UNIVERSIDADE FEDERAL DA GRANDE DOURADOS - UFGD
FACULDADE DE ENGENHARIA - FAEN
CURSO DE ENGENHARIA DE ALIMENTOS

BARBARA MATIAS MOREIRA DOS SANTOS

RECENT ADVANCES IN EDIBLE FILMS AND COATINGS TO FOOD: A REVIEW

Dourados, MS
2019

UNIVERSIDADE FEDERAL DA GRANDE DOURADOS - UFGD
FACULDADE DE ENGENHARIA - FAEN
CURSO DE ENGENHARIA DE ALIMENTOS

BARBARA MATIAS MOREIRA DOS SANTOS

RECENT ADVANCES IN EDIBLE FILMS AND COATINGS TO FOOD: A REVIEW

Trabalho de Conclusão de Curso apresentado a Universidade Federal da Grande Dourados para obtenção do título de bacharelado em Engenharia de Alimentos.

Orientador: Prof. Dr. William Renzo Cortez-Vega.

Dourados, MS
2019

SUMMARY

Acknowledgement **3**

Abstract **4**

1. Introduction **5**

2. General characteristics of edible films **6**

3. Polysaccharides **9**

3.1 Starch *9*

3.2 Chitosan *11*

3.3 Xanthan Gum *13*

3.4 Fibers *14*

4. Proteins **14**

4.1 Fish Protein *15*

4.2 Collagen and Gelatin *18*

5. Lipids **19**

6. Plasticizers **21**

7. Other materials **22**

7.1 Polyhydroxyalkanoate (PHA) *23*

7.2 Polylactide (PLA) *23*

8. Additives **23**

8.1 Essential oils *23*

8.2 Antioxidants *24*

9. Final considerations **25**

10. References **26**

Acknowledgement

Primeiramente a minha mãe, Karen, por me apoiar em todas as decisões que tomei, principalmente a de vir estudar em Dourados e pelas oportunidades que sempre me proporcionou;

A cada um dos meus familiares, principalmente minhas irmãs, Sofia e Catarina, pai, padrasto, meus avós, tios e tias por estarem comigo sempre que precisei;

Ao meu amor, Mateus, pela paciência e pelo apoio em todos os momentos, por tudo o que passamos juntos e ainda iremos passar e por sempre me lembrar que o amor é a chave de tudo;

As amizades que fiz durante a graduação, pois sem o apoio de cada uma delas eu não teria tido uma graduação tão maravilhosa, divertida, especial e memorável;

Aos meus sogros e cunhada, pelo apoio e por sempre estarem presentes;

A todos os professores da graduação, que foram de grande importância para a minha base e para que eu chegasse até aqui;

Ao melhor orientador que pude escolher, William Renzo, e a sua esposa Sandriane Pizato, que muito me auxiliaram na execução deste trabalho e de muitos outros;

E por último, mas não menos importante, ao Universo, por permitir que cada coisa acontecesse da maneira que aconteceu e no momento que aconteceu.

Com muito amor e carinho, muito obrigada!

Abstract

Edible films and coatings can be produced from edible polymers and food additives. As covering materials, they should have packaging properties that protect the food product, and as 'edible', they need to be considered Generally Recognized As Safe (GRAS). Nowadays the world's plastic production generates a lot of plastic waste. The continuous growth in plastic use has brought an increasing environmental awareness from the perspective of waste management, emissions released during manufacture, and resources use. Therefore, the need of reducing conventional nonbiodegradable plastic materials has encouraged the development of innovative biodegradable materials from renewable resources. The biobased polymer film can be developed using naturally occurring sources like polysaccharides, proteins, lipids, and their combinations. Also, there are additives that could be used as well to improve the package characteristics, such as essential oils, antioxidants. The aim of this review seeks to contribute and present the recently advances in edible films and coatings to food, which when applicated in food products, they can enhance food characteristics and extend their shelf-life.

Keywords: biodegradable, polymer, food.

1 Introduction

Edible films and coatings can be produced from edible polymers and food additives. They consist of a thin layer of edible material that coats the food directly, or a film which can wrap food without changing its original ingredients or processing method. (Wihodo *and Moraru, 2013*; Azeredo and Waldron, 2016; Zink *et al.*, 2016). Films and coatings have been used to increase mechanical, barrier, sensorial and antimicrobial properties, helping to prolong the shelf life of many products (Krochta, 2002).

Edible coatings are being used in minimally processed food as a strategy to reduce the effects the minimally process causes in vegetable tissues (Chevalier, R. *et al.*, 2018). Besides, edible coatings can contribute to the increase the life of minimally processed fruits, reducing its moisture and solute migration, respiration and oxidation reactions (Rojas-Grau *et al.*, 2009).

Edible coatings can also be applied in the liquid form of the film-forming dispersion, or as thin sheets (films) used to wrap food products. Both are well considered for food preservation purposes due to their ability to improve food quality (Chillo *et al.*, 2008).

In food industry packages are important to products conservation. However packaging attends consumers' expectations protecting food, they still need improvement in their structure, especially when talking about environmental and economic viability, and practicalness (Soares *et al.*, 2009). Plastics are highly versatile materials with excellent physical and chemical properties, aesthetic quality manufactured at low cost, and have numerous applications including food packaging, consumer products, medical devices and construction. Today, the world's plastic production is more than 320 million tons per year, of which more than 40% is used as disposable packaging material to generate plastic waste (Roy and Rhim, 2019). Due to the non-biodegradable and non-renewable nature of petroleum-based plastics, waste plastics cause serious environmental pollution problems and are paying considerable attention to the development of biodegradable, eco-friendly packaging materials that use renewable resources such as biopolymers instead of plastics (Corrales, Fernández and Han, 2014).

The continuous growth in plastic use has brought an increasing environmental awareness from the perspective of waste management, emissions released during manufacture, and resources use (Rasheed *et al.*, 2016). Therefore, the need of reducing conventional nonbiodegradable plastic materials has encouraged the development of innovative biodegradable materials from renewable resources (Garrido *et al.*, 2019).

The biobased polymer film can be developed using naturally occurring sources like polysaccharides, proteins, lipids, and their combinations (Roy and Rhim, 2019). In this connection, various types of polysaccharides have been widely used for their excellent film formability and suitable structure and mechanical properties. Biodegradable films are made of biologic material and they can serve as packaging (Safaei and Taran, 2018).

They can contain functional properties, such as antimicrobial substances. (Tanada-Palmu *et al.*, 2005.) The biodegradable characteristic is one of their greatest benefits. There are even applications for nonfood products including films for agricultural uses, grocery bags, paper coatings, or cushioning foams. Many functions of biodegradable packaging are similar to synthetic packaging materials and for that, it's possible to say they could, at least partially, replace them, which would help to reduce the environmental impact of the massive use of synthetic plastics (Chiralt *et al.*, 2018).

Nowadays there is more interest in improving quality in packaged products, and at the same time, reducing the waste of packaging has encouraged studies of new materials for biodegradable films, made of natural resources. (Souza, Silva and Druzian, 2012). Among biodegradable materials for films and coatings production the most used are polysaccharides, such as starch, and proteins. There are additives that could be used as well to improve the package characteristics, such as essential oils, antioxidants.

2 General characteristics of edible films

As films and coatings cover materials, they should have packaging properties that protect the inner part from the outside, limiting gas and water vapor transportation between the food product and the environment (Erkmen, and Barazi, 2018). And because of the 'edible' term, films can be consumed together with foods they are in contact with, so they need to be considered Generally Recognized As Safe (GRAS) (Erkmen and Bozoglu, 2016).

