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Right Methods to Extend the Meat Shelf- Life by Using of Natural Preservatives and Their Public Health Importance

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Abstract

Meat is an excellent source of nutrients for human beings. Meat provides a favorable environment for microbial growth. Prevention of microbiological contamination of meat, chemical preservatives, including nitrites, nitrates, and sorbates, have been used in food processing due to their low cost and strong antibacterial activity. The application of chemical preservatives is recently being considered by customers due to concerns related to negative population health issues. Demand for natural substances as food preservatives has increased with the use of plant-origin and animal-origin foods and microbial metabolites. In regarding Natural preservatives inhibit the growth of spoilage bacteria or foodborne pathogens by increasing the permeability of microbial cell membranes, interrupting protein synthesis, and cell metabolism. By using Natural preservatives, we can extend shelf-life and inhibit the growth of bacteria. In regarding to natural preservatives can affect food sensory properties, including flavor, taste, color, texture, and acceptability of food. In regard to Increasing the applicability of natural preservatives, a number of strategies, including combinations of different preservatives or food preservation methods, such as active packaging systems and encapsulation, have been used for applications of methods of natural preservatives in meat.

Key Words: Meat, preservation methods, packaging, food-borne pathogens, population health.

Introduction

Food-borne pathogens, including Listeria monocytogenes, Staphylococcus aureus, pathogenic Escherichia coli, Clostridium perfringens, Campylobacter spp., and Vibrio spp., cause a large number of illnesses, with substantial damage to population health and economy. World Health Organization, food contaminated with food-borne pathogens, chemicals, and allergens results in 600 million cases of foodborne illness and four hundred thousand deaths worldwide/ year, Fifty-six million people die /year and 7.7% of people worldwide suffer from food-borne diseases. Meat is an important nutrient source for human beings due to its excellent protein content, essential amino acids, vitamin B groups, and minerals. Meat provides an appropriate environment for spoilage bacteria or food-borne pathogens due to its high water activity and important nutrient factors **[1,2,3,4,5,6,7]**. Food processing has advanced worldwide, resulting in an enhanced threat of food contamination by food-borne pathogens, chemical residues, harmful food additives, and toxins. Multiplication of spoilage and pathogenic bacteria should be controlled to ensure food safety. Food preservation methods for protecting food from food-borne pathogens and extending shelf-life include chemical methods, such as the use of preservatives; physical methods, such as heat treatment, drying, freezing, and packaging; and biological methods using bacteria that have an antagonistic effect on pathogenic bacteria and produce bacteriocins. The addition of food preservatives that inhibit the growth of bacteria is a widely used food protection technique. Countries in the world have different regulations for food preservatives **[8,9,10,11,12,13,14]**. Chemical preservatives have an advantage for meat production due to low cost, guaranteed antibacterial effect or shelf-life extending activity, and little action on the taste, flavor, color, and texture of meat. Chemical means of meat preservatives tend to be less preferred by consumers because of a number of population health concerns regarding their side actions. Consumers selected preservatives as the most concerned food additive owing to their negative action on population health. Sorbic acid, benzoic acid, and their salts promote mutagenic and carcinogenic compounds. Both methods, Nitrites, and nitrate, used as preservative and coloring agents in meat preservation methods, were associated with leukemia, colon cancer, bladder cancer, and others. Methods of Natural preservatives have emerged as alternatives to chemical preservatives. Methods of Natural preservatives have shown potential to provide effective antimicrobial activity and reduce negative population health action. Meat contaminated by chemical additives is a major concern for population health. Meat producers and researchers have begun to consider the use of natural rather than chemical preservatives **[15,16,17,18,19,20,21]**. 'Clean label' food trends, including meat and its products, began and possessed an important source of food marketing. It includes consumer-friendly characteristics, such as chemical additive-free, least processing, a brief list of food ingredients, and the procedure of traditional methods. clean label food material market, including natural preservatives, is likely to value, mostly owing to growing consumer requests for all-natural products. Natural preservatives such as nisin, natamycin, ε-polylysine, and grapefruit seed extract are registered, but they are not approved for meat, or their concentration is not specified. Replacement of chemical preservatives with natural preservatives has major positive action and is being accepted by customers. Food producers also encounter challenges, including a decrease in price competitiveness due to the relatively high price of natural preservatives and a decrease in antibacterial effect due to food ingredients, such as carbohydrates, proteins, and lipids. In the case of plant-origin substances, standardization is problematic because of the influence of country of origin, soil, and harvest seasons. Toxicity evaluation or identification of exact compounds for several plant-origin compounds contained in extracts and essential oils have been performed. Solving these problems, various studies have been conducted to optimize the extraction process, combine other antimicrobial substances, apply active packaging, and encapsulate antibacterial substances to improve their utilization **[22,23,24,25,26,27,28]**. This review summarizes current knowledge about the application of natural preservatives for meat against food-borne pathogens and spoilage bacteria.

