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Effect of plant extracts on antimicrobial packaging materials on meat and fish products: A Review

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Abstract:

A growing number of producers, experts, and consumers are calling for action to address the present issues that agri-food industry was facing due to their increased understanding of environmental sustainability. Food packaging in particular has been found to be associated with plastic waste and food loss. As a result, using different packaging materials and extending the shelf life of food may be a viable solution. Applying various bio-based polymers or bio-polymers made from various materials, such as sustainable or renewable agricultural commodities, to muscle foods has grown in popularity in recent years. The utilization of films incorporated with bioactive compounds in preserving meat and fish products was reviewed briefly in this paper. When added in the right amounts and under the right circumstances, these compounds can improve the sensory and physicochemical qualities of meat products in addition to acting as preservatives. It has been demonstrated that a range of these bio-based products can stop moisture loss, drip, lower lipid oxidation, and improve flavour characteristics. Because of the growing customer demand for more natural products and ecologically responsible packaging, bio-based films or bio-polymers will remain crucial to the food business since they enhance the quality of numerous products, including processed or fresh muscle foods.

Key words: Bio polymers, meat packaging, antioxidants, antimicrobial activity.

INTRODUCTION:

Food packaging is a crucial stage in the food production process. Synthetic polymers have dominated the packaging of food for many years. Most of the plastics used in food packaging was single-use and used on-the-go, and the waste produced by these non-recyclable or non-biodegradable food packaging wastes poses a serious threat to the environment on land and in water. Nowadays, the development of environmentally-friendly packaging materials is relevant worldwide. Biodegradable packaging materials are promising due to their safety and ability to extend shelf life of food products. (Niu et al., 2021) created biodegradable composite films using gelatin, glycerol, and potato starch. The best conditions, according to the results, were 2.5% starch, 2.0% glycerol, and 1.5% gelatin. At 500 nm, the film exhibited

exceptional qualities with a TS of 4.47 MPa, an E% of 109.91%, a WS of 43.64%, and a T% of 41.21%. Excellent compatibility between starch, glycerol, and gelatin was confirmed by FTIR and SEM.

Hence, the resulting optimized film may be expected to provide theoretical basis and technical support for the food packing industry. This development of biodegradable materials for food packaging has been significantly increasing due to the various environmental problems associated with synthetic materials derived from petroleum. Due to waste accumulation and the environment pollution as well as low recycling percentage of non-biodegradable (synthetic plastic) materials, it is great to develop biodegradable materials which are eco-friendly in nature. Biodegradable plastics are a new generation of polymers emerging on the world market. These materials can be extracted from agricultural by products or waste, increasing their added value and providing significant economic and environmental benefits. (Silva et al., 2019) Films based on cassava starch have been widely used for fruit coating; however, it is necessary to incorporate other polymers in order to improve mechanical properties, once starch only leads to highly hydrophilic films, compromising their application. Lower amounts of starch led to more flexible, less opaque and soluble films, while the combination of higher levels of starch and chitosan was responsible for lowering films water vapor transmission rate showing some interesting properties for fruit surface coating. They have been widely assessed as alternative packaging films because of their admirable degradability, compatibility, and potential for wide range applications.

The fundamental advantage of starches comes from their excellent capacity to be moulded into transparent, odourless films without the need for any chemical treatment. Starch can be subjected to physical, chemical, enzymatic, and genetic treatments that result in new gelatinizing and pasting capabilities as well as better processing results. But there are significant restrictions on using starch alone as a food product packaging material, such as its hydrophilic nature and brittleness, which have an impact on the mechanical and barrier qualities of the films. In addition to enhancing the mechanical and barrier qualities of packaging films, the inclusion of certain plant extracts may also have a good impact on their antioxidant and antibacterial activity.

1. Development of antimicrobial films using plant extracts:

Active and smart biodegradable films were produced from cassava starch and glycerol with 5 wt.% of different natural extracts such as green tea and basil leaves degraded in soil under two weeks and were thermal stable up to 240°C (Medina-Jaramillo et al., 2017). Moringa leaf extract was added to the wheat starch possessed good antioxidative activities and ultraviolet light blocking ability and concluded that films containing 1.0% MLE were biodegradable within 30 days (Ju et al., 2019). Similarly, incorporation of several plant extracts not only enhancing the antimicrobial property but also helps in improving the mechanical properties of the film. Elongation at Break, ultraviolet/visible light barrier and antioxidant properties of sword bean starch film was improved when goji berry extract was added (Kim et al., 2020). Methanolic extract of *Artemisia sieberi* when added to sago starch film the physical properties of the films were significantly enhanced with the increase concentration of the extract (0 to 10%) (Ekramian et al., 2021).

