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BIODEGRADABLE POLYMERIC SYSTEMS FOR MEAT PACKAGING - A REVIEW

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Abstract

Nowadays, plastic materials have become one of the most widely used materials in all aspects of life, such as in automobiles, household appliances, computers and packaging materials. Because of the environmental issues caused by its disposal and incineration, biodegradable polymeric materials (or biopolymers) were recommended as an alternative to synthetic ones. Most of the disposed packaging come from food industry, especially from fresh and ready-to-eat food products, which are also characterized by high perishability. Meat and derived products represent such perishable food items with quick deterioration under improper storage. Many advances have occurred in the field of smart meat packaging; thus, the aim of this study was to review current advances in the development of novel packaging materials for fresh and processed meat, which are also in support of environmental sustainability.

Key words*: meat packaging, biopolymers, biodegradable.*

INTRODUCTION

The development of active and biodegradable materials for replacing conventional ones, having properties for enhancing the shelf-life and safety of packaged food is nowadays one of the most challenging research activities (Van Long et al., 2016; Xu et al., 2021). Antimicrobial packaging has been proposed as an alternative to post-packaging operations to improve the safety of food products. Main natural antimicrobials occur in nature or they are isolated from microbial (nisin, natamycin), plant (e.g., essential oil of basil, thyme, oregano, cinnamon, clove, and rosemary) or animal sources (e.g., lysozyme, lactoferrin), organic acids (e.g., sorbic, propionic, citric acid) and naturally occurring polymers (chitosan) (Perinelli et al., 2018; Tas et al., 2019; Bhavaniramya et al., 2019).

Development of biodegradable, active, edible and nontoxic films represent a new trend in packaging development (Sanches et al., 2021), mainly based on natural and renewable resources such as polysaccharides and proteins (Xu et al., 2021). These films have combined various concepts, such as food, preservation and packaging into a biomaterial that is edible, biodegradable, prevents loss of moisture, color, lipid oxidation, off-odors, enhancing shelf-life, and transmitting functionality on meat, fish and derived food products (Umaraw et al., 2020).

Spoilage of fresh meat during processing, distribution and commerce have a great negative impact on meat industry, in terms of safety and also from an economical point of view. As an alternative for conventional meat packaging, active biodegradable materials with antioxidant properties were proposed in recent years (Domínguez et al., 2018), given the fact that meat is highly perishable due to its high content in nutrients and polyunsaturated fatty acids, being susceptible to oxidation and microbial spoilage (Xiong et al., 2020).

The purpose of the present study was to review the current state of research regarding novel biomaterials for meat packaging, with great properties in terms of preservation and shelf life.

RESULTS AND DISCUSSIONS

Applications on poultry meat

Quail meat was packed using a composite film based on pectin from apple peel and potato starch, modified using ZrO_2 nanoparticles and

microencapsulated whey protein in *Zataria multiflora* essential oil. The packaging film showed stability for chemical, pH and microbial characteristics of quail meat (Sani et al., 2021).

Moreno et al. (2018) incorporated N-α-lauroyl-l-arginine ethyl ester monohydrochloride in starch - gelatin films and used them as food contact active layers in chicken breast fillets which were vacuum packed in pouches (polyamide/polyethylene). The results of this study showed an increased shelf life of the packed chicken samples without affecting meat oxidation process when compared to control samples.

Gelatin nanofibers containing thyme essential oil/βcyclodextrin ε-polylysine nanoparticles were developed by Lin et al. (2018), to control *Campylobacter jejuni* propagation. These nanofibers were subsequently incorporated into gelatin matrix using electrospinning method and applied as packaging for chicken meat. The packed samples presented lower pH, thiobarbituric acid (TBA) and total volatile basic nitrogen (TVB-N) values and also lower aerobic bacterial count. No impact was observed on texture, color and sensory properties, showing that the developed nanofibers represent promising food packaging.

Two double layer materials based on polybutylene succinate and polybutylene succinate-co-adipate obtained from renewable materials were used for vacuum packaging of raw chicken and turkey meat and also smoked turkey meat. For the packed products were found minor changes in pH, microbiological parameters, water activity, color and volatile compounds profiles during their shelf life storage, making these materials suitable for replacing conventional packaging materials (Vytejckova et al., 2017).

