature with chitosan enriched by *Zataria multiflora* and pomegranate juice showed that chitosan coating enriched with *Zataria multiflora* caused improving quality and sensory attributes, reduced protein oxidation and undesirable chemical changes in chicken meat (Bazargani-Gilani et al., 2015). In other study, the protecting effects of chitosan coating containing licorice extract and citric acid in Japanese fresh seafood fillets kept in cold temperature have been assessed and found that both citric acid and licorice extract increase the chitosan function by inhibition of lipid oxidation and results quality improvement and shelf life enhancement (Qiu et al., 2014).

In another study, the effects of chitosan incorporated with *Origanum minutiflorum* and rosemary essential oil on some qualitative characteristics of hot smoked rainbow trout during cold storage showed that the coating with these essential oils had a positive effect on consumer health and extending meat shelf-life (Doğan and İzci, 2017). Edible chitosan coating containing garlic oil in shrimp meat kept at cold temperatures reduced pH, total volatile base nitrogen, and oxidation and have high capacity to improve the quality of shrimp meat. Garlic oil was effective at low concentration (0.5%) for adding to chitosan coating and in higher concentrations may lead to higher oxidation rate (Aşik and Candoğan, 2014).

Another study evaluated the effects of chitosan films combined with peanut skin and pink pepper antioxidants on lipid oxidation, pH and color in chicken meat showed that both pink pepper and peanut butter skin were effective and improved the oxidation. In addition, there was no differences between them in changing color or pH (Serrano-León et al., 2018).

The effect of chitosan coating containing free or nano-capsules of plant essential oil on the chemical, sensory and quality of lamb meat samples at cold temperatures was investigated in Pabast et al. study and results showed that this coating with satureja essential oil nano-capsules effectively prevents chemical changes and they could be a promising way to extending of food's shelf-life (Pabast et al., 2018).

Researchers showed that chitosan film impregnated with anise (*pimpinella anisum L.*) essential oil during cold storage can extend shelf-life of chicken burger and improve physical properties of chitosan films such as moisture, and solubility. Steam permeability reduction of chitosan film and tensile strength of the film increases with higher concentration of anise essential oil. Anise essential oil incorporated with chitosan film delayed lipid oxidation and improved chemical properties in chicken burger (Mahdavi et al., 2018).

A study was conducted to develop chitosan film containing *Thymus moroderi* essential oil and *Thymus piperella* essential oil and determine their impact on shelf life of cooked ham kept in cold storage. The data showed that lipid oxidation was reduced, and shelf-life of cooked ham was increased (Ruiz-Navajas et al., 2015).

The effect of chitosan coating impregnated with eucalyptus essential oil and α-tocopherol on silver carp fillets quality during storage was investigated by Valipour Kootenaie et al. 2017 and the results indicated that coating with this essential oil improved the shelf life of fish meat. In addition, essential oil increased the effectiveness of the coating (Valipour et al., 2017).

The researchers showed protective effect of chitosan coating with grape seed essential oil against lipid oxidation induced by gamma irradiation (Hassanzadeh et al., 2017).

Yu et al. 2017 showed that chitosan coating with clove, cinnamon and lemon grass essential oils have better results on improving the meat quality compare to chitosan alone (Yu et al., 2017).

Chitosan coating containing oregano essential oil protects shrimp and improved the shelf life during cold storage as well as lipid oxidation (Alparslan and Baygar, 2017).

The results of a study to compare chitosan, eugenol, EDTA, and peppermint essential oil for potential antioxidant in chicken noodles and their effect on color and oxidative stability at ambient temperature storage showed that redness of samples treated with chitosan and eugenol protected during storage and free fatty acid and thiobarbituric acid levels improved with eugenol. Moreover, eugenol was effective on the sensorial properties and has a high potential as natural preservative to increase shelf-life of chicken noodles (Khare et al., 2014).

Chitosan coating enriched with cinnamon oil improved chemical, microbial and sensorial attributes of rainbow trout during cold storage as well as quality and shelf life (Ojagh et al., 2010). Other investigation showed that chitosan coating incorporated with bamboo vinegar prevents lipid oxidation, thiobarbituric acid production and it also protects color in ready to cook meat products (Zhang et al., 2018).

In a study results showed that biocomposite film of chitosan and kombucha tea as active food packaging in the beef model increased antioxidant activity to 59% and increased the films protection effect against the ultra violet. The chitosan film with kombucha tea, increased the shelf-life of beef meat effectively (Ashrafi et al., 2018). Krkić et al. 2013 showed that chitosan films containing thyme essential oil reduced lipid oxidation, moisture loss and improved color attributes with beneficial effects on sensorial properties in dried fermented sausage (Krkić et al., 2013).

