



Antimicrobial Packaging: Food safety and product quality

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ABSTRACT

Food Codex requires safe products and packaging is an important factor to comply with this consumer right, so developing packaging with antimicrobial properties that protect the product by eliminating or inhibiting bacteria or pathogens that cause damage to health is important in the food industry. The objective of this work was to perform a bibliographic analysis of some additives that generate antimicrobial properties in packaging by reviewing some studies that have developed antimicrobial films or also called smart films. Microbial agents have become an important factor in maintaining food quality over time. Biopolymers are an excellent alternative due to their availability, low cost, biodegradability and their origin is from renewable sources.

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Introduction

Packaging sector represents one of the main sectors in the plastics industry worldwide, the development of antimicrobial packaging for food products has had a growing acceptance in the last decades due to the promotion of health care against viruses and pathogens that can cause illness or death. Plastics used in food packaging must contribute to food safety and security throughout the supply chain. (Camacho et al., 2020) indicated that polymeric antimicrobials are a good alternative for the development of new antimicrobial polymeric materials with a wide variety of morphologies, functionalities and specific applications.

Petroleum-derived thermoplastic polymers came onto the market in the 1950s. (Valladares, 2017) stated that polymers used in conventional packaging are derived from non-renewable and non-biodegradable fossil sources, unlike biopolymers that are used because of their availability, low cost, biodegradability and their origin from renewable sources. Incorporating natural antimicrobial agents is an alternative for food preservation and shelf life extension.

Food industry today seeks to improve the quality of its products and extend the shelf life of foods, while maintaining their organoleptic and nutritional properties. Concept of active packaging seeks to favor the process of mass transfer and interaction between packaging materials and food. Food packaging must provide mechanical, optical and thermal protection to the packaged food, and also preserve it from microorganisms, oxygen, humidity, chemical contaminants, radiation and high temperatures.

Natural additives for the development of a biopolymer with antimicrobial properties can be obtained from plants, animals, bacteria, algae or fungi, solid organic wastes. Essential oils, whether of natural or synthetic origin from renewable sources, are easy to obtain and have a high antimicrobial and/or antioxidant character, such as carvacrol (5-isopropyl-2-methylphenol) and thymol (2-isopropyl-5-methylphenol).

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Oregano or clove essential oils or compounds with intrinsic activity such as thymol, carvacrol, tocopherols or hydroxytyrosol, copper, zinc, titanium, gold and silver nanoparticles, as well as some of their metal oxides, agroindustrial compounds with high lignin and cellulose content, have also been proposed as active additives to develop new active nanocomposites.

(Fombuena, 2016) indicated that the properties of the polymer depend on the chemical composition of the polymer, the polymer chain or network will be composed of different elements, these elements determine the behavior of a polymer and allow its identification.

COVID-19 coronavirus pandemic has put the food industry in check because it has forcibly developed a new era of quality, which is characterized by the biosafety of products, for which it is necessary to accelerate the development processes of packaging with antibacterial properties that guarantee the control of biological risk when acquiring or consuming a product.

The remainder of this study is organized as follows. The next section provides a review of extant literature. The third section discusses the methodology and data. Finally, conclusions and implications of the study are presented in the final section

Literature Review

Theoretical and Conceptual Background

Packaging acts as a silent seller, conveying the image of the product and the manufacturer's signature. It is an instrument of decision of the marketing of the products for its direct sale, which contains a suitable fraction of the consumer; that informs on the characteristics of use as they are: storage, conservation, properties, among others, also allows the identification of its origin across its image for the design, color and form, which serve as factor of differentiation between an increasingly wide and heterogeneous offer. Packaging allows the product to be handled, stored and transported in perfect conditions due to the conservation, protection and safety it provides (Cervera, 2016).

Everyone has the right to safe, nutritious and sufficient food. Even today, about one in ten people in the world get sick after eating contaminated food. When food is not safe, children cannot learn and adults cannot work. Human development cannot take place. Safe food is fundamental to the promotion of health and the eradication of hunger, two of the main goals of Agenda 2030. There is no food security without food safety, and in a world where the food supply chain has become more complex, any adverse food safety incident can adversely affect public health, trade and the economy on a global scale. However, food safety is assumed. It is often invisible until you have food poisoning. Harmful foods containing bacteria, viruses, parasites or harmful chemicals cause over 200 diseases, ranging from diarrhoea to cancer. (FAO y OMS, 2019).