Besides that, there are other important characteristics edible films and coatings should have, which are (Pavlath and Orts, 2009):

- Not contain any toxic, allergic or non-digestible components;
- Provide structural stability to prevent mechanical damage during transportation, handling, and display;
- Have good adhesion to surface of food to protect and to provide uniform coverage;
- Have a control water migration both in and out to protect food and maintain the desired moisture content;
- Provide semi-permeability to maintain internal equilibrium of gases involved in aerobic and anaerobic respiration, thus retarding senescence;
- Prevent loss or degradation of components that stabilize aroma, flavor, nutritional and organoleptic characteristics, which are necessary for consumer acceptance;
- Provide biochemical and microbial surface stability while protecting against contamination;
- Maintain or enhance aesthetics and sensory attributes (appearance, taste etc.) of product;
- Be able to serve as carrier for desirable additives such as flavor, fragrance, coloring, nutrients, vitamins, antioxidants and antimicrobial agents, and
- Be easily manufactured and economically viable.

3 Polysaccharides

Polysaccharide film-forming materials include starch, non-starch carbohydrates, gums, and fibers.

3.1 Starch

Starch is the main carbohydrate which is stored as a food material in plants. It contains two types of glycose units, amylose and amylopectin. Both have α(1→4) linkage between the polymers in short or long chains. Amylose has a linear chain, while amylopectin can have branches due to α(1→6) linkage (Preiss, 2018).

The formation of starch films starts with the heating of starch granules in excess water to prepare a viscous solution. Aqueous solutions are normally unstable and tend to gel immediately upon cooling due to the association of polymer chains (glycose units) (Wang *et al.*, 2015). At high temperature and in excess water, starch granules gelatinize, transforming from a semicrystalline phase into an amorphous state (Ratnayake and Jackson, 2008). The loss of crystallinity happens in two steps, the first when the starch molecule swells, normally at 60-70˚C (Shanks and Kong, 2012). The second step is observed at temperatures above 90˚C and results in excessive granule swelling and solubilization, which leads to a complete loss of structural integrity (Ivanič, 2017).

Starch is known for being biocompatible, biodegradable, nontoxic and for having low cost (Qiao, C., 2016; Mahmoudian *et al.*, 2012). This material is relatively easy to handle. Besides being totally biodegradable, is also widely available in nature from sources such as cereals, roots, tubers and palms (Araujo-Farro *et al.*, 2010; Colla *et al.*, 2006).

Several authors studied the development of starch films from different sources. Matta Junior (2009) found good barrier results in its work in the development of green peas starch films, and so did Araujo-Farro *et al.* (2010) in quinoa starch films. Other authors studied films physical properties of different native starches, such as extraction of potato, cassava and rice starch, added with plasticizers (glycerol and sorbitol) and Montmorillonite clay (Borges *et al.*, 2015), and found out that rice starch films had higher elongation values and low water solubility, when compared to potato and cassava starch films, which shows potential for coating food products.

Fitch-Vargas *et al.* (2016) studied the extrusion technology as a pretreatment of the casting technique to modify starch structure in order to obtain edible films with improved physicochemical properties, using corn starch. They observed that when combining extrusion and casting technique corn starch edible films showed greater breaking strength and deformation, as well as lower water vapor permeability, which says that these films could be applied on food products to improve their preservation, distribution and marketing.

Starch is recently receiving more attention as a material to be used as packaging. Baranzelli *et al.* (2019) studied the comparison of laboratoryinduced wheat grain germination and pre-harvest sprouting in the field and their effects on starch characteristics and application in films. They found that elongation of starch films increased significantly with wheat germination time, but the germination process did not significantly affect the opacity, water solubility, and water vapor permeability of films. With that, it is possible to consider the use of starch from germinated wheat grains in films, adding value to a commonly discarded product due to its inability to be used in baking.

3.2 Chitosan

Chitosan is a natural non-toxic polymer, biodegradable and economic available, which are reasons for its use in a variety of applications in food industry, counting on the quality control as a substitute for non-biodegradable polymers. Chitosan can form transparent films; it becomes versatile and can fit in any packaging application. (Elsabee *et al.* 2013).

Chitosan is a substance that has been used in antimicrobial films due to its bactericide and fungicide characteristics (Soares *et al.* 2007). Combining antimicrobial agents such as plant essential oils directly into a food packaging is a form of active packaging. Because of that, Ojagh *et al.* (2010) studied chitosan-based films containing cinnamon essential oil (CEO). With the incorporating of the CEO into the films it was possible to observe an increased antimicrobial activity, and also a decreasing in moisture content, solubility in water, water vapor permeability and elongation at break of chitosan films.

Campana-Filho *et al.* (2000) says that chitosan has been considered as a compound of industrial interests, because of its nontoxic characteristics and gel formation, but according to Fitzpatrick *et al.* (2013); Veiga-Santos *et al.* (2005) although chitosan's potential in biodegradable packaging, it shows low values of elongation and high values of solubility and water vapor permeability. An alternative to improve its characteristics would be combining chitosan with other polymers, such as xanthan gum. De Morais Lima *et al.* (2017[a]) studied properties of chitosan films added to different concentrations of xanthan gum and found that the combining improved mechanical properties of the films, as high tensile strength and low elongation.

Several authors studied the use of chitosan as coatings or films added to complements. Chevalier, R. *et al.* (2016) evaluated the effects of chitosan coating associated with montmorillonite clay and essential oil of cloves in minimally processed melon (*Cucumis melo L.*), and concluded that the association of chitosan with the other components showed better results than just chitosan, in order to prolong shelf life and retard microorganism growth. De Morais Lima *et al.* (2017[b]) developed films based on chitosan added with xanthan gum, and protein hydrolysate of Whitemouth croaker (*Micropogonias furnieri*). The addition of xanthan gum increased tensile strength and changed the color parameters of films, and the addition of protein hydrolysate increased the antioxidant activity of the films. They didn't observe significant differences in water solubility and water vapor permeability by the addition of xanthan gum and protein hydrolysate.

3.3 Xanthan Gum

Xanthan gum is a polymer produced by the aerobic fermentation of *Xanthomonas campestris*. According to the literature, this polymer can be applied in several industrial sectors, such as food, cosmetics, pharmaceutics. Another characteristic of the xanthan gum that could be considered an advantage is its stability in a wide range of temperature and pH (Garcia-Ochoa *et al.*, 2000).

Xanthan gum is considered safe, biodegradable and effective in forming a cohesive and continuous matrix with uniform physical and chemical properties. (Fitzpatrick *et al.*, 2013; Garcia-Ochoa *et al.*, 2000). Besides, xanthan gum improves mechanical and sensory properties of films (Veiga-Santos *et al.*, 2005)

Freitas *et al.* (2013) applied xanthan gum coating in fresh-cut apple added to calcium chloride, ascorbic and citric acid, in order to carry these preservative agents, to extend the shelf life of the apples. They noted that xanthan gum was effective in carrying agents in order to avoid browning and lower microorganism growth.

Cortez-Vega *et al.* (2013[a]) studied the conservation of minimally processed papaya with xanthan gum-based coatings applied in it, in different treatments, added to guar gum and chitosan. The coating with 100% xanthan gum showed one of the best results in reduction of mass loss, comparing to the others. And also maintained the color more efficiently than the other treatments.

3.4 Fibers

Natural fibers are subdivided based on their origins, coming from plants, animals or minerals. Generally, plant or vegetable fibers are used to reinforce plastics (Bledzki, 1999).

Composites in forms of fibers have been widely used in plastic industries to reach desirable properties or to reduce prices. When compared to inorganic composites, the organics have some advantages, such as being originated from renewable natural sources, have great availability, low energy consume, low cost, low density and reactive surface, which could be used to introduce specific groups (Wolf, 2007).

