Edible films: the package of the future?

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Nowadays, there is a concern about the methods used for food preservation. One of the most important is that the food industry has been using additives to extend the shelf life of products, which at times, does not turn out to be quite safe, because of the assumption that most of them have health risk associated with cancer, asthma, cardiovascular diseases, allergies, etc. So, their use is justified for the simple fact of reducing costs because of lack of awareness of the producer. In addition, the amount of food waste has increased annually, exacerbating the situation and therefore, increasing the concern of finding the best way to preserve food without changing its physical and nutritional properties at the lowest price.

The use of edible films in the food industry has evolved. Today, the impact they generate, as a means of conservation, is great, because they are composed of polymers, with specific characteristics, of natural origin. They can be polysaccharides, animal and vegetable proteins and lipids, which, when added to food reduce the loss of moisture, also they act as a barrier for CO2 and O2 movement through the food product, and improve they mechanical, physical and nutritional properties of food. On the other hand, they serve as active vehicles for bacteriocins, probiotics, antioxidants and nutrients, each of them having specific benefits in the proper functioning of the organism, optimizing the product for human consumption. Therefore, the present review article has as main objective to highlight the importance of edible films as packages and their application as vehicles of various bioactive compounds, and discuss whether in the future, they would be one of the best sustainable alternatives for the conservation and commercialization of processed foods.

Keywords: edible films; edible coating; edible packages; active films

1. Why use edible films?

One of the main concerns of the food industry is to find suitable packages to market the food and to keep it in good condition for longer. These packaging are intended to be practical and malleable but with sufficient permeability to prevent food contamination by microorganisms, dust, gases or moisture.

Such packaging is expected to prolong the life of the product on the shelf and at the same time retaining its organoleptic properties. Due to increasing pollution and deterioration of resources worldwide in recent years, the industry has opted for organic materials and made from renewable resources to pack their products.

Edible films in the food area function as selective barriers for the transference of gases, moisture and nutrients; Are used because they greatly help to reduce the deterioration of foodstuffs caused by environmental factors. Likewise, it is sought to avoid or reduce the oxidation and loss of volatile compounds responsible for specific flavors and properties of food, therefore, the main objective of this chapter is to discuss if edible films made especially for fresh produce

2. What we know?

Nowadays, most consumers are worried about, not just what they eat and its nutritional characteristics, but also, they are worried about if the food that they eat contains some type of hazardous materials and even more, they are worried about its sustainable characteristics.

As consumers, we all want to eat fresh products, but what we don´t know is how far is the food from the place that has been picked or obtained directly. Now, the time that takes our food to get to our home and to our mouth, could be from hours to days, and this is how the "problem" begins. As soon as the fruit, vegetable, meat or any animal products are obtained, its aging starts.

But, how do we know that some products are fresh? the answers is in its flavor, its appearance and its texture. Therefore, food scientists are focused on generate technologies that maintained product's "fresh like" characteristics for large periods of time.

People have been used some of these technologies for ages. Examples involve, increasing temperature to eliminate pathogens (pasteurization), decrease temperature to prevent bacteria and mold growth (refrigeration and freezing), adding salt or sugar also to prevent bacterial growth (salting and crystallization), etc. The issue with these technologies is that all of them affect either way sensorial quality of food products.

So, as an intent to decrease these changes, producer from China in the year 1100, and to maintain Emperor's food fresh (especially citrus fruits) they used molten wax to cover them for long journeys [1] . Latter, this practice was extended through Europe, known as "larding", in which they also used fats to prevent spoilage, nevertheless, this form to preserve fruits, altered its taste and texture [2]

Then, Japanese used a coat obtained in the processes of boiling soy milk (named yuba) preserving overall quality of food [3]. Later, other technologies came along, such as, smoking, cooling (in iceboxes) and the used of heat. However, coating of products was always a cheap way to maintain their safety and quality.

We could now stablish that an edible film is any primary package (in direct contact with food) used to extend food product shelf life with its quality and sensory characteristics unchanged, with the unique characteristic that could be eaten with the food that contain them. The difference between an edible film and an edible coat is that the first is made to function as a wrap or a bag to cover the product and is usually from 50 to 250 mm thick. On the other hand, edible coating is formed in the product and it could be applied by a variety of method like, brushing, spraying, or dipping.