Application Technique of Natural Preservatives to Meat and its Products

Natural preservatives are manufactured in a variety of formulations including powder formed by drying methods and liquid forms such as essential oils. Natural preservatives are directly added to meat and extend shelf-life by inhibiting bacterial growth. It is possible to increase the antibacterial effect of natural preservatives through a combination of other food processing methods **[29,30,31,32,33,34,35]**. In the case of plant-origin natural preservatives, it is necessary to consider the form applied to food. Natural preservatives are commonly prepared in the form of extracts using organic solvents, water, and essential oils. plant extracts obtained from rosemary, chestnut, sage, cranberry, oregano, grape seed, and others have been used as meat preservatives. application of plant-origin substances to meat products in the form of essential oil because the antibacterial effect of the essential oil type is better than that of the extract type. It is difficult to apply large amounts of essential oil to food because of its distinct organoleptic properties. Recent developments have attempted to solve this problem by applying essential oils with other antibacterial substances. advantage of this application is that it reduces amounts of essential oils with strong flavors and increases antioxidant and antibacterial action through synergistic action. In terms of an industrial perspective, if chemical preservatives cannot be completely replaced with natural preservatives, due to industrial problems, such as increasing economic costs or complexity of the product manufacturing process, they could be replaced gradually by composing a mixed formulation of chemical preservatives and natural preservatives **[36,37,38,39,40,41,42]**. gamma irradiation and high-pressure processing (HPP) treatment are physical food-processing methods that can further increase the antibacterial efficacy of natural preservatives. Unlike thermal food processing, these two food processing techniques could be used for the pasteurization of raw meat because it has a minor effect on food composition. In 1997, WHO, the Food and Agricultural Organization (FAO), and the International Atomic Energy Agency (IAEA) concluded that foods processed in proper doses of irradiation are nutritionally sufficient and safe to consume. Irradiation is permitted for food preservation methods in more than sixty countries. Recent approaches in food irradiation have involved the use of combined treatments with natural preservatives to reduce irradiation doses. Gamma irradiation of medium doses (2–6 kGy) with natural compounds and active packaging has been applied to extend the shelf-life of meat. HPP is also a non-thermal method for food preservation that inhibits the growth of bacteria and maintains food's natural properties. HPP is performed under high pressures (100–800 MPa) at mild temperatures or weak heating. The potential capability of combining HPP and natural preservative methods including essential oil and antibacterial peptides in alleviating both processing conditions of HPP and concentration of natural preservatives while maintaining antibacterial action **[43,44,45,46,47,48,49]**. Encapsulation is one of the effective methods for expanding the applicability of natural preservatives to food. Encapsulation was performed with GRAS (generally recognized as safe) materials such as alginate, chitosan, starch, dextrin, and proteins using various techniques including spray drying, extrusion, freeze drying, coacervation, and emulsification. The use of natural preservatives in meat is limited due to their characteristics, such as low solubility and bioavailability, rapid release, and easy degradation. Environmental conditions, such as pH, storage temperature and time, oxygen, and light exposures could influence the efficacy of natural preservatives. Through encapsulation, natural preservatives, especially hydrophobic compounds (e.g., essential oil), could improve its stability and expand the versatility of food processing while maintaining an antibacterial effect **[50,51,52,53,54,55,56]**. Active packaging is an innovative packaging technology that allows for an interaction with a product and its environment to extend shelf- -life and ensure its microbial safety while keeping the original properties of packaged food. In relation to European Union Guidance to Commission Regulation, active packaging is a type of food packaging with a further beneficial function, while providing a protective barrier against external influence. In meat processing, antimicrobial active packaging could be applied in several methods which are the incorporation of natural preservatives into a sachet inside packaging, packaging film composition with natural preservatives, packaging coated with natural preservatives onto the surface of food, and use of antimicrobial polymers as packaging materials **[57,58,59,60,61,62,63]**. Application of microorganism origin natural preservatives, known as biopreservation methods, in which useful bacteria or their antibacterial substances have antagonistic action on pathogenic or spoilage bacteria, are also a meat preservation method in the spotlight. The method is mainly applied in lactic acid bacteria, Lactobacillus spp., Leuconostoc spp., Pediococcus spp., and Lactococcus spp., that have a GRAS status, widely participate in fermentation processes, and produce various antibacterial metabolites such as organic acids, hydrogen peroxide, and bacteriocins methods. In terms of application to meat products, bio-preservation methods included direct inoculation with lactic acid bacteria, which has an inhibitory effect on spoilage or pathogenic bacteria, the inclusion of bacterial strains producing antimicrobial substances in fermentation starter, and treatment with purified bacteriocins **[64,65,66,67,68,69,70]**.

Natural Preservatives from Plants and Their Application for Meat and its Products

The antibacterial effect of plant-origin natural preservatives is closely related to polyphenols, phenolics, and flavonoids. Plant-origin polyphenols have various classifications and structures, as phenolic acids (caffeic acid, rosmarinic acid, gallic acid, ellagic acid, cinnamic acid), flavones (luteolin, apigenin, chrysoeriol), flavanols (catechin, epicatechin, epigallocatechin, gallocatechin, and their gallate derivatives), flavanones (hesperidin, hesperetin, heridictyol, naringenin), flavonols (quercetin, kaempferol, myricetin), isoflavones (geinstein, daidzin, formononetin), coumarins (coumarin, warfarin, 7-hydroxycourmarin), anthocyanins (pelagonidin, delphinidin, cyanidin, malvidin), quinones (naphthoquinones, hypericin), alkaloids (caffeine, berberine, harmane), and terpenoids (menthol, thymol, lycopene, capsaicin, linalool) **[71,72,73,74,75,76,77]**. Polyphenols have been recognized for their effective antimicrobial properties. Although the antimicrobial mechanism has not yet been clearly elucidated, cell membranes disturb molecules, such as hydroxy group (OH-), which induces leakage of intracellular components, inactivation of metabolic enzymes, and extinction of adenosine triphosphate (ATP) structure; direct pH change in environment by improvement in proton concentration, reduction of intracellular pH by separation of acid molecules, and modification of bacterial membrane permeability; an organic acid in plant extracts may influence the oxidation of nicotinamide adenine dinucleotide (NADH), eliminating, reducing agent used in electron transport system **[78,79,80,81,82,83,84]**.

Rosemary

Rosemary (Rosmarinus officinalis L) is a perennial herb with woody, aromatic, and evergreen needle-like leaves. Originally from the Mediterranean region, it is broadly distributed throughout the globe. Rosemary has been used in food as a spice and flavoring agent. Rosemary essential oil is known to contain fifteen kinds of bioactive compounds. The principal compound was 1,8-cineole (35.32%). Other major compounds were camphor, α-pinene, trans-caryophyllene, α-thujone, and borneol **[85,86,87,88,89,90,91]**. Antibacterial effect of rosemary ethanol extracts against Listeria monocytogenes in beef. Application of 45% rosemary ethanol extract for Listeria monocytogenes on beef led to a two-log CFU / gram reduction in incubation at 4 °C for nine days. In chicken meat, the effect of rosemary essential oil on inhibition of Salmonella Enteritidis and spoilage protective action at four and 18 °C was investigated. Five mg/mL of rosemary essential oil induced a decrease in coliform, aerobic bacteria, lactic acid bacteria, and anaerobic bacteria at 18 °C for one day. Compared with untreated chicken meat, reductions of 1.75 log CFU / gram (coliform), 0.87 log CFU / gram (aerobic bacteria), 1.05 log CFU / gram (lactic acid bacteria), and 1.28 log CFU / gram (anaerobic bacteria) were observed in the group treated with rosemary essential oil at 18 °C. Rosemary oil reduced S. Enteritidis by more than two log Colony Forming Units/gram at 18 °C, but less than one log CFU / gram at 4°C **[92,93,94,95,96,97,98]**. Rosemary essential oil applied with modified atmosphere packaging for inhibition of food-borne pathogens such as S. Typhimurium and Listeria monocytogenes in poultry filets under refrigerated conditions for seven days was examined. The 0.2% rosemary essential oil did not affect the sensory profile and inhibited the growth of food-borne pathogens in laboratory media within one day. Treatment with 0.2% rosemary essential oil did not affect the reduction in S. Typhimurium but showed weak antibacterial activity against Listeria monocytogenes until the first day of storage (0.1 log CFU / gram reduction compared to control) **[99,100,101,102,103,104,105]**.