El Halal *et al.* (2017) developed and evaluated films produced from potato and cassava starches, reinforced with cellulose fibers and/or nanoclay. They found that the addition of reinforcement agents in potato starch films produced more resistant films. These components increased the tensile strength of the cassava starch films and decreased water vapor permeability.

4 Proteins

Proteins are commonly used as film-forming materials. They are macromolecules with specific amino acid sequences and molecular structures. They are different from others film-forming materials because of their conformational denaturation, electrostatic charges, and amphiphilic nature. The structure of proteins can be easily modified in order to achieve the desirable film properties using temperature, mechanical and chemical processes, and crosslinking as well. These treatments can control the physical and mechanical properties of films and coatings. Protein film-forming materials are derived from many different animal and plant sources, including animal tissues, milks, eggs, grains, and oilseeds (Krochta, 2002).

4.1 Fish Protein

The waste of fish industrialization normally is used to process flour, or it is just discarded. An alternative to use this waste is recovering its main components, among them the proteins (Oetterer *et al.*, 2006). The development of fish protein films can add value to a material that would be discarded, contributing to the reduction of environment impacts and offering a viable and low-cost alternative.

Fish-protein based films form a chain that presents good mechanical properties, like plasticity and elasticity, and good oxygen barrier. Although it absorbs a lot of water due to the hygroscopicity of the protein amino acids. This characteristic can be changed by adding plasticizers and/or additives (Paiva *et al.*, 2006; Zavareze *et al.*, 2012).

Researchers have been studying the use of fish protein isolate to develop films and coatings, and their application in different food products.

Cortez-Vega *et al.*, (2013[b]) studied nanocomposite films produced from Whitemouth croaker (*Micropogonias furnieri*) protein isolate with montmorillonite, and noted they were promising from the standpoint of their mechanical properties, visual appearance and easy handling, as well as for their low water vapor permeability and low water solubility. William *et al.* (2015) also evaluated films from Whitemouth croaker protein isolate (CPI) modified with montmorillonite (MMT) and had similar results about the decrease in the solubility, transparency and water vapor permeability (WVP).

In other works, authors used croaker coating applied in fresh-cut papaya (*Carica papaya L.*) (Cortez-Vega *et al.*, 2014) and fresh-cut pear (*Pyrus communis L.*) (Pizato *et al.*, 2015). In both works they did three different treatments, T1 for control, T2 with croaker coating and T3 with croaker coating added to montmorillonite. For both works the result was close. Both treatments with the croaker coating showed low mass loss, low microbiological growth, small decrease of firmness, lightness and pH. However, the treatment with montmorillonite added showed the best results for coating.

In a study of physical, mechanical and antimicrobial properties of protein films from Argentine anchovy (*Engraulis anchoita*) incorporated with organic acids (sorbic or benzoic acids), Rocha *et al.* (2014) found that the increase in concentrations of the acids resulted in greater thickness, color difference, opacity and elongation at break, but decreased tensile strength of the films. They also observed that the more percentage of organic acids, higher the values of water vapor permeability. The films were effective against the microorganism tested, except for *S. Aureus*, that showed no inhibition in any of the organic acid concentrations tested.

Romani *et al.* (2018) investigated different times of cold plasma application as a surface modification strategy for films prepared from fish myofibrillar proteins. The different treatments of application showed changes in the mechanical performance, water vapor permeability, solubility in water and color properties. Films treated for 2 minutes showed increased elongation at break and decreased tensile strength, while the opposite behavior was observed after 5 minutes of treatment. Solubility in water increased with 5 minutes and water vapor permeability increased with 2 minutes of plasma treatment. Color and opacity also increased. According to some authors (Chu, 2002; Geyter and Morent, 2012; Mahmoud, 2016) plasma is a partly ionized mixture of ions, radicals, free electrons and neutral species in the gaseous state. When these particles get excited and ionized, they carry enough energy to induce chemical reactions at the interface with solid surfaces. Pankaj *et al.* (2014) say that cold plasma could promote adhesion or anti-adhesion properties in polymers, to improve printability and sealability and to increase the resistance of materials to mechanical failure.

Also, Romani *et al.* (2019) studied the effects of operating parameters (pressure, power and time) of alternating current (AC) glow discharge plasma to decrease sensitivity of fish protein films to water. They evaluated physicochemical properties of the films and observed a decrease in water vapor permeability and solubility in some treatments, and concluded that, according to the specificity of the application intended, setting could be changed through the adjustment of parameters of exposure.

4.2 Collagen and Gelatin

The use of collagen is increasing in food, cosmetic, pharmaceutical, tissue engineering and biomedical industries day by day because of its excellent biodegradability and biocompatibility (Gómez-Guillén *et al.*, 2011). Collagen can also form insoluble fibers with high tensile strength and stability (Gelse, 2003).

Collagen can be originated from fish skin, bones, fin and scales, and is used as gelling, stabilizing, foaming and emulsifying agent in food. Properties such as insolubility, biodegradability and fibril forming capacity allow its use in active food packaging material (Bhuimbar *et al.*, 2019).

Gelatin is a soluble protein compound obtained by partial hydrolysis of collagen. The source, age of the animal, and type of collagen are factors that influence the properties of the gelatins (Johnston-Banks, 1990).

Gelatin films have poor water-vapor barrier and water resistance due to its hydrophilic nature. This could be a disadvantage in gelatin-based films used as food packaging, especially for moist foods (Bhat and Karim, 2014; Etxabide, Uranga, Guerrero and de la Caba, 2017).

Researchers studied collagen films combined with other components, like chitosan (Bhuimbar *et al.*, 2019), essential oil and montmorillonite

(Nakashima *et al.*, 2016) to investigate their influence in the mechanical properties of the films.

Nakashima *et al.* (2016) studied collagen films added to montmorillonite and essential oil of clove. The films obtained had good mechanical properties, adequate visual appearance, easy handling, low permeability to water vapor and low water solubility.

Other author extracted acid soluble collagen from skin of black ruff, which showed emulsifying activity and emulsion stability (Bhuimbar *et al.*, 2019). The collagen was used to produce collagen-chitosan films, added to different concentrations of pomegranate peel extract (PPE). It was observed that all films prepared had good mechanical strength. Although chitosan has antibacterial properties, collagen-chitosan blend (control) didn't reveal antimicrobial activity due to its low concentration, but the addition of PPE showed some inhibition in pathogens growth.

5 Lipids

Lipids can be divided according to their structure: natural waxes and resins, acetoglycerides, fatty acids, and different types of vegetable oils (Galus and Kadzińska, 2015).

Differently from polysaccharides and proteins, lipids are not biopolymers and do not have the ability to form independent films. Therefore, they can be either used as coatings or incorporated into other biopolymers to make composite films. Waxes, for example, are esters of long-chain aliphatic acids with long-chain aliphatic alcohols. Because of their very low content of polar groups and high content of long-chain fatty alcohols and alkanes, they are more resistant to water migration than most other edible film substances (Cordeiro de Azeredo, 2012).

Yilmaz and Dagdemir (2012) used beewax to evaluate the effects of its application as coating on microbiological, physicochemical and sensory properties of Kashar cheese during ripening. The cheese was coated in single and double-layer and was compared to a non-coated sample and a vacuum packaged sample. The results obtained indicated that the coating with beeswax did not affect microbial growth, although thickness of both beeswax has significantly reduced mold growth and extended the shelf-life when compared to control. Also, the coating retarded moisture loss and better maintained the texture of the cheeses.

Chevalier, E. *et al.* (2018) studied the extrusion of casein and waxes in order to produce edible films as carrier of potassium sorbate (KS). They used different kinds of waxes (beeswax, carnauba and candelilla waxes) and different quantities of KS so they can study the antimicrobial activity against *E. coli*, and mechanical and barrier properties. The comparative study showed that several properties are highly depending on wax origin and concentration. Among the waxes studied, only beeswax was efficient to reduce water vapor permeability. The incorporation of waxes improved KS efficiency at low concentration, and this could help the industry on reducing preservative amount in food or food packaging.

