Original Article

Different types of bio preservatives -a comprehensive review

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Abstract

Bio preservatives are compounds derived from natural sources that can be used to extend food storage life and enhance food safety without any adverse health effects. Since food with synthetic preservatives is being avoided by consumers due to their long-term and short-term health effects, the demand for bio preservatives is largely increasing. Bio preservatives are considered an excellent alternative to chemical preservatives as they are generally recognized as safe (GRAS) and they can be used to retain the quality of food without causing any adverse health effects. This review explores the different agents which are employed as bio preservatives in the food industry, their mode of action, and their overall characteristics as a food preservative.

Keywords: food preservation, bio preservatives, bacteriocins, enzymes, spices and herbs bacteriophages, essential oils, extracts, salt, sugar

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INTRODUCTION

The current demand for food production is increasing invariably to meet up with the increasing population's food habits. Food products derived from animal sources are perishable, and their storage life can be retained by the addition of food preservatives which can reduce the spoilage process to an extent.[1] In this day and age, food products can be stored for a long period of time either by using modern or traditional preservation methods.[2] Traditional techniques such as boiling, burial, canning, confit, cooling, curing, fermentation, freezing, heating, jellying, jugging, pickling, lye, and sugaring are being used to preserve food since the dawn of agriculture.[3] And modern industrial techniques such as pasteurization, vacuum packaging, freeze-drying, pascalization, artificial food additives, irradiation, pulse electric field electroporation, modified atmosphere, hurdle technology, and Nonthermal plasma are being used to preserve food for commercial purposes.[4] A few of these methods of preservation employ supplemental food preservatives which can be grouped into two categories which is natural and artificial preservatives based on their source. Nowadays, consumers are aware of the long- and short-term effects of artificial food preservatives on their bodies. Hence the demand for natural food preservatives is increasing now more than ever. [2] Bio preservatives are newly derived alternatives from natural sources to enhance and extend the shelf-life and quality of the food. Biopreservation uses controlled or natural antimicrobials of animal or plant origin and microbiota to preserve food and extend its shelf life without any adverse health effects. It has been widely gaining attention due to its safe and ecological approach.[5] This review paper focuses on the few types of bio preservatives agents which can be used in the preservation of food and mode of action and their effectiveness

Bacteriocins

Bacteriocins are ribosomally synthesized proteinaceous substances or antimicrobial peptides produced by bacterial strains which usually inhibit the growth of either closely related or similarly related bacterial species.[6] They inhibit the growth of their target organism by attacking their cell envelope or by affecting their gene expression and protein production in the cell.[7]Bacteriocins are generally considered to be more natural as they are believed to have been present in foods consumed since the olden times.[8]Proteolytic enzymes such as proteases from the gastrointestinal tract of mammals can easily degrade bacteriocin which makes them safe for human consumption. Lactic Acid Bacteria(LAB) and its metabolites are of great importance as they are approved by the U.S Food Drug Administration (FDA) to be generally recognized as safe (GRAS, grade one)[9]Hence nisin, produced from the strains of Lactococcus lacti is the most exploited bacteriocin and it is widely used for

food production in more than 50 countries and has obtained 'GRAS' status.[10]The addition of 400 IU/ml nisin with 10 percent water,8 percent sugar, and 0.1 percent salt combination preparation of lassi increased the shelf life of lassi and produced good quality lassi compared to other treatments.[11] Currently, nisin and pediocin are the widely used bacteriocins as bio preservatives in food. pediocin is an antimicrobial peptide produced from the strains of Pediococcus spp. such as P. claussenii, P. ethanolidurans, P. acidilactici, P. cellicola, P. inopinatus, P. pentosaceus, P. damnosus P. parvulus. They are classified based on the isomers and from the strain produced into pediocin AcH, pediocin SJ-, pediocin JD, and pediocin PA-1.[12] It is known to be effective against both pathogenic and spoilage-causing organisms such as Listeria monocytogenes, a member of the Listeria genus which is known cause a disease named listeriosis a foodborne infection caused in humans. The disease is attributed to high mortality rates and is considered life-threatening in certain high-risk groups of the population such as the elderly, pregnant women, newborns, and immunocompromised persons. Pediocin acts as a bio preservative and inhibits listeria growth in fresh meat, milk, and milk products like cottage cheese, ice cream, and reconstituted dry milk. Other than L. monocytogenes it is also effective against Enterococcus faecalis, staphylococcus aureus, Clostridium perfringens, and Clostridium botulinum.[13] There are other certain, not well-known bacteriocins such as Reuterin, a neutral, broad-spectrum bacteriocin produced by Lactobacillus reuteri which acts as a preservative in meat storage and inhibits the growth of E. coli O157:H7 and L. monocytogenes.[14] It is also proven to be effective against E. coli O157:H7 and L. monocytogenes in cottage cheese and milk under refrigeration temperature (7 C).[15]

