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Active edible films for application in meat products

Filmes comestíveis ativos para aplicação em produtos cárneos

Películas comestibles activas para aplicación en productos cárnicos

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Abstract

The packaging protects food from actions of external agents, from alterations and contaminations, in addition to adulteration. Edible films are structures produced from biopolymers, which can replace non-biodegradable packaging. These films have been formulated with naturally polymers of polysaccharides, lipids and proteins, isolated or combined with each other. Edible films produced with polysaccharides and proteins are transparent and flexible, although proteins films are less resistant. They act as a barrier, protecting food and increasing shelf life. Additionally, they can carry antimicrobial and antioxidant compounds, being called active films. The antioxidant power is proportional to the amount of the compound added. Natural extracts such as green tea, cloves, ginger and others can be incorporated into the films, wich could improving the mechanical properties of the films and the characteristics of the food. The use of active edible films has been evaluated in the meat industry as an alternative packaging. This review aims to address the use of edible films added with vegetable compounds, with antimicrobial and antioxidant activity, applied to meat products.

Keywords: Edible film; Biodegradable packaging; Active film; Natural compounds; Meats.

Resumo

A embalagem protege o alimento de ação de agentes externos, de alterações e contaminações, além de adulterações. Filmes comestíveis são estruturas produzidas a partir de biopolímeros, que podem substituir as embalagens não biodegradáveis. Esses filmes têm sido formulados com polímeros de ocorrência natural de polissacarídeos, lipídeos e proteínas, isolados ou combinados entre si. Filmes comestíveis produzidos com polissacarídeos e proteínas são transparentes e flexíveis, embora os proteicos sejam menos resistentes. Agem como barreira, protegendo o alimento e aumentando a vida de prateleira. Adicionalmente, podem carrear compostos antimicrobianos e antioxidantes, sendo denominados filmes ativos. O poder antioxidante é proporcional à quantidade do composto adicionado. Extratos naturais como chá verde, cravo, gengibre e outros podem ser incorporados aos filmes, que podem melhorar as propriedades mecânicas dos filmes e as características do alimento. A utilização de filmes comestíveis ativos têm sido avaliados na indústria de cárneos como embalagem alternativa. Esta revisão, tem por objetivo abordar a utilização de filmes comestíveis adicionados de compostos vegetais, com atividade antimicrobiana e antioxidante, aplicados em produtos cárneos.

Palavras-chave: Filme comestível; Embalagem biodegradável; Filme ativo; Compostos naturais; Carnes.

Resumen

El envase protege los alimentos de la acción de agentes externos, de cambios y contaminación, además de la adulteración. Las películas comestibles son estructuras producidas a partir de biopolímeros, que pueden reemplazar los envases no biodegradables. Estas películas se han formulado con polímeros naturales de polisacáridos, lípidos y proteínas, aislados o combinados entre sí. Las películas comestibles producidas con polisacáridos y proteínas son transparentes y flexibles, aunque las proteínas son menos resistentes. Actúan como una barrera, protegiendo los alimentos y aumentando la vida útil. Además, pueden transportar compuestos antimicrobianos y antioxidantes, que se denominan películas activas. El poder antioxidante es proporcional a la cantidad de compuesto agregado. Se pueden incorporar a las películas extractos naturales como té verde, clavo, jengibre y otros, lo que puede mejorar las propiedades mecánicas de las películas y las características del alimento. El uso de películas comestibles activas se ha evaluado en la industria cárnica como envasado alternativo. Esta revisión tiene como objetivo abordar el uso de películas comestibles añadidas con compuestos vegetales, con actividad antimicrobiana y antioxidante, aplicadas a productos cárnicos.

Palabras clave: Película comestible; Paquete biodegradable; Película activa; Compuestos naturales; Carne.

1. Introduction

Packaging is any form in which food has been conditioned, stored, packaged or filled and according National Health Surveillance Agency is the article that is in direct contact with food, intended to contain it from its manufacture to its delivery to the consumer, in order to protect it from external agents, from alterations and contaminations, as well as from adulteration (Brasil, 2002; Suderman, Isa & Sarbon, 2018; Jaramillo et al., 2016). Packaging plays an important role in the food industry because its multiple functions. Besides to containing the product, the packaging is very important in its conservation, maintaining quality and safety, acting as a barrier against factors responsible for chemical, physical and microbiological deterioration (Jorge, 2013).

The materials commonly used as packaging are one of the major solid wastes in the main cities in the world. Polymers from non-renewable sources are associated with environmental pollution issues (Jaramillo et al., 2016; Piñeros-Hernandez et al., 2017). It is estimated that the production of these materials are around 300 million tons, in which the applications of these plastics as packaging represent about 39.6% of the total demand (Piñeros-Hernandez et al., 2017).

In order to reduce the environmental impact, biodegradable polymers are an attractive alternative to reduce the use of non-degradable and non-renewable materials. Biopolymers have applications such as edible films and coatings, in a wide range of products (Jaramillo et al., 2016; Piñeros-Hernandez et al., 2017; López et al., 2017).