Other authors used fatty acids on their research. Theerawitayaart *et al.* (2018) studied the properties of films from fish gelatin prepared by molecular modification and direct addition of oxidized linoleic acid (OLA), because films from molecularly modified gelatin with hydrophobic substances, such as fatty acids, might not only increase hydrophobicity but also enhance stability. The research showed that molecularly modified gelatin could improve water-vapor barrier of gelatin film more effectively than the one with direct addition of OLA at low levels, and besides, direct addition of OLA had major limitation due to rancid smell in the films, while the molecularly modified gelatin yielded the film with similar appearance to the control gelatin film.

6 Plasticizers

Plasticizers are an important class of compound that have low molecular weight, are non-volatile and that are widely used in polymer industries as additives (Sejidov, Mansoori and Goodarzi, 2005).

In most cases, plasticizers are required ingredients for edible films and coatings, especially for polysaccharides and proteins. These film structures can be often fragile and hard due to extensive interactions between the polymer molecules (Krochta, 2002).

The role of plasticizers consists in the elimination of hydrogen bonds and the increase of free volume, leading to higher mobility of the starch chains and a decrease of the glass transition temperature (Laohakunjit and Noomhorm, 2004; Pushpadass, 2008). Plasticizers could increase the flexibility of protein films by loosening the protein network. Also, could affect the water vapor permeability (WVP), because the higher the plasticizer quantity, the higher the WVP (Lieberman and Gilbert, 2007; Tanaka *et al.*, 2001).

Some authors studied how the properties of films would be affected by plasticizers. Adjouman *et al.* (2017) analyzed the effect of glycerol, peanut oil and soybean lecithin on the water vapor permeability (WVP) of edible films based on improved cassava (*Manihot esculenta Crantz*) native starches. They noticed that WVP, moisture content and thickness of the films increased with higher concentrations of glycerol. But when combining glycerol and peanut oil, WVP of the films increased, while the addition of soybean lecithin had no effect.

Polyols, such as glycerol and sorbitol, have been studied for their efficiency in plasticizing hydrophilic polymers (Ghasemlou, Khodaiyan, and Oromiehie, 2011; Tihminlioglu, Atik, and Özen, 2010). There are also plasticizers from monosaccharides such as glucose, mannose, fructose, and sucrose (Piermaria *et al.*, 2011; Qiao, X.Tang and Sun, 2011).

7 Other materials

Among the bioplastics produced from renewable sources, are noted for its properties polyhydroxyalkanoates (PHA) and polylactides (PLA). PHA are natural thermoplastics that occur in a wide range of bacteria, while PLA are obtained by the polymerization of lactic acid from fermentation (Lopes, 2010).

7.1 Polyhydroxyalkanoate (PHA)

Polyhydroxyalkanoates (PHA) are the polyesters produced by microorganisms from carbon substrates (Oyama, 2009; Bordes *et al.*, 2009). Its properties and degradability offer potential for non-biodegradable polymers substitution, such as polyethylene and polypropylene (Chen, 2005).

7.2 Polylactide (PLA)

Polylactide (PLA) presents mechanical properties compared to the polymers from fossil sources, specially elasticity, toughness, transparency, thermoplastic behavior, biocompatibility and good moldability. (Liu *et al.*, 2011; Zhang *et al.*, 2005; Lim *et al.*, 2008). PLA is also similar in many ways to polyethylene terephthalate (Oyama, 2009).

8 Additives

Antioxidants and essential oils (antimicrobial agents) can also be incorporated into film-forming solutions to achieve active packaging or coating functions (Han, 2002; Han, 2003).

8.1 Essential oils

Essential oils active ingredients can diffuse from the film into the coated food to control target microorganisms (Valencia-Sullca, Vargas, Atarés and Chiralt, 2018). Due to their lipidic nature, they can help reduce the water vapor permeability of hydrophilic films (Atarés and Chiralt, 2016).

According to Seydim and Sarikus (2006) the directly addition of essential oils in food can reduce microbial population in it, but it could change its sensorial characteristics. Then, the addition of essential oils in films and coatings could be more of interest in the conservation of food. They studied the antimicrobial activity of oregano, rosemary and garlic essential oils in whey protein films.

Other authors studied the effects of other essential oils, like Singh *et al.* (2018). They studied the antimicrobial effects of cinnamaldehyde, lemongrass oil, clove oil, peppermint oil in starch films, and found that the optimum level of incorporation of essential oils is 0.5% in starch edible films. The addition increased thickness of films and decreased the moisture content and percent solubility in water. The lemon grass and clove essential oil showed best results in microorganism inhibition.

8.2 Antioxidants

Antioxidants in films have the function of protecting food products from the oxidative degradation, avoiding reactions of oxidation by reacting to free radicals and peroxides, extending the products' shelf life (Pereira, 2017).

In the context of active and intelligent packaging, the incorporation of antioxidants or antimicrobials to packaging materials shows utility to extend the shelf-life and improve food safety or sensory properties (Valdés, Mellinas, Ramos, Garrigós and Jiménez, 2014).

Han *et al.* (2008) studied the addition of antioxidants (α-Tocopherol and ascorbyl palmitate) in whey protein films applied in peanuts, in order to retard the oxidation of fatty acids presents on peanuts. The coated peanuts oxidized slower than uncoated peanuts, which means that the whey protein coating was a good oxygen barrier and reduced the oxygen penetration rate resulting in the retardation of oxidation of peanuts. However, the author observed no significant difference of oxidation retardation between the coated peanuts with and without antioxidants.

Also, Menzel *et al.* (2019) studied the extraction of antioxidants from sunflower hulls, which are an abundant by-product from food industry, and applied them in starch films. It was observed that 1-2% of extracts were enough to produce starch films with high antioxidant capacity. Higher amounts (4-6%) of extract showed the highest antioxidant activity, and also showed the lowest oxygen permeability, high stiffness and poor extensibility.

9 Final considerations

Biodegradable materials, such as polysaccharides and proteins are promising in the development of edible films and coatings, especially when incorporated to fibers, lipids, plasticizers, antimicrobials, antioxidants and other components that could improve their characteristics and properties. While applicated in food products, they can enhance food characteristics and extend their shelf-life. Besides biodegradable materials, techniques such as extrusion and molecular modification seem promising as well in the production of edible films.

10 References

Adjouman, Y. D., Nindjin, C., Tetchi, F. A., Dalcq, A. C., Amani, N. G. and Sindic, M. 2017. Water Vapor Permeability of Edible Films Based on Improved Cassava (*Manihot esculenta Crantz*) Native Starches. Journal of Food Processing and Technology 8: 665. DOI:10.4172/2157-7110.1000665

Araujo-Farro, P. C., Podadera, G., Sobral, P. J. A. and Menegalli, F. C. 2010. Development of films based on quinoa *(Chenopodium quinoa,* Willdenow) starch. Carbohydrate Polymers, 81(4), 839–848. DOI:10.1016/j.carbpol.2010.03.051

Atarés, L. and Chiralt, A. 2016. Essential oils as additives in biodegradable films and coatings for active food packaging. Trends in Food Science & Technology, 48, 51–62. DOI:10.1016/j.tifs.2015.12.001

Azeredo, H. M. C. and Waldron, K. W. 2016. Crosslinking in polysaccharide and protein films and coatings for food contact – A review. Trends in Food Science and Technology, 52, 109–122. DOI:10.1016/j.tifs.2016.04.008

Baranzelli, J., Kringel, D. H., Mallmann, J. F., Bock, E., El Halal, S. L. M., Prietto, L., Zavareze, E. R., Miranda, M. Z. and Dias, A. R. G. 2019. Impact of wheat (*Triticum aestivum L.*) germination process on starch properties for application in films. Starch - Stärke, 1800262. DOI:10.1002/star.201800262

Bhat, R. and Karim, A. A. 2014. Toward producing novel fish gelatin films by combination treatments of ultraviolet radiation and sugars (ribose and lactose) as cross-linking agents. Journal of Food Science and Technology, 51, 1326-1333.