Sage

Sage (Salvia officinalis L.), belonging to the Lamiaceae family, has been used since the prehistoric eras because of its flavor, taste, therapeutic, and preservative properties. Sage is known to contain considerable amounts of rosemary acid, p-coumaric acid, and benzoic acid. Sage essential oils, camphor, carvacrol, R(+) limonene, and linalool are major components in terms of content **[106,107,108, 109,110,111]**. The antibacterial action of various sage preparations was assessed for low-pressure mechanically separated meat in vacuum packaging stored at −18°C for nine months. Mechanically separated meat from chickens with the addition of sage extracts inhibited the growth of all groups of bacteria (mesophilic aerobic bacteria, psychrotrophic bacteria, Enterobacteriaceae, coliforms, and enterococci). The most effective antibacterial effect was exhibited by 0.1% sage essential oil treated groups **[112,113,114,115,116,117]**. Antibacterial effect of sage essential oil (0.625%) on survival of Listeria monocytogenes in Sous vides cook chill beef stored in refrigerated storage (two or 8 °C) for 28 days. A decrease of one log CFU / gram of Listeria monocytogenes was detected in sage essential oil treated groups compared to control at 2 °C. Exponential growth was observed from day 14, and decreased Listeria monocytogenes counts of one log CFU / gram were detected in sage essential oil-treated samples stored at 8°C **[118,119,120,121,122,123]**.

Thyme

Thyme (Thymus vulgaris) is a representative herb used together with meat. Application of thyme in meat processing can elevate antioxidant, antibacterial, shelf-life extension, and sensory properties. In meat sausage, thyme essential oil inhibited 2.69 log Colony Forming Unit/gram of coagulase-positive Staphylococcus and 4.41 log Colony Forming Unit/gram of aerobic mesophilic bacteria, respectively, at a concentration of 0.95% by mixing with 1% (w/w) powdered beet juice. Sensory properties, odor, flavor, and overall acceptability improved **[124,125,126,127,128,129]**. The 1% thyme oil led to a reduction in S. enterica by three log Colony Forming Unit/gram during the margination process with lemon juice and 0.5% Yucca schidigera extract in raw chicken breast. Most compositions of thyme oil revealed 51.1% and 24.1% thymol and O-cymene, respectively. The antibacterial action of thyme may be due to additive or synergistic action with its major and/or minor components. Thymol and its synergistic effect with other phenolic compounds, such as carvacrol, p-cymene, and γ-terpinene, can change the permeability of bacterial cell walls, leading to cell death **[130,131,132,133,134,135]**. Thyme essential oil encapsulated with casein and maltodextrin was evaluated for its antibacterial potential in vitro and in situ (hamburger-like meat products). Encapsulated thyme essential oil showed the same minimum inhibitory concentration (0.1 mg/mL) against Escherichia coli, S. Typhimurium, Staphylococcus aureus, and Listeria monocytogenes as that of unencapsulated thyme essential. In treated groups with 1% (v/v) of encapsulated thyme essential oil for meat, Escherichia coli counts were decreased from 23 most probable number (MPN)/ gram to 0 MPN/ gram, which was similar to conventional preservative (sodium nitrate) used as a control until 14 days of refrigerated storage (4°C) **[136,137,138,139,140,141]**.

Oregano

Oregano (Origanum vulgare) is regularly used in foods of the Mediterranean Sea area. Oregano essential oil has recognized antibacterial and antioxidant properties for extension of shelf-life. The antibacterial action of oregano was due to two bioactive polyphenols, thymol, and carvacrol

[142,143,144,145,146,147]. Oregano essential oil and its effect on the shelf-life of black wildebeest Biceps femoris muscles was investigated at 2.6°C. Components of oregano oil were thymol, carvacrol, ρ-cymene, β-caryophyllene, γ-terpinene, α-humulene, and α-pinene; among them, carvacrol (42.94%) and thymol (17.40%) were highest. Total viable counts and lactic acid bacteria reached the spoilage limit (seven log Colony Forming Unit/gram) after three days. Growth rates for total viable counts and lactic acid bacteria in the treated group were 40% higher than those in untreated groups **[148,149,150,151,152,153]**. The combinatorial effect of oregano essential oil with caprylic acid was studied in vacuum-packed minced beef. Addition of 0.2% oregano essential oil with 0.5% caprylic acid and 0.1% citric acid in minced beef reduced counts of lactic acid bacteria by 1.5 log Colony Forming Unit/gram in vacuum packaging. Cell counts of psychrotrophic bacteria and Listeria monocytogenes were reduced by more than 2.5 log Colony Forming Unit/gram at 3 °C for 10 days. Oregano essential oil inhibits the growth of bacteria by releasing volatile components during the drying process. The addition of oregano essential oil composed of carvacrol (64.5%), p-cymene (5.2%), and thymol (2.9%) inhibited S. Enteritidis and Escherichia coli in the beef drying process. For drying, a filter paper was soaked with oregano essential oil and placed in front of a fan of the drier. Beef samples were dried at 55 °C for 6 hours. Both bacteria (S. Enteritidis and Escherichia coli) were not detected after treatment with three mL of oregano essential oil **[154,155,156, 157,158,159]**.

Chestnut

Castanea crenata was classified into the Castanea family and is a woody plant native to East Asia, including Korea and Japan. Castanea sativa is important for Castanea families and food resources of European areas for long periods. Chestnut shells contain abundant phenols and hydrolyzable tannins. Chestnut inner shell extracts using ethanol exhibited antimicrobial action against C. jejuni in chicken meat at a concentration of two mg/mL Polyphenol and flavonoid contents of chestnut inner shell ethanol extracts were 532.96 ± 3.75 mg gallic acid/100 g and 12.28 ± 0.03 mg quercetin/100 g, respectively **[160,161,162,163,164,165]**. The action of chestnut extracts (Castanea sativa) on leaf, bur, and hull of beef patties under refrigerated conditions (2 ± 1°C) for 18 days to extend shelf-life. Inside chestnut extracts from leaf, bur, and hull, only leaf extract at a concentration of 1000 mg/kg had weak antimicrobial activity. lactic acid bacteria and Pseudomonas spp. were reduced by 0.37 log Colony Forming Unit/gram and 0.33 log Colony Forming Unit/gram at seven days, respectively **[166,167,168,169,170,171]**.