Edible films are structures for wrapping or interleaving products, prepared in order to obtain a thin thickness (layer of material), from biological macromolecules, which act as a barrier to external elements (moisture, gases and oils), protecting the products and increasing your shelf life. Additionally, they can carry antimicrobial and antioxidant compounds, being called of active films (Mostafavi & Zaeim, 2020; Umaraw et al., 2020).

The use of polymers obtained from natural sources has been the focus of recent research. The main biopolymers used in the development of biodegradable films are proteins and polysaccharides. The polysaccharides generally studied comprise chitosan, carboxymethylcellulose, pectin and starch and the proteins commonly studied include soy protein, milk protein such as casein, whey protein and gelatin (Umaraw et al., 2020; Abdollahzadeh, Nematollahi & Hosseini, 2021).

Technological strategies may also involve the application of plant extracts or essential oils in these biocomentible films. Extracts rich in polyphenols are considered potent film additives because they could help to prevent lipid oxidation in food and microbial deterioration. These natural extracts are sources of antioxidants, such as polyphenols and flavonoids, among others, whose activity is well known in the pharmaceutical industry, cosmetic and food (Piñeros-Hernandez et al., 2017; Jaramillo et al., 2016).

Biodegradable films with different concentrations of dry biomass and biomass extract of microalgae obtained positive results in antioxidant activity evaluated by the peroxide index (Carissimi, Flôres & Rech, 2018). Addition of epigallocatechin gallate (EGCG), natural antioxidant abundant in green tea, to the fish gelatin-based film, having antioxidant activity had and higher seal strength and seal efficiency (Nilsuwan, Benjakul & Prodpran, 2018). Jaramillo et al. (2017) observed that gelatin-based films containing oregano or rosemary extract exhibited greater reducing and free radical scavenging capacity. These studies show that the extract added to an edible film can improve functional properties and activity antioxidant.

In meat products the oxidation reaction affects lipids, proteins, meat pigments, microbial growth, enzymatic browning and loss of vitamins, resulting in deterioration of color, flavor, texture and nutritional value (Lorenzo et al., 2018; López et al., 2017; Li et al., 2014). The oxidation of meat components is a process observed during processing and storage, due to this lipid oxidation in meat products must have been avoided in these two stages (Lorenzo et al., 2018; Falowo, Fayemi & Muchenje, 2014). Oxygen also reacts with unsaturated lipids to form lipid peroxides (Min & Ahn, 2012), in a process involving oxygen consumption and rearrangement of double bonds. Eventually, the lipid peroxides formed result in the formation (due to the breakdown) of various chemical compounds, such as alcohols, aldehydes and ketones (Domínguez et al., 2014).

In addition, it generates and accumulates compounds that can pose serious health risks to consumers (Lorenzo et al., 2018; Falowo, Fayemi & Muchenje, 2014). Therefore, preventing and delaying oxidation events in the final product is a major challenge for meat processing technology (Falowo, Fayemi & Muchenje, 2014).

The use of active edible films is an option for meat, providing the probability that in a single product it offers both the packaging and the necessary antimicrobial and antioxidant protection with natural and biodegradable components. Studies have been carried out with active edible films in meat products such as sausage, meatballs, pork and chicken pies, chicken and pork burgers, chicken nuggets, pork liver pate and lamb chops. Therefore, this review addresses the possibilities of using edible films and the application of natural compounds, with antimicrobial and antioxidant activity, from active packaging for meat.

2. Methodology

This work consists of a literature review, developed by bibliographic research carried out on scientific articles, dissertations and theses from online databases and research portals: Wiley Online Library, Science Direct, Scielo (Scientific Eletronic Library Online), Elsevier, Pubmed and Google Scholar. Complete works published between 2011 and 2021 were used, without disregarding relevant works from previous years.