Enzymes

Enzymes and other polypeptides with antimicrobial properties occur in animals, as well as in plants. Lytic enzyme lysozyme present in the hen's egg is effective against several spoiling causing bacteria and foodborne pathogens. Studies indicate that the egg white enzyme effectively lyses and inhibits the growth of certain strains of L. monocytogenes thermophilic clostridia, C. botulinum. Lysozyme is attractive as a preservative due to its safe nature and its specific antibacterial activity. It is also used in certain hard cheeses to prevent the formation of gas and to prevent the cracking of the cheese wheels due to saccharolytic, butyric-forming clostridia, specifically Clostridium tyrobutyricum.[16] Peroxidases and oxidase enzymes such as lactoperoxidase and glucose oxidase respectively are also proven to be inhibitory towards certain foodborne pathogens and spoilage-causing bacteria. Lactoperoxidase is the most abundant enzyme found in bovine milk and it is produced in the salivary glands of mammals. The Lactoperoxidase system (LPS) can be used to preserve raw milk against lactic acid bacteria where refrigeration is not possible.[17] Similarly, glucose oxidase has been proven to be antibacterial and active against the growth of pathogenic organisms including Campylobacter jejuni, Clostridium perfringens, Staphylococcus aureus, Yersinia enterocolitica, Bacillus cereus, Salmonella infantis, and Listeria monocytogenes.[18]

Spices and herbs

Spices and herbs have been used in food since the dawn of agriculture. They are normally used in every household to flavor, season, provide health benefits, and improve the taste of foods in general. But they also play an important role in food preservation due to their strong preservative qualities.[19] Garlic (Allium sativum), a well-known medicinal plant, has numerous benefits and it is proven to have antimicrobial properties. A study done to demonstrate the preservative effects of garlic concluded that it can effectively decrease microbial activity and extend the shelf life of fresh fish (Nile tilapia) for 3 days under suitable storage conditions. It also effectively deterred the emergence and development of maggots on the fish carcass. Hence garlic extracts and paste can be used to preserve perishable foods for a short period of time where refrigeration is not possible. [20] Thyme oil extracted from Omani cultivar is a natural antioxidant and it is inhibitory towards certain foodborne pathogens and spoiling causing bacteria such as S. aureus and E. coli. The antioxidant activity is mainly due to its major phenolic constituent carvacrol and its usage in foodstuffs has been approved by the FDA and is generally recognized as safe (GRAS).[21] Allyl isothiocyanate, a colorless organosulfur compound present in the plants of the Cruciferae family (seeds of black mustard-Brassica nigra and Brassica juncea in particular) has been successfully used to eliminate the growth of E. coli O157:H7 in ground beef.[22]

Bacteriophages

Bacteriophages are one of the abundant organisms present in the world. They are viruses that specifically prey on bacterial cells and do not target mammalian cells thus owing to many clinical and industrial applications.[23] Hence bacteriophages have great importance in the food industry as they play an important role in ensuring food safety and preserving its integrity. As bio preservatives, Bacteriophages are added directly into the food in order to extend their shelf life. Phages can be used to control