Grapefruit Seed Extract

Grapefruit Seed Extract is a by-product of Citrus paradise. Grapefruit Seed Extract contains various phenolic compounds and flavonoids, such as catechin, citric acid, naringenin, procyanidin, and epicatechin gallate. Grapefruit Seed Extract has been described to have a wide-ranging spectrum of antimicrobial, antiparasitic, and antifungal activities. Polyphenols in Grapefruit Seed Extract are unstable but can be chemically modified to become more stable using quaternary ammonium compounds, such as benzethonium chloride, during industrial procedure of commercial Grapefruit Seed Extract preparations **[172,173,174,175,176,177]**. Bacteriostatic effect of commercial Grapefruit Seed Extract (Citricidal) on sous-vide chicken products against Clostridium perfringens. Cell numbers of Clostridium perfringens were consistently 2.5 log Colony Forming Unit/gram regardless of treatment or control groups until 9.5 h of stored at 19 °C; storage of control and 50 or 100 ppm Grapefruit Seed Extract treated groups at 25 °C for more than six hours resulted in fast growth rates of Clostridium perfringens, showing 2–3 log Colony Forming Unit/gram. Grapefruit Seed Extract concentrations at 200 ppm inhibited growth of Clostridium perfringens stored at 19 and 25°C. Active packaging system for inhibition of food-borne pathogens used mixed natural preservatives consisting of Grapefruit Seed Extract (80 mg/m^2) with cinnamaldehyde (200 mg/m^2) and nisin (60 mg/m^2) was assessed for beef storage. Active packaging showed decreased contamination of psychrotrophic and anaerobic bacteria compared to control groups at 1–2 log Colony Forming Unit/gram. Packaged beef samples with mixed natural preservatives showed a decrease in Listeria monocytogenes, Staphylococcus aureus, and C. jejuni for 4.7 log Colony Forming Unit/gram, 0.81 log Colony Forming Unit/gram, and 3.1 log Colony Forming Unit/gram compared to wrapped packaging at 28 days of refrigerated storage, respectively. C. jejuni was observed below the detection limit after 21 days of storage **[184,185,186,187,188,189]**

Cinnamon

Cinnamon is a native plant in Asia that is acquired from the inner bark of the genus Cinnamomum. Cinnamon contains several active compounds, such as cinnamaldehyde, eugenol, cinnamyl acetate, L-borneol, β-caryophyllene, caryophyllene oxide, camphor, L-bornyl acetate, α-terpineol, α-cubebene, α-thujene, and terpinolene. Cinnamon (Cinnamomum cassia) essential oils could inhibit L. monocytogenes in ground beef at refrigerated (0 and 8 °C) and frozen (–18 °C) conditions. The concentration of five percent cinnamon essential oil decreased by 3.5–4.0 log Colony Forming Unit/gram of Listeria monocytogenes at 0 and 8 °C for seven days. Under frozen conditions, Listeria monocytogenes was reduced by 3.5–4.0 log Colony Forming Unit/gram over 60 days. Antibacterial effect and shelf-life extending activity were evaluated using a chitosan edible coating containing 0.6% cinnamon essential oil on roast duck slices under modified atmosphere packaging (30% carbon dioxide (CO_2)/70% nitrogen (N_2)) at storage at 2 ± 2 °C for 21 days. Edible coating with cinnamon essential oil showed total viable counts reduced by one log Colony Forming Unit/gram compared to control after 14 days of storage. It is similar to the results of Enterobacteriaceae counts. The number of lactic acid bacteria decreased than that of control until day 7 of storage, but there was no significant difference from day 11 of storage. Growth of Vibrio spp. was delayed using edible coating with cinnamon essential oil within an earlier period of storage as a result of microbial diversity sequencing **[196,197,198, 199, 200, 201]**.

Turmeric

Turmeric (Curcuma longa L.) has long been used as a flavor and color agent in food and traditional medicine to treat various diseases, mainly in South and East Asia. The main active compounds of turmeric originate from its constituents, called curcuminoids. Curcuminoids (curcumin, demethoxycurcumin, and bisdemethoxycurcumin) content of turmeric varies between about 2–9% based on its growth environments, such as cultivar, soil, and climatic conditions. The antibacterial effect of turmeric on chicken breast meat was assessed for Escherichia coli and Staphylococcus aureus stored at 4 °C for two days. When 1% turmeric powder was added, no difference in Staphylococcus aureus counts was observed between turmeric-treated and control groups. In the case of Escherichia coli, a reduction of 0.2 log Colony Forming Unit/gram was observed, but this was not statistically significant **[202,203,204,205,206,207]**. Chicken meat was treated with turmeric powder and gamma irradiation to improve meat quality and stability. Total aerobic bacteria and coliforms were completely decontaminated with 3% turmeric powder and 2 kGy of gamma irradiation at 4 °C for 14 days. The microbial characteristics of edible coatings using turmeric starch and bovine gelatin were examined in frankfurter sausages. Edible coating was developed with a 5% (w/w) aqueous solution of turmeric starch and gelatin. Microbial growth of coated sausages stored at 5 °C for 20 days decreased by 2.21, 1.01, and 1.65 log Colony Forming Unit/gram for mesophilic bacteria, lactic acid bacteria, and psychotropic bacteria, respectively. At 10 °C, decreases were 1.57, 2.14, and 1.99 log Colony Forming Unit/gram for mesophilic bacteria, lactic acid bacteria, and psychotropic bacteria, respectively **[208,209,210,211,212,213]**.