Edible films and coatings have several applications: they could serve as a barrier against the movement of molecules such as water vapour, ethylene, carbon dioxide, odor molecules, among others. They also could be used as carrier of active compounds like nutrients, antioxidants agents, pigments, antibacterial components to add beneficial effects to the food. The other important property of the edible films is to enhance of food's sensory properties [4]

Food's characteristics determined the type of edible films that can be applied, for instance, polysaccharides and protein based films are used as to carry nutrients and additives due to their bonding capacity, but they could not be used to avoid water loss because of their hydrophilic condition. Fat based edible films tend to break easily due to their no polar solubility but, also because of this, they are very good as water barrier [5]

Protein are a well-known material for films production since they can interact with several components through their amino acid chains creating a cohesive and stable film or coat [6]

Some of the protein used are: casein, whey, gelatin, soy protein, keratin, egg albumen, wheat protein, corn zein and depending on the ingredient the preparation could change.

Gennadios et al. [7] observed that gelatin could be used as a barrier to reduce oxygen, moisture and oil transfer when applied to meat products, but also its applicability is limited because is considered as a hydrophilic material, which means that it doesn't work as a good water vapor barrier. In another research made by Guilbert [8], it was probed that zein has an excellent films formation protein and that it has better water vapor barrier characteristics in comparison with films produced with other protein, it reduces moisture loss and delay color change when applied in fresh fruit. But at the same time, the films made with this protein, need to be combined with fatty acids or with cross-linking reagents to improve its barrier properties.

Gennadios and Weller [9] worked with gluten based films, and they concluded that films made only with gluten, present low flexibility, thus the need to add plasticizer (glycerin), although, they reduce their water vapor barrier characteristics, its strength and elasticity.

In another research conducted by Zhang et al. [10] in which they worked with soy protein, they observed that the films have a high level of stiffness, tensile strength and developed films that are inexpensive and nutritional. On the other hand, casein films showed good free standing formation characteristics, but poor water vapor properties, they also transparent and flexible [11]

When films are produce with polysaccharide gums and naturally depending on the material used, they present certain and specific characteristics, such as plasticity, tensile strength, clarity and solubility due to the hydrogen bonding [12] Some of the gums used in film forming process are methylcellulose, alginate, carboxymethylcellulose, carrageenan, gellan, locust bean, agar, among others.

Nieto [12] concluded that films made with agar are clear, strong, insoluble to water and form stable networks that could be peel off improving its manageability however, they are brittle and with reduce elasticity properties.

Murray [13] showed that films with methylcellulose could be peel off and that they have high levels of tensile strength but it is a unique material since the process must have such heating controls for the gel phase to hold. Similarly, Konjac gum is a hydrocolloid obtained from the common Chinese plant known as *Amorphophallus spp*., according to Takigami [14], this gum produces strong films, due to its possibility to increase viscosity at low concentration, however, this property is could be too the downside for used Konjac gum, making solutions too viscous.

Yuen [15] worked with pullulan, a polysaccharide obtained from fungus *Aureobasidium pullulans*, and observed that the compounds formed a clear, strong and like synthetic polymers, their used in food products is due to its low permeability to oxygen and its high solubility in water.

According to Donati et al. [16] alginate associated with calcium form heat stable gels which also form films with increased tensile strength. Nevertheless, their negative charges, could decreased tensile strength and increased water solubility. On the other hand, Carrageenan, which is also a polysaccharide extracted from a seaweed, possess three different conformation; kappa, iota and lambda each with different characteristics: kappa formed the strongest films of all [17]. Similarly, Gellan gum (obtained from the fermentation process of *Sphyngomonas elodea*, can be classified in two; high acyl (with high flexibility, soft, and transparent) and low acyl (hard and non-elastic gels). Gellan gum form weak films, with low tensile and puncture strength but they are also clear and insoluble in cold water [18].

Pectin has shown to require certain specification to fully hydrate hence, to create gel and films, such as sugar content (from 20 to 55%), pH (as low as 3.5) and temperature of process (from 50 to 85ªC). Pectin films are weaker than alginate films [19]. Chitosan, the principal material of the exoskeleton of crustaceans, formed films strong enough to made plastic wraps for fresh produce, they have high tensile and puncture strength [20].

Fats also are used as ingredient in film production because they are very effective barriers against moisture, meaning, water cannot enter or get out of the food [21] Some of this components are: waxes, margarine, lacs, shortening, resins, essential oils, fatty acids, among others.

Although most of the ingredients by themselves could be used to elaborate edible films, there's some problems or weak points in each of them (Table 1).

Table 1 Advantages and disadvantages of some of the most used ingredients in edible films.