Bhuimbar, M. V., Bhagwat, P. K. and Dandge, P. B. 2019. Extraction and characterization of acid soluble collagen from fish waste: Development of collagen-chitosan blend as food packaging film. Journal of Environmental Chemical Engineering, 102983. DOI: 10.1016/j.jece.2019.102983

Bledzki, A. 1999. Composites reinforced with cellulose based fibers. Progress in Polymer Science, 24(2), 221–274. DOI: 10.1016/s0079-6700(98)00018-5

Bordes, P., Pollet, E. and Avérous, L. 2009. Nano-biocomposites: Biodegradable polyester/nanoclay systems. Progress in Polymer Science. V. 34, n. 2.

Borges, J. A., Romani, V. P., Cortez-Vega, W. R. and Martins, V. G. 2015. Influence of different starch sources and plasticizers on properties of biodegradable films. International Food Research Journal, 22(6).

Campana-Filho, S.P., Desbrières, J. 2000. Chitin, chitosan and derivatives. In Natural polymers and agrofibers composites. São Carlos: Embrapa Instrumentação Agropecuária, p.41-71.

Chen, G. Q. 2005. Polyhydroxyalkanoates. Biodegradable Polymers for Industrial Applications, p32–56. DOI: 10.1533/9781845690762.1.32.

Chevalier, E., Chaabani, A., Assezat, G., Prochazka, F. and Oulahal, N. 2018. Casein/wax blend extrusion for production of edible films as carriers of potassium sorbate—A comparative study of waxes and potassium sorbate effect. Food Packaging and Shelf Life, 16, 41–50. DOI:10.1016/j.fpsl.2018.01.005

Chevalier, R., da Silva, G., da Silva, D., Pizato, S. and Cortez-Vega, W. 2016. Utilização de revestimento comestível a base de quitosana para aumentar a vida útil de melão minimamente processado. Journal Of Bioenergy And Food Science, 3(3) 131-139. DOI:10.18067/jbfs.v3i3.101

Chevalier, R. C., Pizato, S., De Lara, J. A. F. and Cortez-Vega, W. R. 2018. Obtaining protein isolate of tilapia (*Oreochromis niloticus*) and its application as coating in fresh-cut melons. Journal of Food Safety, v. 38, e12496.

Chillo, S., Flores, S., Mastromatteo, M., Conte, A., Gerschenson, L. and del Nobile, M.A. 2008. Influence of glycerol and chitosan on tapioca starch-based edible film properties. Journal of Food Engineering. 88, 159–168.

Chiralt, A., González-Martínez, C., Vargas, M. and Atarés, L. 2018. Edible films and coatings from proteins. Proteins in Food Processing, 477–500. DOI:10.1016/b978-0-08-100722-8.00019-x

Chu, P. K., Chen, J. Y., Wang, L. P. and Huang, N. 2002. Plasma-surface modification of biomaterials. Materials Science and Engineering: R: Reports, 36, 143–206.

Colla, E., Sobral, P. J. A. and Menegalli, F. C. 2006. *Amaranthus cruentus* flour edible films: Influence of stearic acid addition, plasticizer concentration, and emulsion stirring speed on water vapor permeability and mechanical properties. Journal of Agricultural and Food Chemistry, 54, 6645–6653.

Cordeiro de Azeredo, H. M. 2012. Edible coatings. In Rodrigues, S. and Fernandes, F. A. N. (Eds). Advances in fruit processing technologies (pp. 345-361). Boca Raton: CRC Press Inc

Corrales, M., Fernández, A. and Han, J. H. 2014. Antimicrobial Packaging Systems. Innovations in Food Packaging, 133–170. DOI:10.1016/b978-0-12-394601-0.00007-2

Cortez-Vega, W. R., Piotrowicz, I. B. B., Prentice, C. and Borges, C. D. 2013[a]. Conservação de mamão minimamente processado com uso de revestimento comestível à base de goma xantana. Semina: Ciências Agrárias, 34(4). DOI:10.5433/1679-0359.2013v34n4p1753

Cortez-Vega, W. R., Bagatini, D. C., Souza, J. T. A. and Prentice, C. 2013[b]. Biofilmes nanocompósitos obtidos de isolado proteico de corvina (*Micropogonias furnieri*) e Montmorilonita: avaliação das propriedades físicas, mecânicas e de barreira. Brazilian Journal of Food Technology, 16(2), 90–98. DOI:10.1590/s1981-67232013005000011

Cortez-Vega, W. R., Pizato, S., de Souza, J. T. A. and Prentice, C. 2014. Using edible coatings from Whitemouth croaker (*Micropogonias furnieri*) protein isolate and organo-clay nanocomposite for improve the conservation properties of fresh-cut “Formosa” papaya. Innovative Food Science and Emerging Technologies, 22, 197–202. DOI:10.1016/j.ifset.2013.12.007

De Morais Lima, M., Carneiro, L. C., Bianchini, D., Dias, A. R. G., Zavareze, E. da R., Prentice, C. and Moreira, A. da S. 2017[a]. Structural, Thermal, Physical, Mechanical, and Barrier Properties of Chitosan Films with the Addition of Xanthan Gum. Journal of Food Science, 82(3), 698–705. DOI:10.1111/1750-3841.13653

De Morais Lima, M., Bianchini, D., Guerra Dias, A., da Rosa Zavareze, E., Prentice, C. and da Silveira Moreira, A. 2017[b]. Biodegradable films based on chitosan, xanthan gum, and fish protein hydrolysate. Journal of Applied Polymer Science, 134(23). DOI:10.1002/app.44899

El Halal, S. L. M., Bruni, G. P., do Evangelho, J. A., Biduski, B., Silva, F. T., Dias, A. R. G., … de Mello Luvielmo, M. 2017. The properties of potato and cassava starch films combined with cellulose fibers and/or nanoclay. Starch - Stärke, 70(1-2), 1700115. DOI:10.1002/star.201700115

Elsabee, M. Z. and Abdou, E. S. 2013. Chitosan based edible films and coatings: A review. Materials Science and Engineering: C, 33(4), 1819–1841. DOI:10.1016/j.msec.2013.01.010

Erkmen, O. and Barazi, A. O. 2018. General Characteristics of Edible Films. Vol.2 No.1:3

Erkmen, O. and Bozoglu, T. F. 2016 Food Microbiology: Principles into Practice. John Wiley and Sons Ltd, Chichester, UK. p. 458.

Etxabide, A., Uranga, J., Guerrero, P. and de la Caba, K. 2017. Development of active gelatin films by means of valorization of food processing waste: A review. Food Hydrocolloids, 68, 192-198

Fitch-Vargas, P. R., Aguilar-Palazuelos, E., de Jesús Zazueta-Morales, J., Vega-García, M. O., Valdez-Morales, J. E., Martínez-Bustos, F. and Jacobo-Valenzuela, N. 2016. Physicochemical and Microstructural Characterization of Corn Starch Edible Films Obtained by a Combination of Extrusion Technology and Casting Technique. Journal of Food Science, 81(9), E2224–E2232. DOI:10.1111/1750-3841.13416

Fitzpatrick, P., Meadows, J., Ratcliffe, I. and Williams, P. A. 2013. Control of the properties of xanthan/glucomannan mixed gels by varying xanthan fine structure. Carbohydrate Polymers, 92, 1018-1025.