Consumers have the right to demand that the food available in domestic markets is safe and of good quality (FAO, 2019).

Staphylococcus aureus

NTE INEN 1529-14:2013 Primera revisión 2013-09 indicated that this bacterial species belongs to the family Micrococcaceae and the genus Staphylococcus, whose members have the form of cocci that are generally grouped in clusters, immobile, Gram positive, aerobic and facultative anaerobic, optimum temperature 37 ° C. produce a golden yellow pigment, are halotolerant. They possess coagulase, phosphatase and deoxyribonuclease enzymes that distinguish them from other staphylococci. They produce exotoxins: hemolysin and enterotoxin.

Salmonella

NTE INEN 1529-15:2013 Primera revisión 2013-09 indicated that this genus belongs to the Enterobacteriaceae family. It is composed of microorganisms that form typical colonies on solid media and have defined biochemical and serological characteristics. They are generally motile, Gram-negative, ferment glucose with gas formation and do not ferment lactose.

Escherichia coli

Voluntary Ecuadorian Technical Standard (s.f.) indicates in INEN 1529-8, about microbiological control of food, detection and counting of presumptive *Escherichia coli*, in this standard the following definition is considered: *Escherichia coli* is a bacterium belonging to the group of fecal coliforms capable of fermenting lactose at 44 °C with gas production, is capable of producing indole from tryptophan, reacts positively to the methyl red test and negative to the Voges Proskauer test and does not use citrate as the only carbon source.

COVID-19

La (Organización Mundial de la Salud [OMS], s.f.) defined the COVID-19 is the disease caused by the new coronavirus known as SARS-CoV-2. WHO first became aware of this new virus on December 31, 2019, when it was informed of a cluster of "viral pneumonia" cases reported in Wuhan, People's Republic of China.

Total Quality

(Jabaloyes et al., 2020) indicated that total quality is a commitment to continuous improvement, with the objective of achieving optimum quality in all areas. It is a concept that explains how to offer the highest degree of satisfaction to a customer through a

product or service. To achieve total quality, it is necessary to continuously improve the product or service as a whole, thus achieving a quality product or service, measured by customer satisfaction.

(Lizarzaburu et al., 2018) stated that process management, one of the most effective management improvement tools for all types of organizations, consists of realizing competitive processes capable of reacting autonomously to changes, oriented towards the full satisfaction of the customer and their needs.

Research and Methodology

Data Analysis Technique

The model of data analysis in this research is as follows:

Bibliographic methodology was applied for the review and analysis of research on the development of antimicrobial polymeric packaging, for which the following three articles were selected for analysis:

- i. Antibacterial effect of ZnO nanoparticles on *Staphylococcus aureus* and *Salmonella Typhi*
- ii. Development of an antimicrobial polymeric packaging for the control of anthracnose on tree tomato (*Solanum betaceum*).
- iii. Active packaging for food preservation based on polymeric formulations.
- iv. Functionalized edible films and coatings.

Search equations shown in Table 1 were used to consult different sources of information.

Table 1: Search equations used for the research case

Search equation	Result
Antimicrobial AND polymers	353
Antimicrobial polymeric AND packaging	41
Antimicrobial polymeric AND film	90
Antimicrobial polymeric AND Additives	49

Result and Discussion

Analysis of information

(Zavaleta et al., 2019) ZnO nanoparticles demonstrated an antibacterial effect on *Staphylococcus aureus* ATCC 25923 and *Salmonella Typhi*, presenting growth inhibition for *S. typhi* only at the concentration of 2.00 mg/ml, emphasizing that *Staphylococcus aureus* ATCC 25923 was the one that presented the highest antibacterial effect as shown in Table 2 and Table 3.

Table 2: Mean diameters in (mm) of inhibition halos of *Staphylococcus aereus* ATCC 25923

Average diameters in (mm) of inhibition halos of <i>Staphylococcus aereus</i> ATCC 25923					
Concentrations of ZnO nanoparticles (mg/ml)					
Repetition	0.8	1,2	1,6	2,0	PEG- 6000
1	0	11,6	11,13	14,26	0
2	0	10,5	9,83	13,06	0
3	0	11,16	10,16	15,56	0
4	0	10,16	10,03	16,93	0
5	0	10,06	10,23	14,10	0
Average	0	10,71	10,28	14,78	0

Source: (Zavaleta et al., 2019)

Table 3: Average diameters in (mm) of *Salmonella typhi* inhibition halos.

