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Traditional Medicinal Plants for Industrial Application as Natural Food Preservatives

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Abstract

Natural food preservation method refers to application of naturally produced antimicrobial compounds that are obtained from plants, animals and microbes to prevent food spoilages microorganism, proliferation and growth of food borne pathogens in food and foods products. Now it is the time of growing interest of many researchers with the application of these natural antimicrobial compounds as safe replace instead of using chemical and physical food preservatives since it has many sides effects and causes health risks to the consumers. Antimicrobial compounds derived from plants products are considered to be an excellent source of natural food preservatives. Among preservatives, essential oils of some herbs and plants were traditionally used for the preservation of wide variety of foods. Antimicrobial substances such as bacteriocin, proteins or peptides secretions, bioactive molecules from plant have also been exploited in different ways for food preservation. Herbs and spices have been recognized to possess a broad spectrum of active constituents that exhibit antibacterial, antifungal, antiparasitic, and/or antiviral activities. Especially essential oils have been used for centuries as part of natural traditional medicine, to preserve food and different food products among locally community. They are aromatic oily liquids obtained from plant material (flowers, buds, seeds, leaves, twigs, bark, herbs, wood, fruits and roots). Natural antimicrobials compounds can be used alone or in combination with other novel preservation technologies to facilitate the replacement of traditional approaches and to reduce stiffness of using chemical and physical food preservatives. Research priorities and future trends should focusing on the impact of product formulation, intrinsic product parameters, and extrinsic storage parameters on the design of efficient food preservation systems are also presented. Therefore, the main objective of this review paper is to discuss industrial application of traditional medicinal plants as natural food preservatives in enhancing food shelf life.

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1. Introduction

With the idea of current trends of technological development giving value to natural products, the use of natural antimicrobial compounds in food and biomedical applications is becoming very frequent. Because, the direct application of natural compounds obtained to food is the most common method of bio-preservatives, even if numerous efforts have been made to find alternative solutions to the aim of avoiding undesirable inactivation. A number of non-traditional preservation techniques are being developed to satisfy consumer demand with regard to nutritional and sensory aspects of foods. Generally, foods are thermally processed by subjecting them to temperatures varying from 60 to100^{o}C for the duration of a few seconds to a minute in order to destroy vegetative microorganisms. During this period of treatment, a large amount of energy is transferred to the food. However, this energy can trigger unwanted reactions, leading to undesirable organoleptic and nutritional effects, which further can affect consumers' health (Barbosa et al., 1997).

Consequently, there has been a constant increase in the search of alternative and efficient compounds for food preservation, aimed at partial or total replacement of chemical antimicrobial additives. This led to the development of the concept of bio-preservation to minimize the application of chemical preservatives to extend food shelf-life. The bio-preservatives are wide range of natural products from plants, animals and microorganisms that can be useful in extending foods shelf-life. The effects of applying bio-preservatives are to reduce or eliminate survival pathogenic bacteria and to increase overall food quality. Numerous natural biological compounds have a number of antimicrobial properties, behaving as antioxidants, breaking down cellular membranes, and disrupting biosynthetic microorganism's pathways (Burt, 2004; Ponce et al., 2004).

Naturally many food products are perishable they are easily deteriorated and thus, they require protection from spoilage during their harvest, preparation, storage, and distribution to give them desired shelf life. Specially, minimally processed foods, easily prepared, and ready-to-eat fresh food products, globalization of food trade, and distribution from centralized processing pose major challenges for food safety and quality. Food products can be subjected to contamination by bacteria and fungi and they deteriorate flavor, odor, color, sensory, and textural properties of foods. In packaged foods, growth and survival of common spoilage and pathogenic microorganisms are affected by a variety of intrinsic factors, such as pH and presence of oxygen or by extrinsic factors associated with storage conditions, including temperature, time, and relative humidity (Singh et al., 2003; Lòpez-Malo et al., 2005; Rydlo et al., 2006). So, to prevent growth of spoilage and pathogenic microorganisms in foods, several chemical preservation techniques have been used in the food industry as these authors reported (Davidson and Taylor, 2007; Farkas, 2007) and not only this, but also different alternatives methods like combination of natural and chemical preservatives have been also utilized. Because of the great consumer awareness and concern regarding synthetic chemical additives, foods preserved with natural additives have become very safe. Regarding to application of natural preservatives in food industry to prevent the growth of undesirable microorganisms, it is possible to add the antimicrobials in to the product formulation or coated it on its surface of foods or incorporated into the packaging material, but its mechanism of action also different (Appendini and Hotchkiss, 2002; Hanušová et al., 2009).