the growth of several foodborne pathogens such as Escherichia coli O157:H7, Campylobacter, Listeria monocytogenes, and Salmonella.[24] A study made to assess the biocontrol ability of three lytic phages (e11/2, pp01, e4/1c) to lyse Escherichia coliO157:H7 concluded that the phage cocktail was provedto be efficient and inhibited the growth of E. coliO157:H7 on the surfaces of beef meat.[25]Bacteriophage cocktails such as EcoShield™ (previously known as ECP-100) from the family Myoviridae can also be used to tackle the contamination of E. coli O157:H7 on tomato, broccoli, spinach, ground beef, and hard surfaces.[26] The growth of Listeria monocytogenes on raw and ready-to-eat (RTE) products such as sliced cooked ham can be eradicated by the addition of phages and protective cultures.[27] Listex P100, a commercially produced bacteriophage approved by the U.S.Department of Agriculture's Food Safety U.S.Food and Drug Administration can be used to eradicate the growth of L. monocytogenes on the Surface of Fresh Channel Catfish Fillets.[28] Also, phages can be added to suppress the

growth of Salmonella enteritidis in Cheddar cheese prepared from both pasteurized and raw milk.[29] The bacteriophages discussed above are some of the several phages commercially produced for the control of the foodborne pathogen. In recent years, there is a surge in several phage products which are being used as food preservatives. phage products namely endolysins or lysins are hydrolytic enzymes produced by bacteriophages that are potent against gram-positive bacteria and can be used to ensure and enhance food safety.[30] The enzyme cleaves the bacterial cell wall in the last stage of the lytic cycle by targeting peptidoglycan bonds and frees the newly formed progeny to exit the host cell [31]. It is considered to be an advantageous method since there is no sign of bacterial resistance against lysin and in order to do so, the bacterial cell wall has to reconstruct the structure of its cell wall to escape the action of the enzyme.[32]

Essential oils

Essential oils are volatile and aromatic liquids derived from plant parts such as seeds, wood, fruits, leaves, barks, flowers, roots, peel, etc., The chemicals present in essential oils are secondary metabolites, they play a vital role in plant's defense system as they have certain antimicrobial properties [33] Since the olden times, it has been employed for virucidal, anti-parasitical, bactericidal, insecticidal, fungicidal, cosmetics and medicinal purposes. Nowadays it plays important role in the agriculture, food, sanitary, pharmaceutical, and cosmetics industries.[34] In the food industry, it can be used as a natural preservative to prevent the growth of certain foodborne and spoilage-causing organisms. A study pursued to demonstrate the anti-yeast potential of eucalyptus oil concluded that a combination of eucalyptus oil with thermal treatment was proven to be effective against the growth of yeast (S. cerevisiae SPA) in fruit juices. The antimicrobial activity of the oil is attributed to the presence of oxygenated monoterpenes and hence they can be used as a preservative for beverages.[35] Essential oils contain many bio-active compounds such as carvone, thujone, camphor, myrcene, terpineol, neral, myrcenol, and, thujanol, etc., among these carvone has the least toxicity carvone; hence it is used as a flavoring agent and preservative in food products such as sweets and beverages.[36]

Extracts

Extracts are substances extracted from plant compounds that exhibit antimicrobial activity against fungi and bacteria.[37] Extracts of sumac (Rhus coriaria L.) are antimicrobial in nature and they are proven to be inhibitory towards the growth of certain food-borne pathogens(bacteria).[38]Extracts of pomegranate peel(PPE) and cinnamon bark(CBE) are shown to have the strongest antibacterial activity compared to other extracts and can be used as a bio preservative to eliminate the growth of salmonella Typhimurium on meat products.[39]

Salt

Sodium chloride (NaCl), commonly known as salt or table is a chemical compound with a ratio of 1:1 sodium and chloride ions. Since ancient times, salt has been a part of food preparation and preservation. Nowadays it is considered an ideal preservative due to its low cost and its effective nature.[40] Salt is known for its antimicrobial and bacteriostatic properties as it inhibits the growth of microorganisms in many foods. Salt acts as a preservative by decreasing the water content in the food which therefore reduces microbial growth. Microorganisms need water as a 'nutrient source' to survive, so thereby limiting it causes growth retardation or cell death.[41][42] It also has been theorized that in certain microorganisms, salt causes osmotic shock, alters PH, interferes with enzymatic activities, limits oxygen solubility, and forces cells to exhaust energy by excluding sodium ions out of the cell, all of these can deter the rate of growth.[43] A study performed to demonstrate the antimicrobial properties of salt on sheep casings inoculated with bacterial strains concluded that salt successfully inhibited the growth of, Listeria monocytogenes Salmonella typhimurium, Staphylococcus aureus Escherichia coli (except for Clostridium spores) at