Plant-origin Antimicrobial Peptides

Plant origin Antimicrobial Peptides have been studied for their potential to inhibit different pathogenic bacteria, including food spoilage bacteria, food poisoning bacteria, mold, and yeast species. Antibacterial peptide Leg1 from chickpea legumin was reported in meat application of plant-origin Antimicrobial Peptides. Raw pork was pretreated with Leg1 and inoculated with Escherichia coli and B. subtilis. Bactericidal activity was measured at 37 °C for 16 hours. Minimum bactericidal concentrations of Leg1 on pork were 125 µM and 15.6 µM for Escherichia coli and B. subtilis, respectively. This was the same concentration as MBC of nisin, a bacteriocin from Lactococcus lactis, for tested strains. Antimicrobial Peptides from peas (11SGP) and red kidney beans (RBAH) were used to extend the shelf-life of raw buffalo meat. In laboratory media, Gram-positive (L. monocytogenes, B. cereus, and Streptococcus pyogenes) and Gram-negative (Escherichia coli, Pseudomonas aeruginosa, Acinetobacter baumannii) bacteria were inhibited by 11GSP (60 µg/mL) and Gram-negative bacteria by 60% and Gram-positive bacteria by 90%. RBAH (60 µg/mL) alleviated the growth of Gram-negative bacteria by 56% and Gram-positive bacteria by 85%. In buffalo meat, counts of mesophilic bacteria of 11SGP (400 µg/ gram) and RBAG (400 µg/ gram) treated groups decreased by 1.60 log Colony Forming Unit/gram and 1.94 log Colony Forming Unit/gram compared to control groups. Psychrophilic bacteria, 11SGP and RBAG reduced by 1.10 log Colony Forming Unit/gram and 1.47 log Colony Forming Unit/gram, respectively, after 15 d of refrigerated storage (4 °C) **[172,173,174, 175,176]**.

Natural Preservatives from Animals and Their Application for Meat

Various antibacterial systems of animal sources are associated with defense mechanisms against external intruders. Preservatives derived from animal sources include lysozymes, lactoferrin, ovotransferrin, lactoperoxidase, Antimicrobial Peptides from livestock animals, and polysaccharides. Lysozyme can suppress several Gram-positive bacteria because of Lysozyme's distinctive ability to injure bacterial membranes by hydrolyzing 1,4-β-linkage between N acetyl D glucosamine and N acetyl muramic acid of peptidoglycan in the bacterial membrane. Peptide-based antibacterial substances containing Antimicrobial Peptides from animal sources, ovotransferrin, and lactoferrin could influence cell membranes or synthesize Antimicrobial Peptides, peptides, and enzymes. The antibacterial mechanism of Antimicrobial Peptides is due to the attachment to the bacterial cell membrane and disturbs its integrity, resulting in cell lysis. Antimicrobial Peptides may also exert more complex activities that inhibit metabolic and translational systems. Ovotransferrin isolated from eggs increased the cell membrane permeability of Gram-positive and Gram-negative bacteria. Ovotransferrin destroyed cell membrane integrity, increased permeability of pathogen membranes, and induced morphological changes. Lactoferrin has antibacterial action related to large cationic patches present on the surface and iron impoverishment. Lactoferrin has an antibacterial effect only when in its iron-free state and iron-saturated lactoferrin has limited antimicrobial activity. Lactoperoxidase oxidizes sulfhydryl groups of proteins present in bacterial membranes, which could be injured by efflux of potassium ions, amino acids, peptides, and enzymes **[177,178,179,180,181,182]**.

Lysozyme

Lysozyme (muramidase or N acetyl muramic hydrolase) is mainly extracted from hen egg whites and is known as an antimicrobial enzyme. Lysozyme is a glycoside hydrolase that hydrolyses linkages in peptidoglycan at Gram-positive bacterial cell walls. Lysozyme is composed of 129 amino acids, which contain disulfide bonds and tryptophan, tyrosine, and phenylalanine residues. Lysozyme, named Inovapure, has been used commercially against spoilage and foodborne pathogenic bacteria to prolong the shelf-life of raw and processed meat. Modified lysozyme, high hydrophobicity, and low hydrolytic activity compared to lysozyme monomer, at concentrations of 5%, exhibited low-microbial growth rates (total viable count 4.59 log CFU /cm^2; molds and yeasts 2.17 log CFU /cm^2) in pork surface with modified atmosphere packaging with composites of 50% O_2, 40% CO_2, and 10% N_2. Mixed antimicrobials consisting of lysozyme (250 ppm), nisin (250 ppm), and disodium ethylenediaminetetraacetic acid (EDTA) (20 mM) had antibacterial action against Listeria monocytogenes, total viable counts, Enterobacteriaceae, Pseudomonas spp., and lactic acid bacteria in ostrich meat patties with air and vacuum packaging. Mixed lysozyme preparations reduced Listeria monocytogenes below the official detection limit of the European Union (<2 log CFU / gram) in ostrich meat patties. Treated samples showed a decrease in total viable counts by one log CFU / gram after two days of storage and tended to increase thereafter. Enterobacteriaceae and Pseudomonas spp. were not affected by mixed antimicrobials in either packaging atmosphere, and a reduction in lactic acid bacteria was detected at two log CFU / gram. A combination of lysozyme with chitooligosaccharide presented a more effective antibacterial effect against Gram-negative bacteria than lysozyme alone. In minced mutton, a mixture of lysozyme and chitooligosaccharide led to the complete removal of 3–4 log CFU / gram of inoculated Escherichia coli, Pseudomonas fluorescens, and B. cereus during four hours at ambient temperature. Staphylococcus aureus was not completely eliminated but was reduced up to two log CFU/gram **[183,184,185,186,187]**

Ovotransferrin

Egg white contains 13% ovotransferrin (conalbumin), which is a monomeric 77.9 kDa glycoprotein comprised of 686 amino acid residues. Ovotransferrin contains N and C globular parts, each of which can reversibly Fe^{3+} and CO_3^{2-}. Ovotransferrin is the main constituent of the egg's defense system for bacteria, as it renders iron unusable for microbial growth within albumen. Antimicrobial action of ovotransferrin against Escherichia coli in fresh chicken breast involved in κ carrageenan film. Growth of Escherichia coli in fresh chicken breast wrapped with active film was 2.7 log CFU / gram by addition of 25 mg of ovotransferrin in combination with 5 mM EDTA. Ham models, 25 mg/mL of ovotransferrin with 100 mM sodium bicarbonate ($NaHCO_3$) did not show any antibacterial action against Escherichia coli O157:H7 and Listeria monocytogenes in commercial hams, whereas 25 mg/mL ovotransferrin with half percentage citric acid had bacteriostatic action against Listeria monocytogenes **[188,189,190,191,192,193]**.