Freitas, I. R., Cortez-Vega, W. R., Pizato, S., Prentice-Hernández, C. and Borges, C. D. 2013. Xanthan Gum as a Carrier of Preservative Agents and Calcium Chloride Applied on Fresh-Cut Apple. Journal of Food Safety, 33(3), 229–238. DOI:10.1111/jfs.12044

Galus, S. and Kadzińska, J. 2015. Food applications of emulsion-based edible films and coatings. Trends in Food Science and Technology, 45(2), 273–283. DOI:10.1016/j.tifs.2015.07.011

Garcia-Ochoa, F., Santos, V. E., Casas, J. A., Gomez, E. 2000. Xanthan gum: Production, recovery, and properties. Biotechnology Advances, 18(7), 549–579. DOI:10.1016/s0734-9750(00)00050-1

Garrido, T., Penãlba, M., La Caba, K., Guerrero, P. 2019. A more efficient process to develop protein films derived from agro-industrial by-products. Food Hydrocolloids, v. 86, 11-17.

Gelse, K. 2003. Collagens—structure, function, and biosynthesis. Advanced Drug Delivery Reviews, 55(12), 1531–1546. DOI:10.1016/j.addr.2003.08.002

Geyter, N. De and Morent, R. 2012. Non-thermal plasma surface modification of biodegradable polymers. In D. N. Ghista (Ed.). Biomedical science. Engineering and Technology. InTech.

Ghasemlou, M., Khodaiyan, F. and Oromiehie, A. 2011. Physical, mechanical, barrier, and thermal properties of polyol-plasticized biodegradable edible film made from kefiran. Carbohydrate Polymers, 84(1), 477–483.

Gómez-Guillén, M. C., Giménez, B., López-Caballero, M. E. and Montero, M. P. 2011. Functional and bioactive properties of collagen and gelatin from alternative sources: A review. Food Hydrocolloids, 25(8), 1813–1827. DOI:10.1016/j.foodhyd.2011.02.007

Han, J. H., 2002. Protein-based edible films and coatings carrying antimicrobial agents. In: Gennadios, A. (Ed.), Protein-Based Films and Coatings. CRC Press, Boca Raton, FL, pp. 485-499.

Han, J. H., 2003. Antimicrobial food packaging. In: Ahvenainen, R. (Ed.), Novel Food Packaging Techniques. Woodhead Publishing, Cambridge, U.K, pp. 50-70.

Han, J. H., Hwang, H.-M., Min, S. and Krochta, J. M. 2008. Coating of Peanuts with Edible Whey Protein Film Containing α-Tocopherol and Ascorbyl Palmitate. Journal of Food Science, 73(8), E349–E355. DOI:10.1111/j.1750-3841.2008.00910.x

Ivanič, F., Jochec-Mošková, D., Janigová, I. and Chodák, I. 2017. Physical properties of starch plasticized by a mixture of plasticizers. European Polymer Journal, 93, 843–849. DOI:10.1016/j.eurpolymj.2017.04.006

Johnston-Banks, F. A. 1990. Gelatin. In P. Harris (Ed.), Food gels (pp. 233e289). London: Elsevier Applied Science Publishers.

Krochta, J.M. 2002. Proteins as raw materials for films and coatings: definitions, current status, and opportunities. In: Gennadios, A. (Ed.), Protein-Based Films and Coatings. CRC Press, New York, pp. 1–41.

Laohakunjit, N. and Noomhorm, A. 2004. Effect of Plasticizers on Mechanical and Barrier Properties of Rice Starch Film. Starch - Stärke, 56(8), 348–356. DOI:10.1002/star.200300249

Lieberman, E. R. and Gilbert, S. G. 2007. Gas permeation of collagen films as affected by cross-linkage, moisture, and plasticizer content. Journal of Polymer Science: Polymer Symposia, 41(1), 33–43. DOI:10.1002/polc.5070410106

Lim, L. T., Auras, R. and Rubino, M. 2008. Processing technologies for poly(lactic acid). Progress in Polymer Science. V.33, n.8.

Liu, H., Song, W., Chen, F., Guo, L. and Zhang, J. 2011. Interaction of microstructure and interfacial adhesion on impact performance of polylactide (PLA) ternary blends. Macromolecules. V.44, n.6.

Lopes, M. S. G. 2010. Produção de plásticos biodegradáveis utilizando hidrolisado hemicelulódico de bagaço de cana-de-açúcar. Universidade de São Paulo, São Paulo. Instituto de Ciências Biomédicas. Tese de Doutorado em Biotecnologia.

Mahmoud, K. H. 2016. Optical properties of hydroxyethyl cellulose film treated with nitrogen plasma. Spectrochimica Acta Part A: Molecular and Biomolecular Spectroscopy, 157, 153–157.

Mahmoudian, S., Wahit, M. U., Ismail, A. F. and Yussuf, A. A. 2012. Preparation of regenerated cellulose/montmorillonite nanocomposite films via ionic liquids. Carbohydrate Polymers, 88(4), 1251–1257. DOI:10.1016/j.carbpol.2012.01.088

Matta Junior, M. D. da. 2009. Caracterização de biofilmes obtidos a partir de amido de ervilha (*Pisum sativum*) associado à goma xantana e glicerol. Piracicaba: Escola Superior de Agricultura Luiz de Queiroz, Universidade de São Paulo. Dissertação de Mestrado em Ciência e Tecnologia de Alimentos.

Menzel, C., González-Martínez, C., Chiralt, A. and Vilaplana, F. 2019. Antioxidant starch films containing sunflower hull extracts. Carbohydrate Polymers. DOI:10.1016/j.carbpol.2019.03.022

Nakashima, A. Y., Chevalier, R. C. and Cortez-Vega, W. R. 2016. Development and characterization of collagen films with added essential oil of clove india/Desenvolvimento e caracterização de filmes de colágeno com adição de óleo essencial de cravo-da-índia. Journal of Bioenergy and Food Science, 3(1).

Oetterer, M., Regitano-D’Arce, M. A. B. and Spoto, M. H. F. 2006. Fundamentos de Ciência e Tecnologia de Alimentos. Barueri: Manole, 612 p.

Ojagh, S. M., Rezaei, M., Razavi, S. H. and Hosseini, S. M. H. 2010. Development and evaluation of a novel biodegradable film made from chitosan and cinnamon essential oil with low affinity toward water. Food Chemistry, v. 122, p.161-166.

Oyama, H. T. 2009. Super-tough poly(lactic acid) materials: Reactive blending with ethylene Copolymer. Polymer. V. 50, n.3.

Paiva, L. B., Guimarães, T. R., Morales, A. R. 2006. Propriedades Mecânicas de Nanocompósitos de Polipropileno (PP) e Montmorilonita Organofílica. Polímeros: Ciência e Tecnologia, vol. 16, n° 2, p. 136-140.

Pankaj, S. K., Bueno-Ferrer, C., Misra, N. N., Milosavljević, V., O'Donnell, C. P., Bourke, P., … Cullen, P. J. 2014. Applications of cold plasma technology in food packaging. Trends in Food Science and Technology, 35(1), 5–17. DOI:10.1016/j.tifs.2013.10.009

Pavlath, A. E. and Orts, W. 2009. Edible films and coatings: Why, What, and How? In: Embuscado ME, Huber KC (Eds.). Edible films and coatings for food applications. Springer, New York. pp: 1-23.

Pereira, L. C. L. 2017. Desenvolvimento de filmes ativos antioxidantes de PVA incorporado com extrato do farelo da amêndoa de cacau. Universidade estadual do sudoeste da Bahia. Tese de Doutorado.