Material	Advantages	Disadvantages
Protein		
Casein [22]	Good barrier to oxygen	Tend to shrink, brittle
Whey [23]	Water insoluble, flavorless, flexible, high clarity,	Need a process of crosslinking, texture depends on the aminoacid composition
Gelatin [24]	Odorless, cheap, transparent, tasteless	Water soluble, hence limited used in food industry
Gluten [3]	Good oxygen barrier, good tensile strength and elongation break	Poor water vapor barrier, opaque films,
Soy [10]	Inexpensive, environmental friendly, nutritional	Poor moisture barrier, brittle and stiff.
Zein [25]	Flexible, smooth, cheap, good oxygen barriers	water solubility, poor mechanical properties, poor heat sealability
Polysaccharide		
Alginate [26]	Strong films, low permeable to oxygen, tasteless, odorless, glossy	High water vapor permeability
Carrageenan [27]	Solid films, low permeability, high tensile strength	Opaque, low values of elongation at break, poor heat sealability
Gellan [28, 29]	Thermal stability, resistant to acid, clear films, poor solubility in water, clear	High water sorption capacity, brittle and hard
Agar [30]	Good mechanical properties, transparent, flexible, clear	Only soluble in hot water, high swelling capacity
Carboximethylcellulose [31]	Smooth, low water vapor permeability.	Low elongation at break point, low tensile strength
Pullulan [32]	High gas barrier, glossy, water soluble, odorless, tasteless.	Could become sticky, easily soluble at high levels of relative humidity

3. Novel composite films

Now, since any material alone does not have all the properties that consumers want; low water vapor permeability for fresh produce, high flexibility, high tensile and puncture strength and biodegradability, researcher have been studied the combination of two or more materials, composite films. The material, concentration and application mode depends entirely upon the type of food.

Many are the research that have been conducted in composite films; according to Galus and Lenart [33] a composite film made with alginate and pectin shows higher values of tensile strength and elongation at break rather than the ingredients individually. Also, they proved to generate clear and homogeneous films that also had lower water vapor sorption in comparison with alginate only films.

In another work conducted by Otoni et al. [34], they evaluated the properties of a soy protein-oil film and they found that the water barrier properties increased when oil is added to the soy protein solution, in addition, total pore volume decrease. Alvarado-Gonzalez et al. [29] work with a blend of *Aloe vera* and gellan gum to improve their physical and chemical properties, and they found that the combination shows higher levels of transparency, water sorption capacity and water vapor permeability were enhanced. In the same way, Eghbal et al. [35] probed that when sodium caseinate and pectin, tensile strength and elongation at break improved and water sorption decreased.

However, not all blends improve films properties. One example is the research conducted by Jridi et al. [36], they observed that when combined gelatin and chitosan, the composite films shows no significant different in transparent and tensile strength than the observe in chitosan films.

Other researches have been investigated the blend of more than two materials; Tong et al. [37], studied the effect of combine Pullulan, alginate and carboxymethylcellulose in edible films properties. The resultant films had better mechanical, barrier and water solubility properties. Similar research made by Taqi et al. [38] probed that when apple pectin, cassava starch, essential oils and oleic acid are combined, its chemical and physical properties were changed; tensile strength decreased and the elongation at break point increased.

Composite edible films in food industry have been used to maintain fresh fruits microbial, physical and chemical properties. Some other works are show in the list below (Table 2)

Table 2 Recent research on composite edible films.

Ingredients	Changes observed	Reference
Cutin/pectin	Lower water uptake, lower solibility	[39]
Kappa carrageenan/sorbitol/glycerol	Higher tensile strength, higher elongation at break, increased moisture content, water solubility and water vapor solubility	[27]
Gelatin/curcumin	Film change color with pH	[40]
Aloe vera/plpantain flour	Smoother, clear, rigid and plastic films	[41]
Whey protein/pectin/transaglutaminase	Prevent weigh loss of fresh cut produce, prevent microbial growth	[42]
Mesquite seed gum/palm fruit oil	Decrease water solubility, decreased water vapor permeability, improve tensile strength	[43]
Moringa leaf extract/chitosan/carboxymethylcellulose	Lower mass loss, lower respiration rate	[44]
Chitosan/gum Arabic	Lower mass loss, lower respiration rate and ethylene production	[45]
Pomegranate peel pectin/montmorillonite	Improve tensile strength, water vapor permeability decrease	[46]
Shellac/gelatin	Decrease weight loss, maintain post harvest quality of banana for more than 30 days	[47]
Gelatin/defatted soy protein	Increase color properties, tensile strength, water permeability, water solubility	[48]
Water chestnut starch/chitosan/glycerol monolaureate/ nisin/pine needle essential oil	Lower water absorption expansion, tensile strength elongation and puncture strength	[49]
Rice starch/L-carrageenan	Improve tensile strength and elongation at break, better solubility enhance water vapor permeability	[50]
Beeswax/hydroxypropyl methylcellulose	Reduce oxygen barrier, reduce mechanical resistance, improve moisture barrier, reduce weight loss	[51]
Nanoclay/quince seed mucilage	Improve tensile strength, increase elongation, improve gas barriers	[52]

4. Active films

So far, information about edible films and coating with improve physical and chemical properties have been well studied, however, recently, researches has taken notice in the importance and application of bioactive compounds added to edible films. The purpose is to enhance antioxidant, antimicrobial or even nutritional characteristic of the food that contain them, hence, its name “active films”.