The antibacterial activity of the biodegradable starch film with the addition of chicory root extract (1–5%) extracts were tested against Gram-negative bacteria (*Pseudomonas fluorescens, Escherichia coli*) and Gram-positive bacteria (*Bacillus subtilis, Staphylococcus aureus*) using the microculture method (Jaśkiewicz et al., 2020). The influence of avocado seed starch and orange peel essential oil was investigated and optimized using response surface methodology and an artificial neural network on the tensile strength, water vapor permeability, and antimicrobial properties of active films (Waday & Aklilu, 2023). The film composed of polyvinyl alcohol (PVA), corn starch (ST), glycerol, and the active compounds from watermelon rind extract (WMRE), was examined for its mechanical, antioxidant, and functional properties. The results showed that the addition of 10% v/v of watermelon rind extract to the film formulation significantly increased the tensile strength and slightly increased the percent elongation at break. Consumer testing of the packaging film indicated that user acceptance of the product was favourable (Todhanakasem et al., 2022). (Ramesh et al., 2021) developed an edible film using avocado

seed starch. The results revealed that the increment in the contents of sorbitol reduces the WP of the film. Using the response surface analysis, the effect of the aforementioned factors was analyzed; they showed significant impact on WP. The novelty of taro peel starch (TPS) to produce such films using the casting technique is reported for the first time. A response surface method (RSM) approach was employed to optimize different concentrations of TPS (2.5–3.5%, w/w) and glycerol (25–35%, w/w) and investigate their effects on the physico-mechanical and water barrier properties of TPS films. All films exhibited homogenous, transparent surfaces with flexibility and completely degraded in 5 days in simulated river water and composting soil environments which confirmed TPS as a promising film polymer in food packaging.(Bidari et al., 2023). The influence of alginate edible coatings enriched with black cumin (BC) extract was investigated to preserve the quality of guava fruits for 16 days at 11 ± 1 °C and 85 ± 2% relative humidity. The antibacterial activity of BC extract was also proved against *Staphylococcus hominis* and *Escherichia coli* with the inhibition zone diameter. Fruits treated with alginate coating in a combination of BC extract retarded the ripening index of guavas till the end of the storage period compared to control samples. The content of vitamin C, total phenolics, and total flavonoid in fruits treated with BC extract–loaded alginate coating was significantly higher than control, alginate with -CaCl2, and alginate itself treatments. Moreover, the concentrations of BC extract were worked in a dose-dependent manner in the coating systems in retarding respiration rate, weight loss, firmness loss, and ripening processes. These results proved that BC extract as a novel functional ingredient in alginate coatings was efficient in improving the quality of guava fruit and prolonging its shelf life (Hasan et al., 2022). (Rajapaksha & Shimizu, 2021) used black tea extract (SBT) as an active ingredient in food packaging. Incorporating microencapsulated SBT improved the mechanical properties of active films and preserved their antioxidant activity (276 and 627 μg(GAE)/g film). Encapsulates significantly enhanced the release of antioxidant polyphenols into both aqueous and fatty food simulants revealing the incorporation microencapsulated SBT in starch film can be used as a functional food packaging to protect fatty foods from oxidation. Effect of biopolymer materials of red palm oil and miserly leave extract on mechanical and functional characteristics of canna starch based edible film was studied using factorial randomized block design with two treatment factors consisting of red palm oil (0.5; 1.0; and 1.5%v/v) and miserly leave extract (1.0; 2.0; and 3.0%v/v). Research results showed that the concentration increase of red palm oil had increased the thickness, compressive strength, total phenol, antioxidant and antibacterial activity of the edible film, but the percent elongation and the rate of water vapor transmission had decreased (Santoso et al., 2022). (Mustapha et al., 2019) investigated the antimicrobial activity and biodegradability of the biopolymer film using response-surface methodology. The results showed that both the coating thickness and the turmeric oil volume significantly affected these responses. From the response-surface plot, the highest value for the inhibition zone of *Aspergillus niger* and the lowest weight loss during the biodegradation study were due to the slow release of antimicrobial agents indicating the release of antimicrobial agents during the correct stipulated period of time required to inhibit the microorganisms' growth. (Bajić et al., 2020) A hydrolysable tannin-rich extract from fibrous chestnut wood *(Castanea sativa Mill.)* was combined with an active chitosan-based film underwent simultaneous engineering optimisation for measured moisture content (MC), tensile strength (TS), elongation at break (EB), and total phenolic content (TPC). The obtained quadratic (TS or EB), two-factor interaction (TPC), and linear (MC) sets were found to match the distinctive experimental data well ($0.969 < R2 < 0.992$), to be statistically significant ($p < 0.05$), and to be potentially predictive. While every system component had some bearing, the amount of polyol was crucial in determining the characteristics of EB, MC, and TS, and the fluctuation in chestnut extract resulted in a predictable alteration that affected TPC. These methods not only preserve the functional and technological properties of food products, lowers their mass loss, and extends their shelf life, but also reduces costs and is environmentally friendly.