Piermaria, J., Bosch, A., Pinotti, A., Yantorno, O., Garcia, M. A. and Abraham, A. G. 2011. Kefiran films plasticized with sugars and polyols: Water vapor barrier and mechanical properties in relation to their microstructure analyzed by ATR/FT-IR spectroscopy. Food Hydrocolloids, 25(5), 1261–1269

Pizato, S., Borges, J. A., Martins, V. G., Prentice, C.; Cortez-Vega, W. R. 2015. Whitemouth croaker (*Micropogonias furnieri*) protein isolate and organoclay nanocomposite coatings on shelf life and quality of fresh-cut pear. International Food Research Journal, v.22: p.163-170.

Preiss, J. 2018. Plant Starch Synthesis. Starch in Food, 3–95. DOI:10.1016/b978-0-08-100868-3.00001-9

Pushpadass, H. A., Marx, D. B. and Hanna, M. A. 2008. Effects of Extrusion Temperature and Plasticizers on the Physical and Functional Properties of Starch Films. Starch - Stärke, 60(10), 527–538. DOI:10.1002/star.200800713

Qiao, C., Chen, G., Zhang, J. and Yao, J. 2016. Structure and rheological properties of cellulose nanocrystals suspension. Food Hydrocolloids, 55, 19–25. DOI:10.1016/j.foodhyd.2015.11.005

Qiao, X., Tang, Z. and Sun, K. 2011. Plasticization of corn starch by polyol mixtures. Carbohydrate Polymers, 83(2), 659–664.

Rasheed, F., Kuktaite, R., Hedenqvist, M. S., G€allstedt, M., Plivelicd, T. S. and Johansson, E. 2016. The use of plants as a "green-factory" to produce high strength gluten-based materials. Green Chemistry, 18, 2782e2792.

Ratnayake, W. S. and Jackson, D. S. 2008. Chapter 5 Starch Gelatinization. Advances in Food and Nutrition Research, 221–268. DOI:10.1016/s1043-4526(08)00405-1

Rocha, M. da, Loiko, M. R., Tondo, E. C. and Prentice, C. 2014. Physical, mechanical and antimicrobial properties of Argentine anchovy (*Engraulis anchoita*) protein films incorporated with organic acids. Food Hydrocolloids, 37, 213–220. DOI:10.1016/j.foodhyd.2013.10.017

Rojas-Grau, M. A., Soliva-Fortuny, R. C. and Martín-Belloso, O. 2009. Edible coatings to incorporate active ingredients to fresh-cut fruits: a review. Trends in Food Science and Technology, v.20: p.438-447. DOI 10.1016/j.tifs.2009.05.002

Romani, V. P., Olsen, B., Collares, M. P., Meireles Oliveira, J. R., Prentice-Hernández, C. and Martins, V. G. 2018. Improvement of Fish Protein Films Properties for Food Packaging through Glow Discharge Plasma Application. Food Hydrocolloids. DOI:10.1016/j.foodhyd.2018.09.022

Romani, V. P., Olsen, B., Collares, M. P., Oliveira, J. R. M., Prentice, C. and Martins, V. G. 2019. Plasma technology as a tool to decrease the sensitivity to water of fish protein films for food packaging. Food Hydrocolloids. DOI:10.1016/j.foodhyd.2019.03.021

Roy, S. and Rhim, J. W. 2019. Agar-based antioxidant composite films incorporated with melanina nanoparticles. Food Hydrocolloids, v. 94, 391-398.

Safaei, M. and Taran, M. 2018. Optimized synthesis, characterization, and antibacterial activity of an alginate-cupric oxide bionanocomposite. Journal of Applied Polymer Science, 135(2), e45682.

Sejidov, F., Mansoori, Y. and Goodarzi, N. 2005. Esterification reaction using solid heterogeneous acid catalysts under solvent-less condition. Journal of Molecular Catalysis A: Chemical. DOI:10.1016/j.molcata.2005.06.048

Seydim, A. C. and Sarikus, G. 2006. Antimicrobial activity of whey protein based edible films incorporated with oregano, rosemary and garlic essential oils. Food Research International, 39:639-644

Shanks, R. and Kong, I. 2012. Thermoplastic Starch. Thermoplastic Elastomers. DOI:10.5772/36295

Singh, P., Chatli, A. S. and Mehndiratta, H. K. 2018. Development of starch based edible films. International Journal of Development Research, 8, (10), 23501-23506.

Soares, N. F. F. and Geraldine, R. M. 2007. Embalagens. In: MORETTI, C. L. Manual de processamento mínimo de frutas e hortaliças. Pesquisa Agropecuária Brasileira, cap. 4, p. 153-172.

Soares, N. F. F., Silva, S. A., Pires, A. C. S., Camilloto, G. P. and Silva, P. S. 2009. Novos desenvolvimentos e aplicações em embalagens de alimentos. Revista Ceres, v.56, p.370-378.

Souza, C. O., Silva, L. T. and Druzian, J. I. Comparative studies on the characterization of biodegradable cassava starch films containing mango and acerola pulps. Química Nova, v.35, p.262-267, 2012.

Tanada-Palmu, P. S., Proença, P. S. P., Trani, P. E., Passos, F. A. and Grosso, C. R. F. 2005. Recobrimento de sementes de brócolos e salsa com coberturas e filmes biodegradáveis. Bragantia, Campinas, v.64, n.2, p.291-297.

Tanaka, M., Iwata, K., Sanguandeekul, R., Handa, A. and Ishizaki, S. 2001. Influence of plasticizers on the properties of edible films prepared from fish water-soluble proteins. Fisheries Science, 67(2), 346–351. DOI:10.1046/j.1444-2906.2001.00237.x

Theerawitayaart, W., Prodpran, T., Benjakul, S. and Sookchoo, P. 2018. Properties of films from fish gelatin prepared by molecular modification and direct addition of oxidized linoleic acid. Food Hydrocolloids. DOI:10.1016/j.foodhyd.2018.10.022

Tihminlioglu, F., Atik, İ. D. and Özen, B. 2010. Water vapor and oxygen-barrier performance of corn–zein coated polypropylene films. Journal of Food Engineering, 96(3), 342–347.

Valdés, A., Mellinas, A. C., Ramos, M., Garrigós, M. C. and Jiménez, A. 2014. Natural additives and agricultural wastes in biopolymer formulations for food packaging. Frontiers in Chemistry, 2. DOI:10.3389/fchem.2014.00006

Valencia-Sullca, C., Vargas, M., Atarés, L. and Chiralt, A. 2018. Thermoplastic cassava starch-chitosan bilayer films containing essential oils. Food Hydrocolloids, 75, 107–115. DOI:10.1016/j.foodhyd.2017.09.008

Veiga-Santos, P., Oliveira, L. M., Cereda, M. P., Alves, A. J. and Scamparini, A. R. P. 2005. Mechanical properties, hydrophilicity and water activity of starch-gum films: effect of additives and deacetylated xanthan gum. Food Hydrocolloids, 19(2), 341–349. DOI:10.1016/j.foodhyd.2004.07.006

Wang, S., Li, C., Copeland, L., Niu, Q. and Wang, S. 2015. Starch Retrogradation: A Comprehensive Review. Comprehensive Reviews in Food Science and Food Safety, 14(5), 568–585. DOI:10.1111/1541-4337.12143

Wihodo, M. and Moraru, C. I. 2013. Physical and chemical methods used to enhance the structure and mechanical properties of protein films: A review. Journal of Food Engineering, 114(3), 292–302. DOI:10.1016/j.jfoodeng.2012.08.021

William, R. C. V., Daniela, C. B., Sandriane, P. and Carlos, P. 2015. Preparation and characterization of nanocomposite film from Whitemouth croaker (*Micropogonias furnieri*) protein isolate modified with montmorillonite. International Food Research Journal, v.22, n.3, p.1053-1058.