One of the most studied bioactive component is essential oil to prevent microbial growing. Hashemi and Khanaghah [53] added oregano essential oil to basil seed gum based edible films and observed antibacterial activity with 2-6% content of oregano essential oil against *Escherichia coli, Salmonella Typhimurium, Pseudomona aureginosa, Staphylococcus aureus* and *Bacillus cereus*. Another research conducted by Kazerani et al. [54] they probed antibacterial effects against *Staphylococcus aureus* and *Escherichia coli* when *Zataria multiflora* essential oil was added to cress seed gum based edible films, also, they found that the addition of essential oil caused a change in glass temperature transition of the film.

Not only antibacterial effect has been studied, also work about antifungal effect of some bioactive component has been made, Bahram et al., [55] evaluated the effect of cinnamon essential oil against *Candida albicans*, when applied to whye concentrate edible films and the concluded that the film exhibited good inhibitory effect against fungi. Also, Gniewozs et al., [56] showed that with 0.12% of added Caraway essential oil to Pullulan based edible films, *Aspergillus niger* was inhibited along with the population of *Salmonella enteriditis, Staphylococcus aureus, Saccharomyces cerevisae* in fresh baby carrots.

The impact of probiotics in human health have been extensively studied, due to the increased interest of consumer in wellness therefore biopolymeric matrices have been added with probiotics as an alternative to enhance food safety and health. Soukoulis et al. [57] estudied the viability of *Lactobacillus rhamnosus* incorporated in edible films, and concluded that two blends; high viscosity alginate/whey protein and k-carrageenan/locust beam gum/whey protein had the best mechanical and barrier properties. In the same way, pullulan and pullulan /potato starch are the best carriers for *Lactobacillus plantarun, Lactobacillus reuteri* and *Lactobacillus acidophilus* with 80% of viable cells and after 2 months of storage [58], Lopez de Lacey et al., [59] also probed that biopolymers are excellent carriers for probiotics, they incorporated *Lactobacillus acidophilus* and *Bifidobacterium bifidum* in gelatin and observed that probiotic decreased in less that 2 log cycles.

According to Percival [60] an antioxidant compound is the one that “are capable of stabilizing and deactivating free radicals before they attack cells. Antioxidants are absolutely critical for maintaining optimal cellular and systemic health and well-being”. Because of the edible films are good carriers for these compounds, giving a functional property to the food matrix. Suppakul et al. [61] evaluated the radical scavenging and ferric reducing antioxidant power and observed that when combined Indian Goosberry extract to a composite Indian Goosberry puree/methylcellulose based films, it showed the higher antioxidant activity during 90-day storage. Antioxidant compounds are found mainly in plants, such as sage and laurel, which when incorporate to whey based edible films, contribute to the oxidative stability of frozen meatballs [62].

Finally, it could be also incorporate other type of nutrients such as vitamins and minerals; this is the case of the research made by Bilbao-Sainz et al. [63] were they added vitamin D2 to an edible mushroom chitosan based edible films. Another vitamin that was incorporated to edible films is vitamin E or tocopherol and when added to chitosan edible films, decreased film's solubility and increased significantly its drying rate [64].

5. A green option: Edible packages

Other used that has been given, and recently is getting importance from the consumer, is the "green" side of apply them as a wrapping or as a package that would reduce plastic waste. Plastic take thousands of years to break down, meanwhile it would become a contamination problem affecting all types of living beings. So, to counteract the problem, experts proposed two options; to recycle plastic or to gradually change to biodegradable materials. However, recycling involves transporting and sorting costs leaving biodegradable materials in first place to a cost-effective solution. Still, biodegradable material should be created from raw ingredients that would be disposable in other product manufacture.

So, the material used should be safe and nutritious for the people not to dispose any wrapping or packaging material when eating food.

A great example of this is protein based film which have been proven to be biodegradable and compostable source giving nitrogen to the soil to fertilized it [65] being casein a waste product in dairy process. Semolina loaded with nano kaolin have been probed to also make a suitable material for biodegradable edible package [66].