Kamkar et al. (2021) developed films based on chitosan and nano-liposomal garlic essential oil, which were applied on chicken fillet in order to study their preservation capacity. The results of the study showed lower values of pH, thiobarbituric acid reactive substances, peroxide, total volatile nitrogen and microbial count for the packed samples compared with control ones, making the developed films suitable as potential active packaging for chicken shelf life extension.

Biodegradable PVA-montmorillonite K10 clay nanocomposite films with *in situ* generated ginger extract mediated silver nanoparticles were developed by Shiji et al. (2019). These films have proven to be highly effective for reducing microbial load in chicken sausages compared to control films, being taken into consideration for shelf life extension of chicken meat products.

Pirsa & Shamusi (2019) developed films based on bacterial cellulose modified by polypyrrole-Zinc oxide nanocomposite, that were applied in chicken thighs for preservation purposes. The developed film controlled the pH increasing of the tested samples and also decreased the microbial load compared to the control samples, being suitable as antioxidant and antimicrobial packaging.

High pressure treatment combined with active packaging based on polylactide, polyethylene glycol and cinnamon oil was tested on the inactivation of *Salmonella typhimurium* and *Listeria monocytogenes* in chicken samples by Ahmed et al. (2017). The most efficient treatment was the combination of a 300 MPa treatment pressure on chicken packed in films containing 17% cinnamon oil, reducing the pathogens load to a safe level during a period of 21 days of refrigerated storage.

Fresh poultry meat was packed in active biocomposites based on chitosan reinforced with montmorillonite incorporated with rosemary and ginger essential oil. Films proved to be efficient for shelf life extension of the tested samples, reducing lipid oxidation by half and microbiological contamination by 6 to 16% (Pires et al., 2018).

Active edible films composed of semi-refined κ-carrageenan incorporated with a water extract of germinated fenugreek seeds were developed by Farhan & Hani (2020) for fresh chicken breast preservation. The results showed that the developed films efficiently controlled microbial growth on the surface of the samples, in comparison with the control samples.

Polyvinyl alcohol based materials containing *Laurus nobilis* and *Rosmarinus officinalis* essential oils were applied on chicken breast fillets by Goksen et al. (2021). The developed materials inhibited lipid oxidation process and microbial development of the chicken meat,

having a good effect in terms of pH values and color parameters during storage period.

Films based on watermelon rind pectin containing kiwifruit peel extract were developed and applied on chicken tights for preservation purposes. After 9 days of storage the thiobarbituric acid reactive substances were lower for the samples packed in the developed films, compared to control ones (Han & Song, 2021).

Applications on beef meat

Langroodi et al. (2018) studied the antibacterial and antioxidant properties of edible coating based on chitosan containing *Zataria multiflora* essential oil and hydroalcoholic extract of sumac on beef stakes packed in modified atmosphere (MAP) and refrigerated. The results showed that the tested coatings combined with MAP presented high antimicrobial effect, increasing the shelf life and presenting acceptable sensorial properties, while inhibitory effects on lipid oxidation of meat were obtained when using only the coating alone.

Films based on starch, sweet whey and red cabbage extract were used for beef packaging by Sanches et al. (2021). The most effective film to best preserve the quality of ground beef with minor changes was composed of starch, 64.18% red cabbage extract and 4.36% sweet whey, demonstrating also the role of anthocyanins in ground meat preservation.

Xavier et al. (2021) developed an active nanocomposite film based on chitosan and *Cinnamodendron dinisii* Schwanke essential oil nanoencapsulated in zein, which was applied as packaging material on ground beef. This packaging material stabilized the deterioration reactions in ground beef, preserving the color and increasing the shelf life under storage in refrigeration conditions.

Lin et al. (2019) incorporated *chrysanthemum* essential oil in chitosan nanofibers in order to obtain a novel antibacterial packaging. The obtained material was applied on beef and it was proved to be a great inhibitor for *L. monocytogenes* with an inhibition rate over 99.9% at temperatures of 4°C, 12°C and 25°C on a storage period of 7 days. Also, the packaging material presented lower antioxidant activity and pH, when compared to the control sample.

Red meat was packed in a PLA based system (tray and film) using modified atmosphere in comparison with a conventional system (polyethylene terephthalate/polyethylene tray and polyvinyl chloride film) (Panseri et al., 2018). Using the PLA system for beef packaging maintained the redness of the samples and a reduced content of volatile compounds associated with oxidation phenomena.