Lactoferrin

Lactoferrin, a glycoprotein that belongs to the transferrin protein family in milk and milk products as well as neutrophil granules and exocrine secretions in mammals, was able to bind iron within cells. The ability of this 80 kDa protein to control free iron levels contributes to its bacteriostatic and population health beneficial characteristics, such as stimulating bone growth, protecting intestinal epithelium, and promoting the immune system in animals. In ground beef, the application of active lactoferrin, immobilized lactoferrin with glycosaminoglycans, and solubilized in citrate/bicarbonate buffer systems at concentrations of three percent and five percentage resulted in two log CFU / gram reductions of Escherichia coli O157:H7 at 10 °C for nine days. The reduction of S. Enteritidis growth was 0.8 log CFU / gram when active lactoferrin concentration was increased to two-point-five percent. A single application of half percentage active lactoferrin reduced Listeria monocytogenes in beef, resulting in two log CFU / gram. Bovine lactoferrin (half mg) was tested against Escherichia coli O157:H7 and P. fluorescens inoculated on chicken with HPP treatments between 200 and 500 MPa for 10 min at 10 °C. As a result, P. fluorescens was decreased when lactoferrin was combined with HPP treatment at 300 MPa for 2.3 log CFU / gram additional reduction compared to only 300 MPa treatment on day 9. Additional reductions in Escherichia coli O157:H7 counts obtained by combined treatments remained below 0.5 log CFU/gram. **[194,195,196,197,198]**

Lactoperoxidase

Lactoperoxidase is a member of the peroxidase family. It is a ubiquitous active enzyme in bovine milk, which has antimicrobial action. Bovine lactoperoxidase is a glycoprotein that contains a peptide chain of 78.4 kDa and catalyzes the oxidation of thiocyanate ions (SCN) in lactoperoxidase, producing oxidizing products, such as hypothiocyanite and hypothiocyanous acid. lactoperoxidase coated with alginate at concentrations of 2, 4, and 6% on the shelf-life of chicken breast filets. Chicken samples with an active coating of alginate and 6% lactoperoxidase showed a reduction of Enterobacteriaceae, P. aeruginosa, and aerobic mesophilic bacteria by five log CFU / gram, 4 log CFU / gram, and 2.5 log CFU / gram at 16 days of refrigerated storage, respectively. The antimicrobial action of lactoperoxidase was also assessed against Listeria monocytogenes and S. Enteritidis in sliced dry-cured ham for 60 d at 8 °C treated with HPP at 450 MPa. The synergistic effect of lactoperoxidase and pressure was confirmed as S. Enteritidis decreased below the detection limit (one log CFU / gram). Listeria monocytogenes, synergistic effect reduced cell viability by 0.86 log CFU / gram compared with untreated samples at the end of storage. In beef, the effect of lactoperoxidase on the growth of inoculated pathogenic bacteria (four log CFU / gram) composed of Staphylococcus aureus, Listeria monocytogenes, Escherichia coli O157:H7, S. Typhimurium, P. aeruginosa, Yersinia enterocolitica, and indigenous microbiota was investigated. Pathogenic bacteria used in the experiment were reduced compared to control at a chilling regime (−1 to 12 °C) for 42 days. total aerobe and Pseudomonas spp. increased less in the lactoperoxidase-treated group than in the control group, but the antibacterial effect was not exhibited for anaerobes and lactic acid bacteria **[199,200,201,202,203]**.

Livestock Animal Origin

Livestock animal-origin products have been used as a source of Livestock animal origin products. Among byproducts of livestock, blood, bones, collagen, gelatin, liver, lungs, placenta, skin, and visceral mass are important sources of Livestock animal origin products, as well as muscle parts. bovine cruor, a slaughterhouse byproduct containing mainly hemoglobin, broadly described as a rich source of fibrin proteins, was investigated for extraction of Livestock animal origin products. faction named α137–141 (polypeptide with five components, Thr Ser Lys Tyr Arg), a small (0.65 kDa), and hydrophilic Livestock animal origin products deviated from hemoglobin. The α137–141 preservative (0.5%, w/w) had bacteriostatic action on total microbial population, coliform bacteria, yeasts, and molds at 4°C for 14d on beef. Livestock animal-origin products isolated from porcine leukocytes had antibacterial action on the proliferation of Staphylococcus aureus and Escherichia coli inoculated in ground meat (boneless ham) and sausage minces. The 20 µg/ gram Livestock animal origin products decreased by 1.3 log CFU / gram of Staphylococcus aureus and 1.5 log CFU / gram of Escherichia coli in ground meat. It was also achieved that 160 µg/ gram of Livestock animal origin products had the best inhibition and decreased in 3.9 log CFU / gram of Staphylococcus aureus and 3.3 log CFU / gram of Escherichia coli at 6 hours in ground meats. In sausage mince, Livestock animal origin products at concentrations of 160 µg/ gram could decrease by three log CFU /g of Staphylococcus aureus and 2.7 log CFU / gram of Escherichia coli at 12 hours. After one day of storage, no visible colonies of Staphylococcus aureus or Escherichia coli were detected in sausage mince **[203,204,205,206,207,208]**.

Natural Preservatives from Microorganisms and Their Application for Meat and its Products

Lactic acid bacteria strains secrete several bacterial growth inhibitory substances (organic acids, diacetyl, phenyl lactate, hydroxyphenyl lactate, cyclic dipeptides, hydroxy fatty acid, propionate, and hydrogen peroxide), bacteriocins (nisin, acidophilin, Bulgarian, Helvetica, lactacin, pediocin, plantarim, diplococcin, and bifidocin), and bacteriocin like inhibitory substances (Bacteriocin Like Inhibitory Substance), which exhibit antibacterial activity and can control spoilage and food-borne pathogens. various bacteriocins, commercial bacteriocin preparations have been applied using nisin and pediocin. Bacteriocins are peptides or proteins with antibacterial and antifungal action that produce bacteria, mainly lactic acid bacteria. compounds are considered potential natural preservatives because of their inhibitory action on food spoilage or food-borne pathogens. Lactic acid bacteria bacteriocins vary in accordance with molecular size, chemical structure, modifications during biosynthesis, presence of modified amino acid residues, and antimicrobial mechanisms. Lactic acid bacteria bacteriocins can be categorized into two major classes: class I (lanthionine containing antibiotics) with three subclasses (Ia, Ib, and Ic) and class II with four subclasses (IIa, IIb, IIc, and IId). Class I bacteriocins generally include 19–50 amino acid residues (<5 kDa) and are largely post-translationally modified, ensuring non-standard amino acids, such as lanthionine, β methyllanthionine, and labyrinthine. class I bacteriocins are further subdivided into class Ia (lantibiotics), class Ib (labyrinthopeptins), and class Ic (sanctibiotics). Class II bacteriocins comprise small, heat-stable, non-modified peptides (<10 kDa). It can be further subdivided into class IIa (pediocin-like bacteriocins), class IIb (non-modified bacteriocins with two or more peptides), class IIc (circular bacteriocins), and class IId (non-pediocin like bacteriocins). Pediocin-like bacteriocins (class IIa) can be regarded as the main subgroup among all classified Lactic acid bacteria bacteriocins. Class III bacteriocins are classified as high molecular weight (>30 kDa) and thermally unstable peptides. Class IV bacteriocins are large peptides complex with lipids or carbohydrates. bacterial cell surface exhibits a negative charge because the anionic characteristics of the cell membrane consist of phosphatidylethanolamine, phosphatidylglycerol, lipopolysaccharide, lipoteichoic acid, and cardiolipin, and is generally captured by positively charged bacteriocins. cationic charged groups of bacteriocins electrostatically interact with the anionic bacterial cell surface, while hydrophobic surfaces are attached to the membrane and traverse the lipid bilayer. bacteriocins self-associate or polymerize to develop complexes after passing through the lipid bilayer. bacteriocins induce cell death by increasing the permeability of bacterial membranes, forming pores that cause dissipation of proton motive force, exhaustion of ATP, and leakage of intracellular substrates. Gram-positive bacteria-origin bacteriocins only perform for Gram-positive bacteria and are not effective against Gram-negative bacteria because of their different membrane compositions and selective membrane permeability. disadvantages could be compensated by mixing processing with other preservatives and the application of further preservation methods **[209,210,211,212,213]**.