Recently, certain companies launched products with edible packages; Saltwater Brewery ®, create from beer by-products and edible ring used in their beer's six packs, these rings feed marine animals instead of killing them [67].

In the same way, Rodrigo García González a postgraduate student of the Royal College of Art innovate with egg yolk a package that could allegedly, replace water bottles. The design consists in a sphere like package containing water (with the appearance of a jellyfish), that could be thrown away or could be eaten [68]

Is worth mention that not only small producers are interested in this type of packages; for instance, KFC®, introduced a tortilla based bowl "Rice bowlz" as an Indian product, the good news is that this product was well adopted by consumers, this was a initiative that begins when the government of Bangalore banned plastic [69]

Wikicells® is another innovative way to package foodstuff, the brand was invented by Dr. David Edwards whose ideas came from the model of "nature to wrap food". This type of wrapping involves several plastic-like ingredients such as cookie dough, cocoa powder and chia to contain from frozen yogurt to gaspachio [70].

6. Conclusions

After all the facts that were mentioned above, we could conclude that edible packages are now the ultimate way to present processing food. It can be used several ingredients; polysaccharides, proteins and lipids or fats.

Researches have turn around their eyes to this opportunity area of create a new, innovative way to package food, incorporating ingredients that the food does not have such as antioxidants, probiotics, vitamins flavor among others. Many times, ingredients by themselves don't have the properties that the science looking for to contain different types of food, so, composite films (combinations of two or more components) are the best way, to improve material's characteristics such as tensile strength, odor, taste, water sorption, water permeability, flexibility, etc.

Now, small and big companies are seeking out the best, low cost, greener way to sell their products being in recent years when investigations of this type have pay out.

So, we can say that eventually, and hopefully, edible and functional packaging would be the only way in which food would be commercialized to; improve health, lower contamination damage (to us and to the environment), increased product's shelf life and finally increase cost-benefit ratio of foodstuff.

Acknowledgments We would like to thank to the Dirección de Superación Académica (DSA) of the Mexican goverment and the Benemérita Universidad Autónoma de Puebla for the grant conceded to PhD Teresa Gladys Cerón Carrillo.

References

[1] Hardenburg RE. Wax related coatings for horticultural products. A bibliography. Agricultural Research Service Bulletin. 1967; United States Department of Agriculture, Washington, DC

[2] Contreras-Medellin R, Labuza TP. Prediction of moisture protection requirements for foods. Cereal Food World.1981; 26(7): 335–340