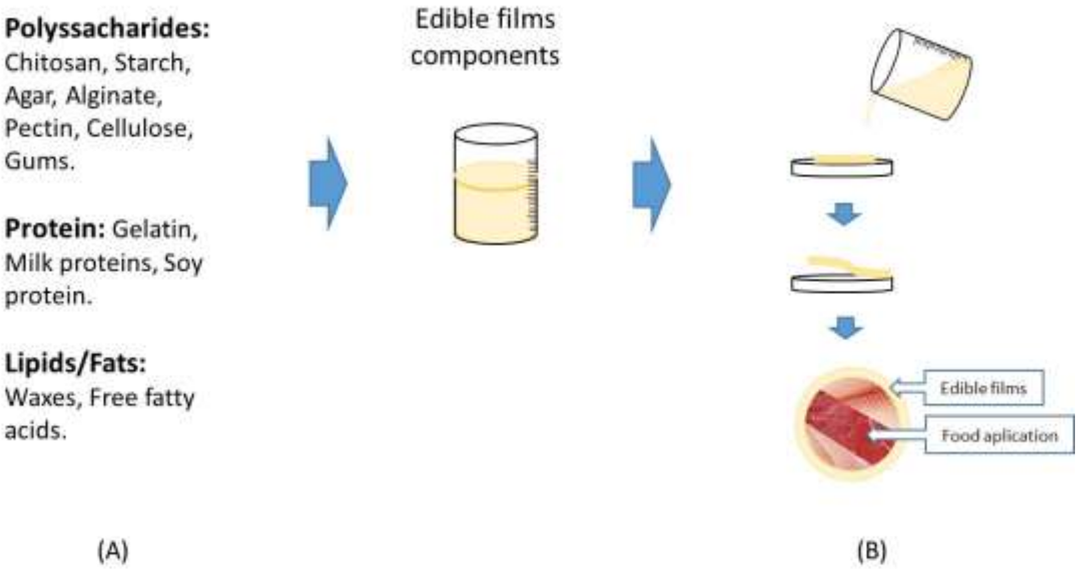
3. Results and Discussion

3.1 Edible Films

There has been an increasing consumer demand for fresher and healthier foods. Edible films could be suitable alternatives for packaging due to their abilities in preventing the transfer of moisture, oxygen, and aromas (Mostafavi & Zaeim, 2020). Biodegradable and/or edible films have potential to reduce or, in some circumstances, completely replace some common polymeric packaging materials for specific applications. However, to develop them, these packages must function like conventional packaging and provide all the necessary functions of containment, protection, preservation, information, convenience in a legal and environmentally correct manner, in an economical way (Mostafavi & Zaeim, 2020; Hanani, Roos & Kerry, 2014).

Among the researched materials, natural biopolymers, such as polysaccharides and proteins, are the most promising, due to the fact that they are abundant, renewable, and capable of forming a continuous matrix (Iturriaga Olabarrieta & Martínez de Marañón, 2012; Hanani, Roos & Kerry, 2014). Different biodegradable materials that can be found and used as food packaging and their production for food are shown in Figure 1. Biopolymers are edible and have the ability to replace traditional plastics, they can also act as edible films and/or coatings in contact with food (Hanani, Roos & Kerry, 2014). These films still need to have sealing strength strong enough to keep products in the package without leakage during handling or storage (Tongnuanchan, Benjakul & Prodpran, 2012). Films obtained from natural materials are economical, due to their low cost. They also have advantages such as being able to be consumed together with the product, retaining aromatic compounds, carrying food additives or components with antimicrobial and/or antioxidant activities (Pranoto, Rakshit & Salokhe, 2005).

Figure 1 – Natural biopolymers for food packaging (A) and the schematic representation of the production of food films (B).



Source: Authors (2021).

These biomolecules are compatible with each other and with other hydrocolloids, surfactants and additives. Polysaccharides are known for their structural complexity and functional diversity (Tharanathan, 2003). Linear structures of some polysaccharides, such as cellulose, starch, chitosan, give rise to resistant, flexible and transparent films. Other components are also added to edible films, such as plasticizers (glycerol) and active agents with different properties (antioxidant, antimicrobial, pigments, etc.) (López et al., 2017).

The term "biodegradable materials" is used to describe those materials that can be degraded by the enzymatic action of living organisms, such as bacteria, yeasts, fungi and the end products of the degradation process, such as CO_2, H_2O and biomass under aerobic conditions, and hydrocarbons, methane and biomass under anaerobic conditions (Jaramillo et al., 2016; Hanani, Roos & Kerry, 2014).

For the use of biodegradable packaging and with active compounds that can improve the quality of the products they protect, further contributing to the nutritional value of the food, guaranteeing and extending the safety and quality of the products during their useful life, it is necessary to development of these eco-friendly, active and intelligent materials. In this sense, several researchers have investigated the use of antioxidants or antimicrobial agents in matrices, obtaining the "functional packaging" (Musso, Salgado & Mauri, 2016; Jaramillo et al., 2017; Kanatt et al., 2012).

Edible carboxymethylcellulose (CMC) and chitosan films have been extensively investigated for their ability to prolong the shelf life of various foods, such as white cheese, shrimp, minced trout fillet and powdered beef. Due to these studies, the authors Khezrian & Shahbazi (2018) developed new films based on nanomontmorillonite-chitosan (MMT-Ch) and nanomontmorillonite-carboxymethylcellulose (MMT-CMC) and incorporated different concentrations of essential oil of *Ziziphora clinopodioides* (ZEO; 0, 5, 1 and 2%) isolated and in combination with *Ficus carica* extract (FCH; 1%) to investigate them as active packaging materials for minced camel meat, and increase their shelf life (microbial, chemical and sensory properties) and inhibit the growth of *Listeria monocytogenes* and *Escherichia coli* O157: H7 during storage.