Wolf, K. L. 2007. Propriedades físico-químicas e mecânicas de biofilmes elaborados a partir de fibra e pó de colágeno. São José do Rio Preto: Universidade Estadual Paulista – UNESP. Tese de Mestrado.

Yilmaz, F. and Dagdemir, E. 2012. The effects of beeswax coating on quality of Kashar cheese during ripening. International Journal of Food Science and Technology, 47(12), 2582–2589. DOI:10.1111/j.1365-2621.2012.03137.x

Zavareze, E. R., Halal, S. L. M., Telles, A. C. and Prentice-Hernández, C. 2012. Filmes biodegradáveis à base de proteínas miofibrilares de pescado. Brazilian Journal of Food Technology, IV SSA, p. 53-57.

Zhang, J. F. and Sun, X. 2005. Poly (lactic acid)-based bioplastics. In: Smith, R. Biodegradable Polymers for Industrial Application. Cambridge: Woodhead Publishing.

Zink, J., Wyrobnik, T., Prinz, T. and Schmid, M. 2016. Physical, chemical and biochemical modifications of protein-based films and coatings: An extensive review. International Journal of Molecular Sciences, 17, Article1376.

Este trabalho está nas normas do periódico International Food Research Journal. Disponível em: http://www.ifrj.upm.edu.my/doc/IFRJ%20Guide%20to%20Contributors%20V10_Jan2019.pdf.

Type of Papers

Research papers and Review articles are accepted on the understanding that they have not been and will not be published elsewhere without the Editor-in-Chief's permission. Papers accepted become the copyright of the Journal.

a) Research papers - original full-length research papers that have not been published previously, except in a preliminary form, and should not exceed 7,500 words from introduction to conclusion (not including references) (including no more than five tables and figures combined - additional tables and figures can be submitted as supplementary material). Research papers should not contain more than 40 references.

b) Review articles - will be accepted in areas of topical interest, will normally focus on literature published over the previous five years, and should not exceed 10,000 words from introduction to conclusion (not including references) (including allowance for no more than five tables and figures combined). Review articles should not contain more than 120 references.

Preparation of Manuscript

Authors are recommended to follow the Guide to Contributors to prepare their manuscript accordingly. A single word processor containing title page information, manuscript, figure(s) and/or table(s) should be uploaded in a SINGLE file.

Language

Manuscripts to be submitted should be ensured written in clear and comprehensible English. Authors whose native language is not English are strongly advised to have their manuscripts checked by an English-speaking colleague prior to submission. It is the author's responsibility to pay attention to grammar and spelling.

Originality

The author must ensure that when a manuscript is submitted to International Food Research Journal, the manuscript must be an original work. The Author should check the manuscript for any possible plagiarism using any program such as Turnitin or any other software before submitting the manuscripts to IFRJ.

All submitted manuscripts must be in the Journal's acceptable similarity index range:

< 30% - PASS;

> 30% - REJECT.

Authorship

All persons designated as authors should qualify for authorship. Each author should have participated sufficiently in the work to take public responsibility for the content. Authorship credit should be based only on substantial contributions to 1) conception and design, or analysis and interpretation of data; and to 2) drafting the article or revising it critically for important intellectual content; and on 3) final approval of the version to be published. Conditions 1, 2, and 3 must all be met. Participation solely in the acquisition of funding or the collection of data does not justify authorship. General supervision of the research group is not sufficient for authorship. Any part of an article critical to its main conclusions must be the responsibility of at least one author. Editors may ask authors to describe what each contributed; this information may be published. Increasingly, multicenter trials are attributed to a corporate author. All members of the group, who are named as authors, either in the authorship position below the title or in a footnote, should fully meet the above criteria It is necessary for the authors to suggest at least FOUR potential reviewers and provide their complete contact details and fields of specialization in the system and cover letter. Authors are advised to suggest reviewers from other institutions.

Title Page Information

Title – Concise and should be written in the form of lower-case with capitalization of the first word.

Author names and affiliations – Please ensure that all authors' names are correctly spelled. Authors' names should be abbreviated and arrange as last name first, followed by given names in initials. Present the authors' affiliation addresses below the names. Indicate all affiliations with number superscripts, before the author's name and in front of the appropriate address. Please provide full postal address of each affiliation.

Corresponding author – Clearly indicate who with (*) in front of the author's name and only the e-mail address of the corresponding author is allowed.

Manuscript Style

Manuscripts should be double-spaced, typed using 11 point Arial of equivalent typeface with a margin of 4 cm (1.5 inch) on all four sides. Request authors to kindly submit your manuscript with continuous line numbers.

The manuscript should be divided into the following sections:

a) Abstract – Provides essential information which includes stating the purpose of the research, the principal results and main conclusions. It should be intelligible without reference to the paper itself. Non-standard or uncommon abbreviations should be avoided, but if essential they must be defined at their first mention in the abstract itself.

b) Keywords – A minimum of 3 keywords and maximum of only 6 words allowed indicating the essentials of the research work. Separate the keywords with comma.

c) Introduction – Provides the aim of the investigation and a brief statement of previous relevant work with references.

d) Materials and Methods – Only new techniques need to be described in detail for reproducibility. Known or published methods must have adequate reference. Relevant modifications should be described.

e) Results – Clear and concise. Presentation of results with tables and figures may improve its clarity.

f) Discussion – Explains the significance of the results.

Note: Results and Discussion can be separated or combined.

g) Conclusion – Summary of results interpretation with suggested recommendations. The conclusion should not merely repeat points made in the preceding sections.

h) Acknowledgement – Should be kept to the absolute minimum

Headings of the sections are to be bold and not underlined. They should appear clearly on its own. Any subsections should be given a brief heading, italicize and it should also appear clearly on its own separate line. Authors are advised to minimize subsections.

Tables, Graphs, Figures and Photographs

Tables, graphs and figures should be displayed on separate pages in the manuscript after the reference section. Tables and figures should be numbered consecutively in accordance with their appearance in the text. Tables are captioned on top of the table body and place any table notes below the table body with proper indications to the contents in the table body (if needed).

Figures are captioned at the bottom of the figures. Scanned or digital photographs should be in high resolution, minimum 300 dpi in the PC format. A maximum of 5 Figures and Tables combined only allowed; hence, be sparing.

Footnotes

Footnotes should be kept to a minimum; in most cases, it will be possible to incorporate the information in the text. If footnotes are used, they should be numbered in the text indicated by superscript numbers and kept as brief as possible.

References

Citation in text

References should be cited in the text by the author. All references in the text must be listed at the end of the paper, with the names of authors arranged alphabetically, and titles of papers given.

Reference style

It is the authors' responsibility to provide the accurate details of the bibliographic citations.

Please ensure that all references cited within the text must also be present in the reference list (and vice versa).

Citation in text:

1. Single author: the author's name (without initials) and the year of publication

2. Two authors: both authors' names and the year of publication

3. Three or more authors: first author's name followed by 'et al.' and the year of publication.

Citation may be made directly (or parenthetically). Groups of references should be listed chronologically according to the year of publication.

Miscellaneous

Do not use '&' to indicate 'and'.

The Journal does not include any appendices, abbreviations and supplementary materials into publication. Hence, authors are advised to include them in the manuscript text they are necessary. Any abbreviation should be stated in brackets next to the full name at the beginning of the text before proceeding to use the abbreviation. Chemical compounds should be stated with its full name, first and the chemical formulae in brackets.

Standard units – Please follow these examples: 5 g, 1 h, 30 s, 5 min, 10%, 37°C, 2 mL,

2 mg/mL (not 2 mg mL -1)