[3] Gennadios A, Weller CL, Testin RF. Modification of physicaand barrier properties of edible wheat gluten-based fils. Cereal Chemistry. 1993; 70(4):426-429
[4] Pascall MA, Lin SL. The application of edible polymeric films and coatings in the food industry. Journal of Food Processing and Technology. 2013; 4(2): 100e116
[5] Hernandez-Izquierdo VM, Krochta JM. Thermoplastic processing of proteins for lm formation a review. J Food Science. 2008; 73: R30-R39.
[6] Barone JR, Schmidt WF. Nonfood applications of proteinaceous renewable materials. Journal of Chemical Education. 2006; 83(7): 1003–1009
[7] Gennadios A, McHugh TH, Weller CL, Krochta JM. . Edible coating and films based on protein. In: Krochta J M, Balwin EA, Niperos Carriedo M O, editors. Edible Coatings and Films to Improve Food Quality. Lancaster, Technomic Publishing; 1994. p. 201-277
[8] Guilbert S. Technology and application of edible protective films. In: Matholouthi M. editor. Food packaging and preservation, Theory and Practice. London: Elsevier Applied Science Publishing; 1986. pp. 371-394.
[9] Gennadios A, Weller CL. Edible films and coating from wheat and corn proteins. Food Technology, 1990; 44(10): 63-69.
[10] Zhang, J., P. Mungara, J. JaneMechanical and thermal properties of extruded soy protein sheets. Polymer. 2001; 42: 2569-257
[11] Avena-Bustillos, R. J.; Cisneros-Zevallos, L. A.; Krochta, J. M. & Saltveit, M. E. Optimization of edible coatings on minimally processed carrots using response surface methodology. Transactions of the ASAE. 1993; 36(3): 801-805.
[12] Nieto MB. 2009. Structure and function of polyssacharide gum based edible films and coating. In Embuscado ME, Huber KC. Editors. Edible films and coatings for food applications. New York, EUA. Springer. 2009. p 57-112.
[13] Murray JCF. Cellulosics. In: Phillips GO, Williams PA. editors. Handbook of Hydrocolloids. Cambridge: Woodhead Publishing Ltd; 2000. p 219–229
[14] Takigami S. Konjac Mannan. In: Phillips GO, Williams PA. editors. Handbook of Hydrocolloids. Boca Raton: CRC/Woodhead Publishing; 2000. p 413–424
[15] Yuen S. Pullulan and its applications. Process Biochemistry. 1974; 9:7–9
[16] Donati I, Holtan S, Mørch YA, Borgogna M, Dentini M, Skjåk-Bræk. New hypothesis on the role of alternating sequences in calcium-alginate gels. Biomacromolecules. 2005; 6:1031–1040
[17] Falshaw R, Bixler HJ, Johndro K. Structure and performance of commercial kappa-2 carrageenan extracts I. Structure analysis. Food Hydrocolloids. 2001; 15:441–452
[18] Sworn G. Gellan gums. In:. Phillips GO, Williams PA, editors. Handbook of Hydrocolloids. Boca Raton: CRC/Woodhead Publishing; 2000. pp 117–35
[19] May CD. Pectins. In: Phillips GO and Williams, PA, editors. Handbook of Hydrocolloids. Cambridge: Woodhead Publishing Ltd; 2000. pp. 219–229
[20] Srinivasa P, Baskaran R, Ramesh M, Harish Prashanth K, Tharanathan R. Storage studies of mango packed using biodegradable chitosan film. European Food Research and Technology. 2002; 215(6):504–508
[21] Morillon V, Debeaufort F, Blond G, Capelle M, Voilley A. Factors affecting the moisture permeability of lipid-based edible films: a review. Critical Reviews in Food Science and Nutrition. 2002; 42(1):67–89
[22] Mauer LJ; Smith DE, Labuza TP. Water vapor permeability, mechanical, and structural properties of edible beta-casein films. International Dairy Journal. 2000;10, 353–358.
[23] Pérez-Gago MB, Nadaud P, Krochta JM. Water vapor permeability, solubility, and tensile properties of heat-denatured versus native whey protein films. Food Technology. 1999; 64(6):1034-1037.
[24] Ramos M, Valdés A, Beltrán A, Garrigós MC. Gelatin-based films and coatings for food packaging applications. Coatings. 2016; 6:41: 1-20
[25] Bradenburg AH, Weller CL, Testin RF. Edible films and coatings from soy protein. Journal of Food Science, 1993; 58(5): 1086-1089.
[26] Pranoto Y, Salokhe VM, Rakshit SK. Physical and antibacterial properties of alginate-based edible films incorporated with garlic oil. Food Research International. 2005; 38:267-272
[27] Farhan A, Hani NM. Characterization of edible packaging film based on semi-refined kappa-carrageenan plasticized with glycerol and sorbitol. Food Hydrocolloids. 2017; 64:48-58
[28] Jampen S, Britt IJ, Tung MA. Gellan polymer solution properties: Dilute and concentrated regimes. Food Research International. 2000; 33: 579–586
[29] Alvarado-Gomzalez JS, Chanona-Pérez JJ, Welti-Chanes JS, Calderón-Domínguez G, Arzate-Vázquez I, Pacheco-Alcalá SU, Garibay-Febles V, Gutierrez-López GF. Optical, microestructural, functional and mechanical properties of Aloe vera gel/Gellan gum edible films. Revista Mexicana de Ingeniería Química. 2012; 11(2):193-210.
[30] Phan The D, Debeaufort F, Voilley A, Luu D. Biopolymer interactions affect the functional properties of edible films based on agar, cassava starch and arabinoxalyn blends. Journal of Food Engineering. 2009; 90(4):548-558
[31] Martelli SM, Motta C, Caon T, Alberton J, Belletini IC, Do Prado ACP, Barreto PLM, Soldi V. Edible carboxymethyl cellulose films containing natural antioxidant and surfactants: a-tocopherol stability, in vitro release and films properties. LWT Food Science and Technology. 2017; 77:21-29
[32] Rhim JW. Characteristics of Pullulan based-edible films. Food Science Biotechnology. 2003; 12(2):161-165
[33] Galus S, Lenart A. Development and characterization of composite edible films based on sodium alginate and pectin. Journal of Food Engineering. 2013; 115(4):459-465
[34] Otoni CG, Avena-Bustillos RJ, Olsen CW, Bilbao-Sáinz C, McHugh TH. Mechanical and water barrier properties of isolated soy protein composite edible films as affected by carvacrol and cinnamaldehyde micro and nanoemulsions. Food Hydrocolloids. 2016; 57, 72–79.
[35] Eghbal N, Yarmand MS, Mousavi M, Degraeve P, Oulahal N, Gharsallaoui A. Complex coacervation for the development of composute edible films based on LM pectin and sodium caseinate. Carbohydrate Polymers. 2016; 151: 947-956