Average diameters in (mm) of Salmonella typhi inhibition halos.					
Concentrations of ZnO nanoparticles (mg/ml)					
Repetition	0,8	1,2	1,6	2,0	PEG- 6000
1	0	0	0	10,80	0
2	0	0	0	12,36	0
3	0	0	0	10,83	0
4	0	0	0	10,06	0
5	0	0	0	11,03	0
Average	0	0	0	11,01	0

Source: (Zavaleta et al., 2019)

In another study Solano (2019) developed a new antifungal packaging for tree tomato, this packaging was based on low density polyethylene (LDPE) and lauric acid as an antifungal agent, for which he prepared by extrusion three films of LDPE / lauric acid and a white LDPE without additive. In vitro antimicrobial tests showed that the film with a higher concentration of lauric acid affected the growth and morphology of the fungus *Colletotrichum tamarilloi*, while in vivo tests extended the shelf life of infected fruit by up to two weeks under ambient conditions, the active packaging reduced weight loss and maintained fruit firmness better than the control packaging, and the physicochemical characteristics of the fruit were not affected by the lauric acid.

In an analysis by (Contreras, 2018) indicated that the techniques for the development of active packaging have a high cost, and also the use of metals, so it becomes an obstacle in commercial use, in addition the risks associated with the possible migration of metals into food and beverages, for human consumption.

(Solano et al., 2020) concluded that the most common materials used in the elaboration of edible films and coatings are proteins, polysaccharides, lipids and combinations of these. The use of smart films are able to detect any failure in the food atmosphere or microbial contamination and are able to report by means of visual signals any alteration or contamination of the product, which ensures the safety of the product. Safety refers to all those risks associated with food that can affect the health of people, both natural risks, such as those caused by contamination, incidence of pathogens, or that may increase the risk of chronic diseases such as cancer, cardiovascular diseases and others (Food and Agriculture Organization of the United Nations [FAO], n.d.). Edible films are made with materials such as carbohydrates, proteins or lipids, with physical and mechanical characteristics similar to non-degradable packaging, but with the advantage of functioning as bioactive barriers, since, through the addition of plant extracts, they can present antimicrobial activity, protection against UV and visible light, and serve as carriers of antioxidants and/or colorants, thus improving the visual characteristics of the product.

(Villas et al, 2016) they combined the biopolymers chitosan (CHI) and hyaluronic acid (HA) has been extensively explored as a promising approach for designing natural antibacterial PEMS. HA is a linear *glycosaminoglycan* composed of repeating disaccharide units of β -(1,4)- *D-glucuronic acid* and β -(1,3)-N-acetyl-D-glucosamine that has proven to be an effective polyanion and displays a naturally non-adhesive nature due to its highly hydrophilic and moisturizing nature. CHI, is a partly acetylated *(1,-4)-2-amino-2-deoxy- β -D-glucan*, natural and biocompatible that has shown antibacterial "killing contact" properties by disruption of the negatively charged cell membranes of bacteria. Antibacterial activity (R) of PEMS was quantitatively determined according to ISO22196:2007 against *Escherichia Coli*. The number of viable bacteria (CFU/cm²) decreased significantly after the adsorption of HA and CHI layers onto PET, giving R values of 4, 1-4.2 (R<2 is assumed as effective antibacterial substrates).

Material biodegradable a base de polímeros termoplásticos

Currently, some biodegradable polymers such as *polylactic acid* (PLA), cellulose esters, *polyhydroxyalkanes* and starch polymers are known, as well as polymers reinforced with natural fiber such as flax, hemp, kenaf, jute or cotton fibers, have contributed to research and development, in addition to being known as "green compounds" for their tribute to the environment, mentioned Calderón Freire et al. (2019).

According to (Calderón Freire et al., 2019) bioplastics are called biodegradable plastic materials that have their origin in organic materials from renewable sources. They are degraded by the action of microorganisms".

PLA is produced by fermentation of agricultural products such as corn, rice, potato, sugar cane, agricultural wastes, lactic acid can be produced by direct condensation or as polymerization according to the PLA polymerization process (P.K.Bajpai, and J. Madaan, 2014) referred by (Calderon et al., 2019).

Antimicrobial copper film: innovation against coronavirus

Rivera, limpieza integral y servicios auxiliares. (s.f.) indicated that copper, a metal well known for its properties against microbes, has gained special relevance in recent months as an ally in the fight against Covid-19 and this adhesive film incorporates this material for greater security in hot spots of contagion. The coronavirus only lasts 4 hours on a copper surface, while it could last up to three days on other materials such as plastic or steel, and one on cardboard.