0.85 aw (water activity) on a 30 day period.[44]Salt can be used to preserve cured meats such as bacon, ham, and dry-cured ham.[45]Salts are also used to preserve canned fish products such as sardines, mackerel, tuna, anchovies, etc.,[46]

Sugar

Sugar functions the same way as salt does to preserve food. Hence sugar works by dehydrating the food and the microorganisms present in the food thus killing them. This process is known as plasmolysis.[47] The earliest civilizations used sugar as a preservative, it was common practice to keep fruits stored in honey. Sugars can be used to preserve fruits such as apricots, apples, plums, peaches, and pears in an antimicrobial syrup or in a crystallized form in which the product preserved is cooked in sugar and dried.[3] This process is known as sugaring. Sugar is also used as both a preservative and a flavoring agent in jams and jellies.[41]

Other bio preservative agents

Yeast: yeasts are also known to have a bio preservative effect on food due to their competitive nature and antagonistic activities. The antagonistic activities are attributed mainly to pH alterations in the medium, competition for nutrients, tolerance of high ethanol concentrations, and the production of antimicrobial compounds called killer toxins also known as “mycotoxins” which are highly effective against the growth of foodborne pathogens and spoilage causing microorganisms in food. The antagonistic activities of yeast on bacteria are not well documented as compared to yeast-yeast antagonism., however except for certain studies since the concept is fairly new. The production of killer toxins is predominant in many yeast species such as Zygosaccharomyces, Torulopsis, Saccharomyces, Kluyveromyces, Candida, Williopsis Cryptococcus, Pichia, and Debaryomyces.[48] However, it was first observed in the strains of Saccharomyces cerevisiae during beer production.[49] Antagonistic starter yeast cultures can be applied as bio preservatives in the food industry overall to improve and preserve the quality and integrity of the food. A study was performed to evaluate the effectiveness of Williopsis Saturnus var. Saturnus, a variety of killer toxin-producing yeast concluded that it was successful in inhibiting the growth of galactose fermenting and lactose fermenting yeasts such as Kluvyveromyces marxianus and Candida kefir and it also deterred the growth of dairy molds such as Penicillium, Eurotium, and Byssochlamys in plain yogurt. Hence, it can be applied as a preservative in yogurt production to extend its shelf life.[50]

Lactoferrin: Lactoferrin (Lf), is an iron-carrying protein (glycoprotein) belonging to the family of transferrin with a molecular weight of about 80 KDa with several physiological properties. It plays an important role in the clinical industry due to its anticancer, antifungal, antimicrobial, and anti-inflammatory properties.[51] It has widely present in mammalian secretions such as tears, milk, saliva, etc., Lactoferrin acts as a preservative by deterring the growth of microorganisms present in the food by reducing the iron content in the surrounding atmosphere.[41]

Chitosan: Chitosan, is a biopolymer derived from the exoskeleton of shellfish such as lobster, crab, and shrimp. It possesses certain antimicrobial properties and other beneficial qualities. It also recently garnered attention for being biodegradable, biocompatible, and non-toxic by nature. chitosan plays a fairly important role in the pharmaceutical industry due to its therapeutic qualities.[52] Other than that, chitosan also plays an important role in the food industry as it is used in biofilms to decrease water activity, limiting oxygen transmission all of which retards microbial growth, therefore extending the shelf life of fruits.[53]

Conclusion

Bio preservatives are a novel approach to food preservation, so further research must be pursued to understand their other potential applications. There are other numerous agents which can be used as bio preservatives. Among those some of the widely used agents are discussed here such as bacteriocins, enzymes, spices, herbs bacteriophages, essential oils, extracts, salt, sugar, etc., The potency of bio preservatives differs from one to another based on several factors such as their mode of action, preservation mechanisms and also factors surrounding food itself too. They also possess their fair share of limitations as any method of preservation must have proper modifications can be done to meet specific requirements.

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