[36] Jridi M, Hajii S, Ayed HB, Lassoued I, Mbarek A, Kammoun M, Souissi N, Nasri M. Physical, structural, antioxidant and antimicrobial properties of gelatin-chitosan composite edible films. Macromolecules. 2014; 67:373-379

[37] Tong Q, Xiao Q, Lim L. Preparation and properties of pullulan-alginate-carboxymethylcellulose blend films. Food Research International. 2008; 41:1007-1014

[38] Taqi A, Mutihac L, Stamatin I. Physical and barrier properties of apple pectin/cassava starch composite films incorporating lauris nobilis L. oil and oleic acid. Journal of Food Processing and Preservation. 2014; 38:1982-1993.

[39] Manrich A, Moreira FKV, Otoni CG, Lorevice MV, Martinis M, Mattoso LHC. Hydrophobic edible films made up of tomato cutin and pectin. Carbohydrate polymers. 2017; 164:83-91

[40] Musso YS, Salgado PS, Mauri AN. Smart edible films base don gelatin and curcumin. Food hydrocolloids. 2017; 66:8-15.

[41] Gutierrez TJ, González G. Effect of cross-linking with Aloe vera gel on surface and physicochemical properties of edible films made from plantain flour. Food Biophysics. 2017;12(1):11-22

[42] Marquez GS, Di Perro P, Marinello L, Esposito M, Giosafatto CVL, Porta R. Fresh cut fruit and vegetable coatings by transaglutaminase-crosslinked whey protein/pectine edible films. LWT Foo Science and Technology. 2017; 75:124-130

[43] Rodrigues DC, Cunha AP, Brito ES, Azeredo HMC, Gallao MI. Mesquite seed gum and palm fruit oil emulsion edible films: influence of oil content and sonication. Food hydrocolloids. 2016; 56:227-235

[44] Tesfay SZ, Magwaza LS. Evaluating the efficacy of moring leaf extract, chitosan and carboxymethylcellulose as edible coatings for enhancing quality and extending postharvest life of avocado (Persea amaericana Mill.)fruit. Food packaging and shelf life. 2017; 11:40-48

[45] Khaliq G, Mohamed MTM, Ding P, Ghazali HM, Ali A. Storage behavior and quality responses of mango (*Mangifera indica L.*) fruit treated with chitosan and gum arabic coatings during cold storage condictions. International Food Research Journal. 2016; 23:S141-S148

[46] Oliveira TIS, Zea-Redondo L, Moates GK, Wellner N, Cross K, Waldron KW, Azeredo HMC. Pomegranate peel pectin films as affected by montmorillonite. Food Chemistry. 2016; 198:107-112

[47] Soradech S, Nunthanid J, Limmatvapirat S, Luangtana-anan M. Utilization of shellac and gelatin composite film for coating to extend the shelf life of banana. Food Control. 2017; 73:1310-1317.

[48] Tulamandi S, Rangarajan V, Rizvi SSH, Sighal RS, Chattopadhyay SK, Saha NC. A biodegradable and edible packaging film based on papaya puree, gelatin, and defatted soy protein. Food Packaging and Shelf Life. 2016; 10:60-71

[49] Mei J, Yuan Y, Guo Q, Wu Y, Li Y, Yu H. Charaterization and antimcirobial properties of wáter chestnut starch-chitosam edible films. International Journal of Biological Macromolecules. 2013; 61:169-178

[50] Thakur R, Saberi B, Pristijono P, Golding J, Stathopoulos C, Scarlett C, Bowyer M, Vuong Q. Characterization of rice starch l-carrageenan biodegradable edible films. Effect of stearic acid on the films properties. International Journal of Biological Macromolecules. 2016; 93(A):952-960

[51] Navarro-Tarazaga ML, Massa A, Pérez-Gago MB. Effect of beeswax content on hydroxypropyl methylcellulose-based edible film properties and postharvest quality of coated plums (Cv. Angeleno). LWT Food Science and Technology. 2011; 44(10):2328-2334.

[52] Shekarabi AS, Oromiehie AR, Vaziri A, Ardjmand M, Safekordi AA. Investigation of the effect of nanoclay on the properties of quince seed mucilage edible films. Food Science and Nutrition. 2014; 2(6):821-827

[53] Hashemi SMB, Khaneghah AM. Characterization of novel basil-seed gum active edible films and coating containing oregano essential oil. Progress in Organic Coatings. 2017; 110:35-41

[54] Kazerani H, Fahimdanesh M, Jouki M, Tayefi F, Tayyari F. Physical, mechanical, thermal and antimicrobial properties of active edible films made from cress seed gum incorporated with Zataria essential oil. Carphatian Journal of Food Science and Technology. 2016; 8(4):83-90.