Main natural compounds are essential oils derived from plants, enzymes obtained from animal sources, bacteriocins from microbial sources, organic acids and naturally occurring polymers (chitosan) have been used in different food industry. In this perspective, plant essential oils are gaining a wide interest in food industry for their potential as decontaminating agents, as they are Generally Recognized as Safe (GRAS). The active components are commonly found in the essential oil fractions and it is well established that most of them have a wide spectrum of antimicrobial activity, against food-borne pathogens and spoilage bacteria (Gutierrez et al., 2008, 2009). The antimicrobial activity of plant essential oils is due to their chemical structure, in particular to the presence of hydrophilic functional groups, such as hydroxyl groups of phenolic components and/or lipophilicity of some essential oil components (Dorman and Deans, 2000; Skandamis et al., 2002; Mangena and Muyima, 1999; Marino et al., 2001).

Plants and spices are excellent sources of biologically active compounds with potential antimicrobial activity. Essential oils, secondary metabolites produced by plants, have valuable capability of suppressing growth of wide variety of food-spoilage and food-borne microorganisms including bacteria, yeasts and molds. From chemistry point of view, they consist of aromatic and volatile compounds which play an important role in plant defense and possess antimicrobial properties (Hyldgaard et al., 2012). They can be extracted from different parts of plants, including flowers, roots, bark, leaves, seeds, peel, fruits, wood, buds and the entire plant (Hammer et al., 1999; Sánchez et al., 2010). Beside their medical application, essential oils have been used for centuries in perfume and cosmetic industries and also in food industry as flavoring agents and preservatives. Several investigators attempted to apply essential oils as potential bio-preservative to extend shelf-life and improve microbiological quality of dairy products (Abou-Dawood, 1999; Adb-Alla, 2000; El-Nemer, 2003, 2004; Hussein, 2004). This review focuses on the use of natural compounds from plants sources to control microbiological and physicochemical shelf life of main food categories, such as meat, fish, dairy products, minimally processed fruit and vegetables and cereal-based goods its industrial application as biological food preservatives.

2. Application of plant antimicrobials in shelf-life extension of food

Antimicrobials derived from plants sources are phytochemicals which are important for the proper functioning of the plant. These antimicrobial compounds are helped the plants as defense mechanism to protect them from plant pathogens and other predators. It also regulates growth, pollination and fertilization (Cowan, 1999) increase the soil fertility. Phytochemicals in plants are broadly grouped into phenolic compounds, terpenoids and essential oils, alkaloids, lectins and polypeptides. The contribute to the sensory properties when added to food and have antioxidant and antimicrobial properties (Balasundram, 2006), characteristics that are useful in extending the shelf-life of food. The antioxidant and other biological properties in phenolic compounds has been attributed to beneficial health effects when consuming foods rich in polyphenols (Manach, 2004). In summary antimicrobials are chemical compounds or substances that may delay microbial growth or cause microbial death on entering a food matrix. Antimicrobials can be classified as traditional and novel substances called “naturals”. Natural antimicrobials are obtained from raw materials of vegetable, fruit, herbs/spices or microbiological origin. An example would be plant extracts which can provide properties such as antioxidants, shelf-life extension (natural antimicrobials), as well as exciting new flavors. Let we discuss the application these antimicrobial compound in used in food industry to preserve the foods and foods shelf life.