Polymers used in manufacture of edible films may be obtained from agricultural food stock, animal origin, marine food processing industry wastes, and microorganisms, as well as through chemical synthesis (Tharanathan, 2003). The polysaccharide biopolymers used in packaging form transparent, resistant and flexible films, their barrier properties are improved with the use of a higher amylopectin content, while starch with a high amylose content contributes to the mechanical resistance, the protein biopolymers produce transparent, flexible and highly brittle films, which their water vapor barrier can be improved with crosslinking agents, while lipids form fragile and thicker films due to their hydrophobicity, in addition to presenting organoleptic problems (Bolívar-Monsalve et al., 2019)

Chitosan

Chitosan is a cationic polysaccharide with excellent film-forming properties. It is formed from chitin by deacetylation in the presence of alkalis (Bonilla et al., 2014). Corresponds to a copolymer consisting of 2-acetamido-2-deoxy-D-glycopyranose and 2-amino-2-deoxy-D-glycopyranose units joined by the same type of glycosidic bond in chitin, with a predominance of the second unit type (Cardoso, 2008).

The conversion of chitin to chitosan is carried out by treatment with sodium or potassium hydroxide solution (40-50%), usually at 100ºC or more, to hydrolyze some or most of the polymer's acetamide groups (Cardoso, 2008). It is a promising biopolymer because it is environmentally friendly due to its biodegradability. In the food industry, chitosan-based films have immense potential as an active packaging material due to their antimicrobial activity, non-toxicity and low oxygen permeability (Kanatt et al., 2012; Noorbakhsh-Soltani, Zerafat & Sabbaghi, 2018).

Several studies have demonstrated the effect of molecular weight and chitosan concentration on antibacterial and antifungal activities. As chitosan contains hydroxyl and amine groups, it is potentially miscible with polyvinyl alcohol due to the formation of hydrogen (Bonilla et al., 2014). In addition, in chitosan mixture films, substances, as natural extracts or inorganic metal particles, can be incorporated in order to improve these characteristics (Kanatt et al., 2012; Bonilla et al., 2014).

Starch

Starch has been considered one of the most promising candidates for future materials due to its low price, abundance and thermoplastic behavior. In addition, has a good formation property from a wide variety of botanical sources, such as corn, wheat, cassava, rice, potatoes, yams, among others. The physico-chemical properties of starch films vary widely depending on the botanical origin of the starch, the content and type of the plasticizer and the processing conditions (Piñeros-Hernandez et al., 2017). The starch-based film presents a faster degradation than other polymeric materials, such as PLA (lactic polyacid) or PBAT (polybutylene adipate-co-terephthalate), with this there is an advantage, the reduced waste volume (Jaramillo et al., 2016).

Certain plasticizers can be added to the starch films in order to decrease the fragility. Although the mechanical and barrier properties of starch films depend on moisture, and this can be resolved by introducing hydrophobic components to improve the water vapor sorption properties. For example, glycerol is added to starch (plasticized wheat starch) to improve processing capacity through conventional extrusion. Low mechanical resistance and high sensitivity to moisture can also be overcome by associating starch with moisture-resistant polymers with good mechanical properties, maintaining biodegradability (Noorbakhsh-Soltani, Zerafat & Sabbaghi, 2018).

Cassava starch is appreciated due to the clarity of the paste, low gelatinization temperature and good gel stability. In addition, cassava starch films have been described as odorless, tasteless, colorless, non-toxic and biodegradable (Piñeros-Hernandez et al., 2017).

Agar

Agar is a polysaccharide extracted from specific species of marine red alga. The chemical structure is composed of a mixture of agaropectin (non-gelling fraction) and agarose (gelling fraction) (Mostafavi & Zaeim, 2020). This thermoplastic, biodegradable and biocompatible polysaccharide has shown high mechanical strength with moderate water resistance as packaging material and has been used in blends with other biopolymers (López de Lacey et al., 2013).

The most important attribute of agar is its ability to form hard gels at very low concentrations (0.04%) and it has been broadly utilized as a gelling agent in processed foods, pharmaceutical products and cosmetics, besides applications in biotechnology and medicine (Atefa, Rezaeia & Behroozb, 2014).

Alginate

Alginate, as biodegradable polymers, are widely utilized to prepare edible films owing to their novel properties as gel and film formation (Abdel Aziz, Salama & Sabaa, 2018). Alginate is a polymer of D-β-mannuronic acid (M block) and L-α-glucuronic. (G block), extracted from brown algae. The proportion and distribution of these blocks determine the physicochemical properties of the biopolymer. Is water-soluble and one of the natural compounds that can be used as an oral coating due to its unique colloidal property (Xiao, 2018; Kazemeini, Azizian & Adib, 2021).

Second Khan et al. (2013) alginate-based films can reduce meat shrink and improve juiciness and texture, but free calcium and metal cations needed tofix alginate coatings may induce undesired proteolytic activity.

Pectin

Pectin is one of the most widely investigated water soluble polysaccharides and it is commonly used as a thickening agent and stabilizer in food industry (Guerra-Rosas et al., 2016). Chemically, pectin is poly α1–4-galacturonic acids, with varying degree of methylation of carboxylic acid residues and/or amidated polygalacturonic acids (Espitia et al., 2014; Hosseinnia, Khaledabad & Almasi, 2017).