Nisin

Nisin is a most representative class I bacteriocin. Nisin is produced by several strains of Lactococcus lactis, a species that is widely used for dairy production. Nisin was first approved as a food preservative in the United Kingdom in the 1950s and is now widely used worldwide and is permitted in over 50 countries. The structure of nisin consists of a polypeptide with 34 amino acids, a 3.5 kDa molecular mass, and contains methyllanthionine and lanthionine groups. Nisin has antimicrobial activities against a wide range of Gram-positive bacteria, including Staphylococcus spp., Bacillus spp., Listeria spp., and Enterococcus spp. Nisaplin is a typical commercial nisin formulation. Nisin could provide long-lasting bacteriostatic action on pathogenic bacteria in beef jerky at room temperature. Shelf- life extensive effect of nisin in B. cereus inoculated with beef jerky. beef jerky without nisin, counts of mesophilic bacteria, and B. cereus increasing is unlikely for beef jerky treated with nisin at 25°C for 60 days. B. cereus grew after three days in 100 IU nisin/ gram. treated groups and after 21 days in 500 IU/ gram nisin-treated groups. nisin-containing fermentate from L. lactis 537 strain was evaluated for inhibition of Listeria monocytogenes in ready-to-eat sliced ham. addition of fermentate to ready-to-eat sliced ham led to an immediate decrease in Listeria monocytogenes counts from three log CFU / gram to below the detection limit stored at 4°C (20 CFU / gram). Nisin with cinnamaldehyde and grapefruit seed extract presented synergistic antibacterial action. It reduced counts of Listeria monocytogenes by three log CFU / gram in raw pork loin at 4°C for 12 hours. minimum inhibitory concentration of nisin against Listeria monocytogenes was 250 ppm in laboratory media, but it was possible to reduce the concentration of 5–6 ppm against the growth of Listeria monocytogenes by mixing with natural antibacterial substances in pork **[214,215,216,217,218,219]**.

Pediocin

Pediococcus spp., Pediococcus acidilactici, and Pediococcus pentosaceus are the main pediocin-producing strains. Pediocin was classified into bacteriocin group class IIa, characterized as small non-modified peptides (<5 kDa) comprising less than 50 amino acids. Remarkably, pediocin showed antimicrobial activity even at nanomolar concentrations. Using Food-grade medicine-containing formulations are commercially available and marketed as ALTA 2341 and MicroGARD. Pediocin has been studied for inhibition of Listeria spp. for meat preservation methods. antibacterial activities of pediocin PA 1 in frankfurters and P. acidilactici MCH14, pediocin PA 1 producing strain, in Spanish dry fermented sausages were assessed against Listeria monocytogenes and Clostridium perfringens. In frankfurters treated with 5000 bacteriocin units /mL of pediocin PA 1 produced by P. acidilactici MCH14, Listeria monocytogenes was reduced by 2 and 0.6 log CFU / gram after storage at 4°C for 60 days and at 15°C for one month, respectively. Clostridium perfringens decreased with 5000 BU/mL of pediocin PA 1 by two and 0.8 log CFU / gram after storage at 10 °C for 60 d and at 15 °C for one month, respectively. growth of Listeria monocytogenes was inhibited by the pediocin-producing strain, P. acidilactici MCH14, in Spanish dry fermented sausages at two log CFU / gram compared to control. bacHA 6111-2, pediocin from P. acidilactici HA 6111-2, was applied to Portuguese fermented meat sausage (Alheira) with HPP treatment (300 MPa, five min, 10 °C) to inhibit Listeria innocua. bacteriostatic effect was verified for high inoculation counts of L. innocua at 4 °C for 60 days. decreasing inoculated L. innocua, an antibacterial effect was observed below two log CFU / gram from day three of storage until the end of storage. antibacterial activities of a mixed preparation containing pediocin from Pediococcus pentosaceus and Murraya koenigii (curry tree) berries in a raw goat meat emulsion at 4 °C for 9 days. L. innocua was reduced for 4.1 log CFU / gram in treated samples concentrations at 8.3 mL pediocin/1000 grams of meat emulsion with 10% (v/w) Murraya koenigii berries extract at the end of storage. Total viable count and psychrophilic count were also observed to decrease in treated samples, 2.2

log CFU /gram and 1.6 log CFU / gram, respectively **[220,221,222,223,224,225]**.