[55] Bahram S, Rezaei M, Soltani M, Kamali A, Ojagh SM, Abdollahi M. Whey protein concentrate edible film activated with cinnamon essential oil. Journal of food Processing and Preservation. 2014; 38:12511258

[56] Gniewozs M, Krasniewska K, Woreta M, Kosakowska O. Animicrobial activity of a pullulan –caraway essential oil coating on reduction of food microorganisms and quality in fresh baby carrot. Journal of Food Science. 2013; 78(8):M1242-8

[57] Soukoulis C, Behboudi-Jobbehdar S, Macnaughtan W, Parmenter C, Fisk ID. Stability of *Lactobacillus rhamnosus* GG incorporated in edible films: impact of anionic biopolymers and whey protein concentrate. Food hydrocolloids. 2017; 70: 345-355

[58] Kanmani P, Lim ST. Development and characterization of novel probiotic-residing pullulan/ starch edible films. Food chemistry. 2013; 141(2):1041-1049.

[59] Lopez de Lacey AM, Lopez-Caballero ME, Gómez-Estaca J, Gómez Guillén MC, Montero P. Functionality of Lactobacillus acidophilus and Bifidobacterium bifidum incorporated to edible coatings and films. Innovative Food Science and Emerging Technologies. 2012; 16:277-282.

[60] Percival M. 1998. Antioxidants. Clinical Nutrition Insights. Available in https://acudoc.com/Antioxidants.PDF.

[61] Suppakul P, Boonlert R, Buaphet W, Sonkaew P, Luckanatinvong V. Efficacy of superior antioxidant Indian gooseberry extract-incorporated edible Indian gooseberry puree/methylcellulose composite films on enhancing the shelf life of roasted cashew nut. Food Control. 2016; 69:51-60.

[62] Akcan T, Estevez M, Serdaroglu M. Antioxidant protection of cooked meatballs during frozen storage by whey protein edible films with phytochemicals form *Laurus nobilis L.* and *Salvia officinalis*. LWT-Food Science and Technology. 2017; 77:323-331

[63] Bilbao-Sainz C, Chiou B-S, Wolliams T, Wood D, Du W-X, Sedej I, Ban Z, Rodov V, Poverenov E, Vinokur Y, McHugh T. Vitamin D-fortified chitosan films from mushroom waste. Carbohydrate Polymer. 2017; 167:97-104.

[64] Lin SL, Pascall MA. Incorporation of vitamin E into chitosan and its effect on the film forming solution (viscosity and drying rate) and the solubility and thermal properties of the dried film. Food hydrocolloids. 2014; 35:78-84

[65] Aimutis WR. Bioactive properties of milk proteins with particular focus on carcinogenesis. Journal of Nutrition. 2004; 134849:989S-95S

[66] Jafarzadeh S, Alias AK, Ariffin F, Mahmud S, Najafi A, Sheibani S. Characterization of a new biodegradable edible film from semolina loaded with nano kaolin. International Food Research international. 2017; 24(1):304-309.

[67] Wanshel E. Edible rings on six packs feed marine life if they end up in the ocean [internet]. Huffpost. 2016 [cited 2017 june 13]. Available from: http://www.huffingtonpost.com.mx/entry/saltwater-brewery-edible-six-pack-rings-beer-plastic-marine-life_us_573b796ce4b0ef86171c5fe4

[68] Gosden E. Drunk your water? Now eat the bottle it came in. [internet] The telegraph. 2014 [cited 2017 june 16]. Available from: http://www.telegraph.co.uk/news/newstopics/howaboutthat/11095793/Drunk-your-water-Now-eat-the-bottle-it-came-in.html

[69] Boult A. KFC introduces edible bowls to replace plastic packaging [internet]. The Telegraph. 2016 [cited 2017 june 1st] Available from http://www.telegraph.co.uk/food-and-drink/news/kfc-introduces-edible-bowls-to-replace-plastic-packaging/

[70] Stevens J. Packaging you can eat: food “skins” that mimic nature could slash plastic waste [internet]. Daily mail.com. 2012 [cited 2017 may 23]. Available from: http://www.dailymail.co.uk/news/article-2160092/Packaging-eat-Food-skins-mimic-nature-slash-plastic-waste.html?ICO=most_read_module