According to the degree of esterification with methanol, which is the ratio of esterified galacturonic acid groups to total galacturonic acid groups, pectin can be classified as high methoxyl pectin (HMP) or low methoxyl pectin (LMP). HMP has over 50% of their carboxyl groups esterified and forms excellent films (Espitia et al., 2014; Tharanathan 2003). Plasticized blends of citrus pectin and high amylose starch give strong, flexible films, which are thermally stable up to 180°C (Fang & Hanna, 2000).

Gelatin

Gelatin is an animal protein obtained by controlled hydrolysis of the insoluble fibrous collagen present in the bones and skins of animals (Lopez et al., 2017). It has a film-forming capacity to protect food from drying and exposure to light and oxygen. It has gelling, sparkling and emulsifying properties that contribute to a wide range of applications. It has as its unique property the ability to form thermo-reversible gels with a melting temperature close to the temperature of 35º C and has good solubility in water (Lopez et al., 2017; Sarbon, Nazlin & Howell, 2013).

Gelatins from different sources have different physical and chemical properties, as they contain different levels of amino acids. Packaging films can be successfully produced from all sources of gelatin and the behavior and characteristics of gelatin-based films can be changed by incorporating other food ingredients to produce composite films that have improved physical and mechanical properties (Dou et al., 2018; Suderman, Isa & Sarbon, 2018; Lopez et al., 2017; Hanani, Roos & Kerry, 2014).

Due to the water vapor permeability of gelatin, alternatives have been sought to optimize the designs of biodegradable materials for food packaging. The addition of plasticizers improves the functional properties of films, increasing their extensibility, dispensability, flexibility, elasticity and rigidity. Plasticizers such as glycerol, sorbitol and glycol are essential to make films more flexible, softer and to prevent pores and cracks in the polymer matrix (Suderman, Isa & Sarbon, 2018; Hanani, Roos & Kerry, 2014).

Plasticizers are of low molecular weight, so they can use intermolecular spaces between the polymer chains, secondary forms between them. These molecules alter the three-dimensional molecular organization of polymers, the energy required for molecular movement and the formation of hydrogen bonds between chains. Thus, the degree of plasticity of the polymers is largely dependent on the chemical structure of the plasticizer, including chemical composition, molecular weight and attributable groups (Jaramillo et al., 2016).

Milk proteins

Milk proteins are divided into whey protein and casein protein. Casein protein comprises 80% of milk protein and it contains α, β, and κ-casein components (Mohamed, El-Sakhawy & El-Sakhawy, 2020). Whey protein is obtained after precipitation of casein protein. Whey proteins contain several materials, such as β-lactoglobulin, α-lactalbumin, bovine serum albumin immunoglobulins, and proteose peptones (Enujiugha & Oyinloye, 2019).

The films containing milk proteins have demonstrated high mechanical efficiency as well as excellent aroma, oxygen, and lipid barriers; however, due to the hydrophilic nature of their constituents, they show poor water vapor barrier (Abdollahzadeh, Nematollahi & Hosseini, 2021). Casein-based films remain stable for a range of pH, temperatures and salt concentrations (Mohamed, El-Sakhawy & El-Sakhawy, 2020). Edible films of whey protein isolate (90% protein) are better oxygen barrier at low or intermediate relative humidity, nevertheless, they have poor water vapor permeability. Whey protein concentrate (25-80% protein) is another whey protein used in the past to form edible films, nevertheless, it has other impurities, as lactose that could enhance water vapor permeability, but worsen the mechanical properties (Oses et al., 2009).

Soy protein

Soy protein is available as soy flour, soy concentrate and soy isolates. All forms are extracted from soybeans (Mohamed, El-Sakhawy & El-Sakhawy, 2020). Soy protein films are smooth, flexible and clear in contrast to films formed by other proteins from plant sources (Djenavi et al., 2002). Soy protein isolate can interact with agar gum through the formation of intermolecular hydrogen bonds between their available hydroxyl groups, forming conformational changes in the secondary structure of the protein and orientation of the hydrophobic groups (Mostafavi & Zaeim, 2020).

3.2 Active Films

In meat products, processes such as lipid oxidation, microbial growth, enzymatic browning occur since the pre-slaughter stages and the beginning of slaughter, processing and storage (Lorenzo et al., 2018; Lopez et al., 2017; Papuc et al., 2017). Oxygen is responsible for the degradation processes in food (Lopez et al., 2017). In meat products, the oxidation reaction affects lipids, proteins and meat pigments, resulting in deterioration of color, flavor, texture and nutritional value (Lorenzo et al., 2018; Li et al., 2014).

In order to produce active edible films that avoid the negative effects of oxygen, the addition of antioxidants to these films are investigated. Several synthetic antioxidants, such as butylated hydroxytoluene (BHT), butylated hydroxyanisol (BHA) and tertbutylhydroquinone, are used successfully to prevent oxidative deterioration of food. However, synthetic antioxidants and additives have, in general, a negative impact on some groups of consumers more aware of the possible effects on human health (Lopez et al., 2017; Martins, 2018).