Sakacin

Sakacins, a class II bacteriocin, is mainly produced by Lactobacillus sakei or Lactobacillus curvatus strains. Commercial sakacin products are currently not presented. Compared to nisin and pediocin, sakacins have a relatively narrow antimicrobial spectrum, especially with effective inhibition against Listeria species. antibacterial effect of sakacin-producing strain, L. sakei CWBI B1365, and L. curvatus CWBI B28, on the fate of Listeria monocytogenes in raw beef and poultry. In refrigerated (5 °C) raw beef, L. sakei induced a decrease in Listeria monocytogenes concentration by 1.5 log CFU / gram after seven days to two log CFU / gram after 14 days, and below the detection limit at 21 days. addition of L. curvatus reduced Listeria monocytogenes to below the detection limit after seven days. In poultry, bacteriocin-producing strain did not affect inhibition of Listeria monocytogenes. It was assumed that type of meat may have influenced bacteriocin production by Lactic acid bacteria. Antibacterial activity of different bacteriocin preparations using sakacin Q produced by L. curvatus ACU 1 on meat surface was evaluated against L. innocua. freeze-dried reconstituted cell-free supernatant (3200 AU/mL) was effective for inhibition of L. innocua on meat surface, decreasing its bacterial cell number to the detection limit (<2 log CFU / gram) after two weeks of storage at 4–5 °C. adsorption of sakacin Q to meat products, main ingredients, meat proteins, and fat tissues did not affect its antibacterial activity **[226,227,228,229,230,231]**.

Bacteriocin Inhibitory Substance

Bacteriocin Inhibitory substances are among the antimicrobial substances produced by bacteria and are not completely categorized in terms of amino acid composition, molecular size, and nucleotide sequence. Inside ready-to-eat pork ham, the antibacterial action of Bacteriocin Like Inhibitory Substance produced by Pediococcus pentosaceus American Type Culture Collection 43200 was assessed and compared with those of commercially available nisin preparations (Nisaplin). Bacteriocin-like inhibitory Substance showed effective antibacterial activity against Listeria seeligeri by 0.74 log CFU / gram in ready-to-eat ham stored at 4 °C after two days. A slight increase in Listeria seeligeri counts was detected in Bacteriocin-like inhibitory Substance-treated samples from six days to the end of storage. Nisaplin did not present any antibacterial effect for up to two days. After two days, Nisaplin started to induce a decrease in Listeria seeligeri counts throughout refrigerated storage. This might have been due to the higher sensitivity of Bacteriocin-like inhibitory Substance to residual proteases compared to nisin, so weakening its antibacterial effect. Bacteriocin Like Inhibitory Substance producing Lactic acid bacteria strains, P. acidilactici KTU05 7, Pediococcus pentosaceus KTU05 9, and Listeria's sake KTU05 6, were used to ferment plants (Jerusalem artichoke, Helianthus tuberosus L.), and 5% of fermented products were tested to inhibit foodborne pathogen at 18 °C for half day in ready to cook minced pork. P. acidilactici fermented product presented the highest antimicrobial activity compared to other strains. counts of Escherichia coli, Enterococcus faecalis, Staphylococcus aureus, and Streptococcus spp. were reduced by 5.53, 4.37, 4.86, and 3.84 log CFU / gram, respectively, compared to control groups, suggesting that fermented product of Bacteriocin Like Inhibitory Substance producing strains showed an enhanced antibacterial effect. Bacteriocin- Inhibitory Substance obtained from Enterococcus faecium DB1 inhibited growth and formation of biofilms of Clostridium perfringens in chicken meat. The 2.5 mg/mL of DB1 Bacteriocin Like Inhibitory Substance suppressed the growth of Clostridium perfringens by 30%. Clostridium perfringens growth was inhibited by 50% at 5 mg/mL DB1 Bacteriocin Like Inhibitory Substance. Biofilm formation by Clostridium perfringens treated with 5 mg/mL DB1 Bacteriocin Like Inhibitory Substance was radically reduced by 90% at 4 °C for three days compared to control groups. The 2.5 mg/mL of DB1 Bacteriocin-like Inhibitory Substance also inhibited biofilm formation by Clostridium perfringens under the same conditions. Bacteriocin Like Inhibitory Substance could inhibit the formation of Clostridium perfringens biofilms on chicken surfaces due to its antibacterial effect **[232,233,234,235,236,237]**.

Other Microorganism Sources

mytichitin CB peptide, which was isolated from blood lymphocytes of Mytilus coruscus, showed antibacterial action against Gram-positive bacteria and fungi. myricetin CB peptide expressed by Pichia pastorisi and applied to pork preservation methods. total viable counts of the treated group with 6 mg/L of mytichitin CB derived from P. pastorisi was reduced by 33% (1–2 log CFU / gram) compared to the control group after storage at 4°C for 5 days. Mytichitin CB effectively inhibited total bacterial growth during storage compared to groups treated with 50 mg/L of nisin. Mytichitin CB at 6 and 12 mg/L suppressed Staphylococcus spp. and Escherichia spp., respectively, with a reduction of 1–2 log Colony Forming units/gram, respectively. Listeria spp. And Pseudomonas spp. were not detected during storage, unlike control and nisin-treated groups. Hispidalin is a unique antimicrobial peptide derived from seeds of Benincasa hispida and has been shown to exhibit antimicrobial action against various bacteria. hispidalin expressed by P. pastorisi was used as a preservative for pork. Pork treated with 100 μg/mL hispidalin showed bacteriostatic action during the entire refrigerated storage period. total viable count of pork with 100 μg/mL hispidalin was one log CFU /gram decrease than that of the control group at 4°C for seven days **[236,237, 238,239,240]**.

Conclusions

Meat is an important nutrient source due to its abundant protein content, essential amino acids, vitamins, and minerals. Meat is susceptible to contamination by food-borne pathogens and various spoilage bacteria because of its high water activity and important nutrient content. The application of preservatives is an indispensable element in livestock food processing to prevent food poisoning, delay spoilage, and extend their shelf-life. Industrial preservatives, commonly made up of chemicals, are not demanded by food customers because of their negative population health concerns. Natural preservatives derived from plants (rosemary, sage, chestnut, Grapefruit Seed Extract, and turmeric), animals (lysozyme, lactoferrin, lactoperoxidase, ovotransferrin, and others), and bacteria (organic acids, bacteriocins, and Bacteriocin Like Inhibitory Substance) have been explored as alternatives to chemical preservatives. versatility of natural preservatives compared to chemical preservatives is limited due to production cost, standardization, insufficient toxicity studies, and negative sensory action on food. To compensate for these disadvantages, various applications have been studied for their synergistic effect with other natural preservatives with reduced application concentrations compared to single use, application of physical treatment such as gamma irradiation, high-pressure processing, drying, encapsulation, and the possibility of packaging materials. various natural preservatives and application methods to inhibit the growth of food-borne pathogens and spoilage bacteria in animal feed. Natural preservatives are expected to be in high demand due to consumer and industrial requests. Therefore, it is necessary to explore various applications of existing natural preservatives, while continuously searching for novel ones.

Conflicts of Interest

The author declares no conflicts of interest

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