Carboxymethyl cellulose (CMC) films and coatings

Some studies have been reported quality improvement and extending shelf-life of meat products, using CMC films and coatings enriched with various bioactive components. CMC coating incorporated with tween and rosemary essential oil and ethanol extract were used to enhance shelf-life and prevention of oxidation in smoked eel fillets. In this study, higher concentration of extract, increased the antioxidative condition. Essential oils showed lower effects than ethanolic extract of rosemary (Choulitoudi et al., 2017). Baghlani et al. studied the effect of CMC coating impregnated with savory (*Satureja hortensis*) essential oil on spangled emperor (*Lethrinus nebulosus*). The data showed that lipid oxidation was delayed in treated samples as well as sensory properties and hardness (Baghlani et al., 2019).

Raeisi et al. 2015 stated that CMC coating incorporated with *Zataria multiflora* and grape seed essential oils were improved sensorial attributes, increased shelf-life, enhanced chemical, and microbial properties of coated rainbow trout fish during cold storage (Raeisi et al., 2015). The data obtained by study Ranjbar et al. 2017 showed that gelatin-CMC coating incorporated with Bene (*Pistacia atlantica*) essential oil showed acceptable antioxidant and sensorial properties in treated chicken fillets. Therefore, it can be used in meat product (Ranjbar and Azizi, 2017).

Starch films and coatings

Several studies have been conducted to evaluate and increase food quality and extending shelf-life by starch enriched with various bioactive components. Evaluation of beef meat packaging with edible potato starch-based films containing antioxidant agents butylated hydroxy toluene–Green tea extract showed reduction in metmyoglobin formation and lipid oxidation (u Nisa et al., 2015). Results of a survey on packaging of ground beef with cassava starch film incorporated with oregano essential oil and pumpkin residue extract showed considerable antioxidative effects, color improvement and pH control (Caetano et al., 2017).

The active packaging of sausages by starch-films incorporated with clove essential oil (*Syzygium aromaticum*) showed significant reduction in lipid oxidation of the product with no significant changes in flavor and taste compared to control samples (Ugalde et al., 2017).

Sarteshnizi et al. 2017 investigated the effects of resistant starch-β–glucan combination on frying performance, oxidative stability and shelf life of prebiotic sausage during refrigerated storage. The results showed that addition of resistant starch and β–glucan caused reduction of thiobarbituric acid and peroxides. They stated that the best ratio to retard fat oxidation is 1.33% β-glucan and 2.22% resistant starch (Sarteshnizi et al., 2017).

In another study, application of corn starch edible films with clove and cinnamon essential oils to extend shelf life of red meat showed that combination of clove and cinnamon essential oil creates antioxidant activity and antimicrobial in films. It can also increase raw meat stability, improve meat color and reduce enumeration of microbes during cold storage (Radha Krishnan et al., 2015).

Using biocomposite edible films as active packaging to preserve foods was studied by several researchers. For example, high antioxidative activity was seen in pea starch-guar gum biocomposite edible film incorporated with natural plant extracts such as macadamia and banana peel extract, blueberry fruit extract and epigallocatechin gallate (Saberi et al., 2017).

It was showed that coating of shrimp by sweet potato starch impregnated with thyme essential oil reduced lipid oxidation and melanosis. In during cold storage, treated shrimps had better color, texture, kept their freshness, and their shelf-life was improved (Alotaibi and Tahergorabi, 2018). Another study showed that application biocomposite of cassava starch-based edible coatings combined with kaffir lime leaves oleoresin can keep the quality of fresh beef meat at cold storage and it can be used as an alternative preservation method to improvement shelf life of fresh beef meat (Utami et al., 2017).

The cassava starch edible coating enriched with *kaempferia rotonda* and *curcuma xanthonhiza* essential oil reduced the formation of thiobarbituric acid, increased the quality of fish fillets, and extended shelf-life, thus they can be used as a preservative in the fish (Utami et al., 2014).

CONCLUSIONS

Edible film/coating with a wide range of properties are available as an alternative for synthetic plastics in food technology. Several types of film and edible coatings have been applied to meat and meat products. Polysaccharide films are a new opportunity to develop biodegradable packaging and can be effective to increase the shelf-life of fresh, cooked and other meat products. Oxidative reaction happens during processing and preserving meat and meat products due to the presence of oxygen. These reactions affect all biomolecules, including lipids, proteins and carbohydrates and cause rancidity and finally decrease the quality of product. Natural compounds can be used to prevent oxidation in the food industry including, essential oils and plant extracts. But their use is limited due to their high flavor and toxicity in higher doses. An interesting strategy is to using film and coatings as carriers of these compounds and/or encapsulating lipophilic particles, especially on the nanoscale.

Since the excellent results were observed in improving the overall quality of meat and meat products by adding various additives and bioactive compounds combined into films and edible coatings, this practical strategy can be used in the meat industry to improve the quality and safety of meat and meat products and as well as provided new products for consumers.

AUTHORS CONTRIBUTION

All authors have been contributed to form the idea and writing of the manuscript.

CONFLICT OF INTEREST

All authors declare no conflict of interest.

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