Natural extracts that present one good perform due to the presence of phenolic compounds with antioxidant properties are extensively studied, because they inhibit lipid oxidation, and also participating in processes responsible for color, aroma and astringency in various products (Martins, 2018; Bolívar-Monsalve et al., 2019). Natural biosubstances, such as plant extracts, have been used for a long time as herbal medicines. A variety of chemicals have been developed to analyze and characterize phytochemicals, therefore, research on natural extracts with biological activities, such as antimicrobial, antioxidant, anti-aging and anti-inflammatory properties are extensively carried out (Kim et al., 2016).

Brazil, country rich in biodiversity, uses little of these resources and inappropriately. Researches that search the isolation of active principles from natural extracts, identification, verification of their use in the food, pharmaceutical and cosmetic industry, as well as obtaining different extracts of the vegetables involved, are relevant activities (Serafini et al., 2002).

Among the various biological activities, the antimicrobial property is one of the common properties of natural compounds and can be widely applied to various fields, such as food preservation or the antibacterial agent in consumer products (Kim et al., 2016). In addition to the antimicrobial properties, the antioxidant properties of plant extracts have aroused interest due to the prospect of being an alternative to the demands of consumers regarding the use of natural additives in different products (Cansian et al., 2010; Tassou, Koutsoumanis & Nychas, 2000; Ugalde et al., 2017; Dalla Rosa et al., 2019; Borella et al., 2019; Meregalli et al., 2020). Herbs and spices contain many phytochemicals that are potential sources of natural antioxidants, including catechins, phenolic diterpenes, flavonoids, tannins and phenolic acids. Some also have anti-inflammatory and anti-cancer activities (Lopez et al., 2017).

Natural extracts are also sources of antioxidants capable of preventing oxidation during storage and increasing the shelf life of foods. These compounds not only increase the stability of food components, especially polyunsaturated lipids, and prevent degradation, discoloration and oxidative rancidity, but also maintain their initial sensory properties. The effectiveness of antioxidants depends on their molecular structure (number and position of OH/OCH_3 radicals, molecular weight, among others) and polarity (water-soluble or lipophilic compounds) (Lorenzo et al., 2018).

There are many compounds capable of inhibiting oxidation, but only part of them are suitable for human consumption due to toxicological reasons. Food grade antioxidants must be approved by regulatory bodies to satisfy safety and from the application point of view, should not negatively affect color, odor or taste; be effective in low concentrations (0.001-0.01%);

be compatible with food and have easy application; retain stability during processing and shelf life; and have low cost (Lorenzo et al., 2018).

Antioxidants can be classified according to their mechanism of action as primary and secondary compounds. Primary antioxidants are also referred to as type 1 or chain-breaking antioxidants. Due to the chemical nature of these molecules, they can act as acceptors / scavengers of free radicals and delay or inhibit the initiation stage or interrupt the propagation phase of self-oxidation (Lorenzo et al., 2018; Falowo, Fayemi & Muchenje, 2014). Secondary antioxidants are considered hydroperoxide-decomposing substances, which are transformed into stable products, therefore non-reactive. As singlet oxygen suppressors, secondary antioxidants capture the energy of singlet oxygen ($^1O_2$), which returns to the fundamental state (O_2). As metal ion chelators, these antioxidants are capable of interacting and deactivating metal ions that catalyze lipid peroxidation reactions. To this group of antioxidants belong hete thioesters and phosphites (Chaillou & Nazareno, 2006).

Lipids contribute to the taste, odor, color and texture, but also give a feeling of satiety and palatability to foods. However, the main problem of lipids resides in lipid oxidation during food storage or processing, which can lead to rancidity (Ahn et al., 2008). Oxidative processes in meat and meat products during storage lead to the degradation of color pigments, lipids and proteins that can contribute to the deterioration of the flavor, texture, color and nutritional value of the product. Lipid oxidation is a critical point for meat packaged under aerobic conditions, limiting its quality and acceptability, since it affects sensory properties, due to off-flavor and off-odor development, and the production of potentially toxic compounds, such as fatty acid peroxides, cholesterol hydroperoxide and peroxide radicals. In addition, color changes are an important factor that influence the quality and acceptability of meat and meat products (Lorenzo et al., 2014).

Antioxidants are added to meat products during processing to delay oxidation (Djenane et al., 2002). This is one of the reasons for the increased demand for natural ingredients of plant origin (Lorenzo et al., 2014). Some components in natural products, such as carotenoids, flavonoids, anthocyanins and phenolic compounds, are known to act as scavengers in the primary and secondary oxidation process. In particular, it has been reported that there are potential antioxidants in various natural plant extracts (Ahn et al., 2008).

Essential plant oils and extracts are perceived as potential sources of natural antimicrobials. Plants are traditionally used in foods as flavoring and/or preserving agents, as popular medicines to cure diseases. Herbal and spice extracts are generally considered safe, due to their lack of harmful effects documented during historical use, or based on detailed toxicological studies (Yuan, Lee & Yuk, 2017).