2. Application of plant-based polymers in meat and fish packaging:

The transformation of muscle into meat requires certain technological procedures; any insufficiency at this step will have a severe detrimental influence on the final product and/or process. In addition to cleanliness and storage temperature, the degree of spoiling is also influenced by the acidity of the meat and the composition of the muscle tissue. Meat deterioration progresses to the point that lipid oxidation, protein degradation, and the loss of other essential components occur. The formation of chemical compounds that alter the

flavour, tenderness, juiciness, texture, appearance, and smell of meat is triggered by this harmful breakdown of fat and protein. Therefore, to maintain the freshness of these muscle foods for a longer period of time, it is imperative to prevent spoiling of meat and meat products. Packaging that involves not only protecting the product from the outer environment but also protecting them from internal spoilage is required. Many plant-based polymers that are incorporated by bioactive compounds extracted from various parts of plant is gaining a lot of attention now a days.

Different types of plant-based polymers were tested and used effectively in wrapping meat and fish products. Incorporation of oils and bio-active compounds from different plants into the polymers played a significant role in inhibiting different kinds of microbes. Enhancement of storage period of different meat products was observed along with the inhibition of various types of microbes. Incorporation of rosemary extract into the biofilm composition to monitor the freshness of fish fillets showed good compatibility of the components and good dispersion of RE in the matrix (Du et al., 2021).Vegetable oils and essential oils were incorporated into the films. the best antioxidant properties were observed in films with flaxseed oil, ginger essential oil, grape seed essential oil and rose oil, were selected and applied as active packaging for fresh meat and tested at industrial scale(Wrona et al., 2021). The best packaging was 50 µm LDPE film mixed with flaxseed oil, which allowed fresh meat to have a 22% longer shelf life. It has been established that the flaxseed oil concentration was essential to the film's antioxidant properties.

As a way to increase shelf life, the impact of a bioactive coating made of guar gum and thyme oil on the quality of tilapia fish fillets was assessed after 15 days of storage at 4 °C. Between coated and uncoated fish fillets, there were variations in textural and sensory characteristics and reduced ($p < 0.05$) degradation. The results of the microbiological investigations showed that the uncoated fillets had more microbial growth than the coated ones (Ruelas-Chacon et al., 2020). (Echeverría et al., 2018) analysed whether the clay diffuses from the package to food and assessed the possible use of active nanocomposite films based on soy protein isolate (SPI)-montmorillonite (MMT)-clove essential oil (CEO) for preserving the muscle fillets of bluefin tuna (*Thunnus thynnus*) during refrigerated storage. During the storage period under investigation, tuna fillets' lipid autooxidation and microbiological growth (measured by TVBN and microbe counts) were reduced by protein sheets nanoreinforced with 10 g MMT / 100 g SPI and activated with CEO. As clay extends clove oil's antibacterial properties, it appears to facilitate the release of the oil's active ingredients (*Pseudomonas spp).*

(Bharti et al., 2020) developed *Manihot esculenta* and Carrageenan bio-based composite active film functionalized with anise, caraway, and nutmeg essential oils (EOs) and to assess the shelf life of chicken nuggets. Overall, the Minimum Inhibitory Concentration (MIC) values of the three EOs ranged from 0.4 to 0.8% v/v of which nutmeg EO was found most effective. The treated samples were well acceptable during whole storage period of 15 days. The application of composite, active edible bio-based film was found proficient in confining product quality attributes throughout storage. Carrageenan-based active packaging film was prepared by adding olive leaf extract (OLE) as a bioactive agent to the lamb meat packaging. The effects of the OLE on the thickness, water vapor permeability (WVP), tensile strength (TS), elongation at break (EB), elastic modulus (EM), color, solubility, and antimicrobial capacity of the carrageenan film were determined. The results showed that the addition of OLE increased the thickness, EB, and WVP, and decreased the TS and EM of the film.(Martiny et al., 2020) film with the OLE was shown to have an antimicrobial capacity during the storage of lamb meat, reducing the count of psychrophiles five-fold when compared to the samples packed by the control and commercial films therefore, this novel film has the potential to increase the shelf life of lamb meat, and as such, is suitable for use as active packaging.