Dr. Cu antimicrobial copper film is a self-adhesive PVC membrane that is placed on high contact surfaces, and therefore, high risk of contagion such as doorknobs or light switches, desks and reception desks. This revolutionary film is made of copper nanoparticles containing an antimicrobial agent capable of suspending the growth of microbes where viruses and bacteria are found. The electrically charged copper particles break the outer membrane of the microbes, whereupon the ions destroy the pathogen's genetic material. Thus, the free radicals generated by the copper damage the bacteria and viruses, making it impossible for them to replicate.

Natural esparto fiber (*juncus ramboi subsp.colombianus*)

A study conducted by (Gómez et al., 2017) about the physical and chemical characterization of natural esparto fiber as a reinforcement alternative in composite materials, the results of the thermal analysis evidenced a maximum limit for the elaboration of a composite material and the possible polymeric matrices, it also confirmed the hydrophilic character of the natural fiber; the micrographs revealed a cross-sectional area with the presence of large areas with a solid cell wall of good size; the mechanical tests showed that the tensile stresses are relatively low for this type of structure, so esparto fiber can be used as reinforcement in composite materials that are subjected to moderate tensile loads.

The eighth generation of quality

Quality has evolved according to market demands as shown in Figure 1 and with the advent of covid-19 it takes much more importance the development of packaging with antimicrobial properties so that the safety of the product is guaranteed, as well as the biosafety of both products and services, in addition to customer satisfaction which has always been the priority in a quality management system. (Lizarzaburu et al., 2018) defined customer satisfaction as one of the most important outcomes in the provision of quality services and products and indicated that it is made up of three elements: perceived performance, expectations and satisfaction levels.

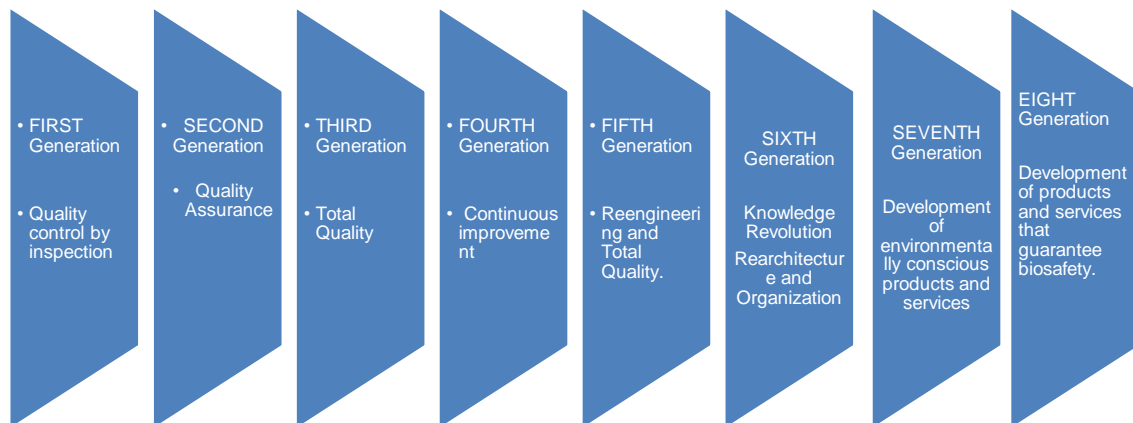


Figure 1: Quality Evolution

Biosecurity as the eighth generation of quality is a challenge for businessmen and entrepreneurs because they must develop strategies that allow them to provide packaging for their food products to ensure both their quality and safety throughout the supply chain. These strategies must be based on a commercial, financial and operational approach so that the products are available in the market at a competitive price.

Conclusions

Development of packaging with antimicrobial properties is a deployment opportunity for food industries because it will allow them to innovate and better manage their costs and risks throughout the supply chain due to increased product shelf life. According to the literature review the development of antimicrobial films or also called smart films have been shown to inhibit or kill *Staphylococcus aureus*, *Escherichia coli*, Salmonella after 24 hours of contact. Such films can be made by combining the biopolymers chitosan (CHI) and hyaluronic acid (HA) to design natural antibacterial PEMS. Also using low density polyethylene (LDPE) and lauric acid as an antifungal agent or with ZnO nanoparticles because they also proved to have an antibacterial effect.

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