Bacteria such as psychrophils, psychrotrophs, mesophiles and thermophiles, are able to survive under various processing conditions and cause spoilage and waste in food. However, meat-spoiling bacteria can be reduced by applying natural antioxidants directly to meat products. The use of natural compounds such as organic acids and essential oils has been identified for the decontamination of beef, pork and poultry products against *Salmonella* (Falowo, Fayemi & Muchenje, 2014). Authors such as Yuan & Yuk (2018) also cite that plant extracts are valuable sources of phytochemicals, which have demonstrated broad-spectrum antimicrobial activities of some of these extracts against the deterioration of food and pathogenic microorganisms, including *Escherichia coli* O157: H7, *Salmonella Typhimurium* and *Staphylococcus aureus*.

Natural antimicrobial compounds have a good potential to be applied as food conservation. Essential oils (EOs) and other extracts of plants, herbs, spices and some of their constituents, have shown antimicrobial activity against different food pathogens and microorganisms. Extracts of rosemary, oregano, cloves, thyme and citrus fruits (for example, lemon, orange and grapefruit) are among the most studied natural antimicrobials for food applications (Iturriaga, Olabarrieta & Martínez de Marañón, 2012). In fact, oregano and thyme have proven to be among the most active extracts (Burt, 2004; Busatta et al., 2007; Cansian et al., 2008).

Phenolic compounds, such as thymol, carvacrol and eugenol, are some of the most active components of essential oils (Burt, 2004). Other extracts obtained from plants and fruits, have polyphenolic compounds, such as flavonoids, which also showed antibacterial activity against a wide variety of microorganisms (Iturriaga, Olabarrieta & Martínez de Marañón, 2012). They act as antioxidant and antimicrobial agents, which can migrate from the packaging to the food product (or the adjacent eye space) to prolong the shelf life of food and improve its safety and quality properties (Piñeros-Hernandez et al., 2017). In addition to all the characteristics presented, the incorporation of natural extracts can improve the plasticizing properties of biomaterials (Jaramillo et al., 2016). Natural antioxidant compounds are used in several food matrices such as hamburgers, meatballs, sausages, dehydrated and marinated cuts and in edible films used in meat products with satisfactory results (Busatta et al., 2007; Busatta et al., 2008; Mariutti & Bragagnolo, 2009; Borella et al., 2019; Umaraw et al., 2020).

Table 1 shows natural compounds used in edible films, with positive effects such as antioxidants, antimicrobials and plasticizing properties in meat products.

Table 1 – Natural compounds used in edible films, with positive effects such as antioxidants, antimicrobials and plasticizing properties in meat products

Natural compound	**Active componentes**	**Application of natural compound in active films for meat/fish**		
		Film	**Compound**	**Product**
Green tea (*Camellia sinensis*)	Epicatechin, epigallocatechin-3-gallate, epicatechin-3-gallate, epigallocatechin, gallocatechin, catechin (Abdollahzadeh, Nematollahi & Hosseini, 2021)	Agar	Green tea extract and probiotic strains	Hake fillets (López de Lacey et al., 2014)
Turmeric (*Curcuma longa*)	Curcumin (Abdollahzadeh, Nematollahi & Hosseini, 2021)	Pectin	Curcumin-cinnamon essential oil (CCN), curcumin-garlic essential oil (CGN), curcumin-sunflower oil (CSN)	Chilled chicken fillets (Abdou, Galhoum & Mohamed, 2018)
		Gelatin and cassava-gelatin	Turmeric residue and purified curcumin	Sausages (Tosati et al., 2018)
Ginger (*Zingiber officinale*)	α-zingiberene, β-sesqui-phellandrene, camphene, sesquisabinene hydrate, zingiberenol (Noori, Zeynali & Almasi, 2018)	Sodium casein	Ginger essential oil	Hicken breast fillets (Noori, Zeynali & Almasi, 2018)
		Protein and chitosan blend	Ginger essential oil	Fish sarcoplasmic proteins (Cai, Wang & Cao, 2020)
Ajowan (*Trachyspermum ammi*)	Thymol, γ-terpinene, para-cymene (Dhaiwal et al., 2017)	Alginate	Trachyspermum ammi essential oil	Turkey fillets (Kazemeini, Azizian & Adib, 2021)
Oregano (*Oreganum heracleoticum*)	Carvacrol, thymol, g-terpinene and p-Cymene (Abdollahzadeh, Nematollahi & Hosseini, 2021)	Soy	Thyme and oregano essential oils	Fresh ground beef patties (Emiroğlu et al., 2010)
		Whey Protein	Oregano or clove essential oils	Chicken breast fillets (Fernández-Pan, Carrión-