In order to determine whether the recently developed intelligent pH-indicator furcellaran (FUR) films made with extracts from beetroot root (BTR), elderberry (EB), blueberry (BB), green tea (GT), and yerba mate (YM) can function as pH-change indicators, as well as to determine how colour changes in the films correspond with changes in the microbiological, physicochemical, and sensory parameters of fresh Atlantic mackerel while it is being stored at 2°C in a food packaging system. The trained sensory panellists were not adequately

informed about the spoiling of the stored Atlantic mackerel by the colour changes in the films. The fish spoiling test revealed that the recently created films were unsuitable for use as intelligent pH sensors, despite encouraging first results.(Jamróz et al., 2019).

(Albertos et al., 2019) used seaweeds extracts of (*Himanthalia elongata* and *Palmaria palmata*) for formulation of active edible films. Compared to films prepared with *P. palmate*, those formulated with *H. elongata* exhibited higher levels of total phenols and antioxidant capacity. The use of seaweed-enriched edible films in the fish burgers considerably decreased microbial growth and controlled pH and water activity variations over storage, particularly when *H. elongata* was used in the formulation of the edible films as opposed to the control group. (Ehsani et al., 2020) Used active biodegradable sheets containing lactoperoxidase system (LPS) or sage essential oil (SEO), the deterioration of fish burgers made of common carp flesh was minimized. When compared to other treatments, chitosan films containing LPS were the most successful in considerably suppressing the growth of TVC, PTC, Pseudomonas spp., Shewanella spp., and TBARS throughout a 20-day storage period at refrigerated conditions.

(Kanatt, 2020) reported the effect of Amaranthus leaf extract (ALE) on the physical, mechanical and functional properties when incorporated into the film. Samples in active films spoiled after 12 days, whereas those in tidy films had a 3-day shelf life. This is the first study of its kind to make a gelatin extract from carp skins enhanced with dry herbs, in this case rosemary or thyme. Furcellaran coatings were enhanced with extracts that were made in this manner. (Tkaczewska et al., 2023)Coatings were tested for their mechanical properties and the obtained results showed that the control coatings, and those with the addition of rosemary, had the best strength-related parameters. A new ready-to-cook product was evaluated with regard to the preservative effects of carp skin gelatin coatings containing rosemary and thyme extracts in terms of pH, biogenic amine formulation, microbial changes and sensorial characteristics. The coatings with added rosemary proved effective in inhibiting the formation of biogenic amines, and slowing down the microbial deterioration of carp fillets (reduction by 0.53 and 0.29 log cfu/g). The evaluated herb coatings changed the characteristic taste of fish. Interestingly, the coatings emphasized the natural saltiness of fish meat.

(Derbew Gedif et al., 2023) examined how carp fish quality was maintained when refrigerated and the impact of furcellaran-gelatine coatings combined with herb extracts. The results indicated a tendency towards redness and yellowness as well as a slight deepening of colour in the carp fillets treated with the extracts of thyme and rosemary. As a result, the innovative coatings created from leftover fish processing material may prove to be highly beneficial as additives in quick-fix meals and may extend the shelf life of carp fillets stored in cold storage.

(Giro et al., 2020) studied the properties of biodegradable film based on a bacterial exopolysaccharide (xanthan) with the view to extend the quality and shelf life of chilled meat products. The ecological safety of the raw materials as well as sensory, physicochemical, and microbiological characteristics improved with the use of biodegradable packaging. Microbiological and sensory markers verified that the carp had been preserved in terms of quality and freshness with the usage of biodegradable film. Carp packaged in biodegradable film had a one-day longer shelf life than unpacked samples due to a considerable reduction in total microbial contamination. (Moon et al., 2020) evaluated the antimicrobial activity of 10 essential oil compounds against Salmonella. The study's conclusions demonstrated that bacteriophage combined with carvacrol and thymol considerably decreased the amount of Salmonella in chicken flesh. These findings offer a viable method to lessen the risk of Salmonella contamination in uncooked poultry products. (Van Haute et al., 2016) studied the usage of essential oil (EOs) in marinades were used on fish and meat and the effect on the microbial growth during storage was assessed. EOs from *Oreganum compactum* (oregano), *Cinnamomum zeylanicum* (cinnamon), and *Thymus zygis ct*. Thymol (thyme) were chosen. The marinade was composed of water, Na-lactate/lactic acid buffer (2 w/w %), NaCl (10 w/w %), and EO emulsified with Tween 80 and with a pH of 4.5. The necessary Tween 80 to emulsify the EOs in the marinade depended on the EO type and was increased more than tenfold by the NaCl and lactate buffer. The treatment consisted of immersion of meat (pork filet, pork bacon, chicken filets, chicken 25 skin), salmon or scampi for 2 min in marinade solution. The samples were stored at 4°C in air. Samples were analyzed for microbial