Alirezalu et al. (2021) packed beef fillets using active chitosan films containing ε-polylysine. These films protected the packed samples, for which lower values for microbial load and also higher sensory properties were obtained when compared to control samples.

Gelatin/palm wax/lemongrass essential oil coated Kraft paper was used for beef packaging by Syahida et al. (2021). The results of the study showed that the developed packaging material showed a reduction in pH, color and moisture changes, delaying also lipid oxidation and microbial spoilage of the tested samples.

Applications on pork meat

Blended films based on curdlan/nanocellulose were used as packaging material for chilled pork meat by Qian et al. (2021), which led to 12 days increased shelf life for the tested samples.

Zhang et al. (2020) developed curdlan/polyvinyl alcohol/thyme essential oil biodegradable films, which were applied for chilled pork meat preservation. The results showed great antibacterial and antioxidant activity of the developed materials, extending the shelf life of pork meat with 10 days.

Yang et al. (2016) developed films based on distiller dried grains with solubles rich in protein, with the addition of green tea, oolong tea and black tea extract as antioxidants. The films were further used as packaging for pork meat and during the storage period they led to lower lipid oxidation compared to control samples.

Edible coatings based on pectin loaded with a nanoemulsion from oregano essential oil and resveratrol were used for fresh pork loin preservation under high oxygen modified atmosphere packaging. The results of the study

showed that the tested materials prolonged the shelf life of fresh pork loin, leading to lower pH values and color changes, delaying lipid and protein oxidation and inhibiting microbial growth (Xiong et al., 2020).
Song et al. (2020) used two antioxidant packaging based on polyethylene terephthalate containing rosemary oleoresin and green tea extract for minced pork meat preservation. The results showed that both tested materials have antioxidant activity, inhibit the oxidation of lipids and proteins and thus extend the shelf life of minced pork samples.

Applications on fish preservation

A novel bacteriocin from *Weissella hellenica* BCC 7293 (Bac7293) was used in order to obtain biodegradable and antimicrobial food packaging, by diffusion coating onto PLA (polylactic acid)/sawdust particle biocomposite film. The resulted film inhibited the growth of both Gram-negative and Gram-positive bacteria in pangasius fish fillets during storage in chilled conditions, demonstrating good antimicrobial properties (Woraprayote et al., 2018).
Ehsani et al. (2020) developed biodegradable films based on chitosan, gelatin or alginate, containing lactoperoxidase system or sage essential oil as active ingredients for common carp fish burger packaging. The packed samples were maintained at refrigeration temperatures for up to 20 days. The results showed that the most effective film to inhibit the total viable count, psychrotrophic bacterial count, *Pseudomonas* spp., *Shewanella* spp. and TBARS was the film based on chitosan incorporated with lactoperoxidase system, extending the shelf life of the tested fish samples.
Socaciu et al. (2021) developed films based on heat-denatured whey protein isolate incorporated with tarragon essential oil, which were applied as packaging for brook trout. The film enhanced the quality preservation of samples, showing lower values for physical-chemical parameters, for microbial load and higher sensory characteristics compared to control samples.
Edible coating based on RA and ε-PL were prepared by Li et al. (2018) and were applied in combination with MAP for preservation of Half-smooth tongue sole. The results of the study showed great characteristics of the film and an extension of shelf life with 8-12 days.
Vizzini et al. (2020) developed an active packaging material with antibacterial properties, being represented by an alginate film reinforced with zinc magnesium oxide nanoparticles for cold-smoked salmon preservation. The salmon samples were inoculated with *L. monocytogenes*. The results showed the tested film provided good antibacterial properties, with no bacterial proliferation at refrigeration temperature for 4 days.
A whey protein concentrate film incorporated with green tea extract was used for fresh salmon packaging (Castro et al., 2019). The packaging proved to be efficient delaying lipid oxidation of salmon samples.

CONCLUSIONS

Active packaging represents a great alternative to conventional packaging, both from an economical point of view and great characteristics such as biodegradability, nontoxicity and availability of raw materials. This study showed that edible films and coatings applied to meat as packaging materials demonstrated great antimicrobial and antioxidant properties, capacity to reduce lipid oxidation and preservation of physical-chemical properties, thus prolonging the shelf life of the tested samples.

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MISCELLANEOUS