		Isolate		Granda & Maté, 2014)
Clove (*Syzygium aromaticum*)	Linalool (Ugalde et al., 2016), Eugenol, eugenyl acetate, β-caryophyllene (Lima et al., 2021)	Starch	Clove essential oil	Sausages (Ugalde et al., 2017)
Black Caraway (*Bunium persicum*)	ρ-cymene, monoterpenes, limonene, γ-Terpinene, Cuminaldehyde, Carvone, β-Pinene (Hassanzadazar et al., 2018)	Chitosan	*Bunium persicum* essential oil	Rainbow Trout Fillet (Kazemeini, Azizian & Shahavi, 2019)
Boldo (*Peumus boldus*)	Proanthocyanidins, flavonol glycosides, alkaloids (Girardi et al., 2016); Isorhamnetin glucosyl-di-rhamnoside; di-glucosyl-di-rhamnoside (Simirgiotis & Schmeda-Hirschmann, 2010)	Chitosan and Chitosan with gelatin	Boldo extract	Beef hamburger (Bonilla Lagos & Sobral, 2019)
Nettle (*Urtica dioica* L.)	Neophytadiene, β-Ionone, α-Ionone, Farnesylacetone, 2,4-di-*t*-butylphenol, Hexahydrofarnesyl acetone, Phytol (Gharibzahedi & Mohammadnabi, 2016)	Jujube gum (*Zizyphus jujuba* Mill)	Nettle essential oil	Beluga sturgeon fillets (Gharibzahedi & Mohammadnabi, 2017)

Source: Authors (2021).

Li et al. (2014) researched different natural extracts that have excellent antioxidant activity and delay lipid oxidation in various food matrix systems, which may be the ideal choice to be suitable for films to improve the quality and extent of shelf life. López de Lacey et al. (2014) observed that the application of green tea films in fish delayed the growth of microorganisms, mainly counts of H_2S-producing bacteria and total viable bacteria, extending the shelf life of hake for at least a week. Abdou, Galhoum & Mohamed (2018) report that curcumin nanoemulsions/pectin coatings prepared with cinnamon and garlic essential oils improved the microbiological quality properties and delayed the appearance of microbial spoilage in chilled chicken fillets, resulting in an increase of the shelf life up to 12 days.

The phenolic compounds can affect enzymes and thereby, down regulate energy-dependent mechanisms and bacterial colonization is delayed (Bolívar-Monsalve et al., 2019; Rashidi et al., 2017). When incorporate in food products, can improve taste, delay lipid oxidation, inhibit the growth of microorganisms and also play a role in reducing the risk of disease (Lopez et al., 2017; Li et al., 2014).

Lima et al. (2021) observed that the poly lactic acid (PLA) film with essential oils of cloves, orange and cinnamon showed an improvement in performance regarding its thermal property and antimicrobial activity. The PLA with clove essential oil film stood out for having an intense bactericidal action without degradation of film. Another work carried out with the objective of examining the effects of the polylactic acid film (PLA) containing ethanol extract of propolis, cellulose nanoparticle and essential oil of *Ziziphora clinopodioides* of ground beef during storage in a refrigerator extended the shelf life of minced beef during storage, without any unfavorable organoleptic properties (Shavisi et al., 2017). However, Giménez et al. (2013), observed that despite agar allows the release of antioxidant and antimicrobial compounds; the inclusion of the green tea extract decreased tensile strength and elongation, and increased water solubility.

Jaramillo et al. (2017) reported that the degree of antioxidant power is generally proportional to the amount of the added extract, making the film more active. The incorporation of natural extracts to the films can also be an alternative to improve the mechanical properties, resulting in an intelligent edible film with antioxidant activity (Tougnuanchan et al., 2012).

However, we highlight that, although publications using bioactive films in meat products were listed, the present review did not address the physical-chemical and sensory properties of the products after the application of the films, which influence the increase in shelf life. In addition, further studies on the probable toxicity of the active ingredients added in the films would be appropriate. More research must be carried out for these films to be applied to food products on an industrial scale.

4. Conclusion

The search for biodegradable products, which do not have a negative impact on nature, led to the development of edible films produced from natural compounds. They can be activated with the incorporation of natural extracts, with antioxidant and antimicrobial properties. These active films have been studied in the application of meat products.

The most used biopolymers are polysaccharides (starch, chitosan, agar, alginate, pectin) and proteins (gelatin, milk proteins, soy). The films formed with these compounds have better transparency and resistance properties. Polysaccharide films also exhibit good strength. Edible films with good mechanical properties are excellent substitutes for conventional packaging.

The incorporation of natural compounds, mainly with the capacity to reduce microbial growth and lipid oxidation of the product, originates the active films. Various natural extracts and essential oils have been studied, and have in common phenolic compounds. Different active films, added of extracts and/or essential oils such as cloves, ginger, bilberry, green tea, were used in beef, fish, chicken and sausages with promising results. The active films used in these studies demonstrated antimicrobial and antioxidant activity, increasing the shelf life of the products.

Research should still be developed in order to establish the best active film option for each type of product. However, we can establish that the replacement on a commercial scale of non-biodegradable packaging with active films is promising, and will have a positive impact on food quality, economy and environment.

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