counts. The results in this study show that the sensorial properties of the meat/fish are inevitably affected when the necessary EO concentrations to extend the microbial shelf life are applied. (Priyadarshi et al., 2021) produced films that were combined with zinc oxide nanoparticles and grape seed extract (GSE, 5 weight percent of CMC) using the solution casting technique. The CMC-based films showed almost 95% and 25% scavenging activity against ABTS and DPPH oxidative free radicals, respectively, with the addition of GSE, which gave the films outstanding antioxidant activity. In order to look into quality alterations, high-fat beef was wrapped in the CMC-based film and refrigerated for 15 days. 5.9 Log CFU/g of psychrotrophic bacteria were found in the meat wrapped in CMC/ZnO3%/GSE film, which is within the permissible range.

3. Discussion:

Most of the plastics used in food packaging is single-use and used on-the-go, and the waste produced by these non-recyclable or non-biodegradable food packaging wastes poses a serious threat to the environment on land and in water. As a result, there is an increasing understanding of the necessity for food packaging material to adhere to environmental standards. The films must also adhere to the requirements for reducing food loss and maintaining the quality of food products in addition to greater ecological importance it can be made from biopolymeric materials that have been incorporated with natural active chemicals that operate as oxygen scavengers, antioxidants, antimicrobials, ethylene scavengers, and moisture absorbers. The advantages of edible films and coatings made from natural materials over synthetic ones have attracted a lot of interest in recent years. These films decompose more quickly than polymeric materials since they were made solely from edible, renewable elements. The current demand of consumers for more durable food products makes it necessary to develop of materials that are eco-friendly and functional, such as packaging with active compounds that can improve the quality of the products they cover, further contributing to the nutritional value of food. Because of its widespread availability, ease of extraction, high yield, low cost, and variety of functional characteristics that improve its biocompatibility in the food system.

Different types of plant extracts when incorporated into the film reacts differently with the food products due to the presence of various types of bio active compounds present in the film. These compounds have attracted a great deal of attention in the scientific field. Plant extracts demonstrate a broad spectrum of active properties and relatively low toxicity while not causing significant side-effects on human health. Polysaccharide-based films protect raw materials and food products from mass loss (due to reduced moisture evaporation rate) and from the penetration of oxygen and other substances. As a result, it slows down the changes in the product quality. Films based on microbial polysaccharides are not yet sufficiently used in national economies. It has also improved the stability of lipids and lipid-containing foods, thereby preventing sensorial and nutritional quality loss. Many herbal extracts have antioxidant activity due to their polyphenolic, phenolic acid, biological and anticoagulant compounds. These constituents have made it possible to replace chemical preservatives with them. They are also adequate for daily consumption. They have lower barrier and mechanical properties (resistance to high product and environment moisture) than polymeric films. But their main advantage is that they do not pollute the environment because they are biodegradable.

4. Conclusion:

The development of novel food packaging materials can be stimulated by the application of edible films and coatings. Eco-friendly food films and packaging have been made by using agro-based polymers such as starch, sodium alginate, pectin, chitosan, cellulose, whey protein, gelatin, soy, and gluten proteins. Furthermore, the synthesis of bioactive films with antioxidants, antimicrobial activity, and eye-catching colours is made possible by the combination of derived-plant bioactive chemicals (phenolic compounds, carotenoids, and vitamins, among others) and agro-based polymers. The film's enhanced stability and regulated release rate facilitate the transport of

bioactive chemicals from the film to the food's surface, where they initiate their antimicrobial action and inhibit the oxidation of various components, including lipids. Comparing films made of agro-based polymers to synthetic plastic films, the later often possess superior mechanical and barrier qualities. Over the years, researchers have created contrasting edible films for the packaging of meat. Nonetheless, there are still several issues with meat and meat products, such as their affordability, application, and least sensory change. In addition to improving food quality and safety, the application of edible films to muscle foods containing other food-grade compounds (such as chelators, antimicrobials, and antioxidants), bio-based, edible, or biopolymer packaging can also delay deterioration, increase shelf life, and, in certain situations, give the food desirable qualities (colour, flavour, etc.). Not much information is known about the mechanisms underlying this process, particularly with regard to the regulated release of the bioactive ingredient into the food. Films are still produced on a laboratory scale, despite having many advantageous qualities like biodegradability and bioactive properties. In order for their production to shift to an industrial scale, problems with processing, high cost, and standardising film properties must be fixed.

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