2.1. Vegetables

Different preservatives technology were used to preserve food and to increase food shelf life. Dipping, impregnation, coating, and spraying are the different ways of applications of active agents to fresh-cut fruit and vegetables, but among them, the most recent results on the application of active compounds to ready-to-eat fruit and vegetables deal with coating systems. As the report of Raybaudi-Massilia et al. (2009) and Mulaudzi et al. (2011), the use of traditional antimicrobials in food preservative is presented as good alternative. Most of the time its application needs combining use of antimicrobials with other methodologies of food preservation to reduce the impact of these compounds on sensory properties (Raybaudi-Massilia et al., 2009). Different studies have demonstrated the effectiveness of essential oils and their active compounds to control or inhibit the growth of pathogenic and spoilage microorganisms in both fresh-cut fruit and fruit juices. With the support of this idea, Raybaudi-Massilia et al. (2009) incorporated active compounds of herbs and spices into an alginate-based edible coating and applied on fresh-cut apples where they found a high effectiveness for reducing populations of inoculated *E. coli* O157:H7 during storage time.

Malic acid in combination with various stabilizing compounds was used by Raybaudi-Massilia et al. (2009) for fresh-cut apples. As reported by Bico et al. (2009), the combined effect of chemical or edible coating, controlled atmosphere (CA) on quality of fresh-cut banana was investigated. Raybaudi-Massilia et al. (2008) investigated the combined effects of malic acid and essential oils of cinnamon, palmarosa, and lemongrass (0.3 and 0.7%) and their main active compounds on microbiological and physicochemical shelf-life of fresh-cut melon. The active compounds were incorporated into an alginate-based edible coating. Melon pieces were inoculated with a *S. enteritidis* (10^8 CFU/ml) culture before applying the coating. The incorporation of essential oils or their active compounds into the edible coating prolonged the microbiological shelf-life by more than 21 days. Pure citral and citron essential oil were added in the syrup of industrial ready-to-eat fruit salads stored at 9°C. Both citral (25-125 ppm) and citron essential oil (300, 600, 900 ppm) were able to prolong the microbial shelf-life. Generally, when applying bioactive coatings containing essential oils to fruits and vegetables, one of the limiting factors is the impact of such components on the sensory characteristics of the coated products, mainly due to the great amount of volatile compounds which mask the natural flavor of fruits and vegetables. The use of compatible essential oil-foodstuff could also be a good alternative. One solution to the above-mentioned problem may be the use of combinations of different food preservation systems that would give the benefits of each of them while at the same time appreciably reducing the amount of antimicrobial required. For this reason, the application of moderate heat treatments and/or the preservation of the foodstuff in cold, refrigerated temperatures may play a key role. By using this method, a stable and, from a microbiological viewpoint, safe food can be produced without any loss in sensory quality.

2.2. Dairy products

Fresh dairy products are ready-to-eat foods easily contaminated by undesirable microorganisms. Some of them are spoilage microorganisms which may produce unwanted visual appearance and diminish the commercial value of cheese, other ones are pathogens that affect product safety. Recently, some studies have recorded the efficacy of natural compounds, alone or in combination with other preservation methods, when directly applied to milk (Cava et al., 2007) or to cheese by spraying, immersing, or dusting the products. Antimicrobials may also be spread onto the packaging materials that come in contact with the cheese or incorporated into the plastic films used for packaging (Conte et al., 2007). Under this sub topic we are going to discuss some research conducted on the application of plants extract to preserve dairy products. Abdalla et al. (2007), have been shown that extract of mango seed kernel could reduce total bacterial count, inhibit coliform growth, exert remarkable antimicrobial activity against an *Escherichia coli* strain and extend the shelf life of pasteurized cow milk. High water activity positively affects the application of antimicrobial compounds in milk by speeding the transfer and movement of antimicrobial compounds toward the targeted micro-organisms (Cava et al., 2007). Satureja cilicica has been used as essential oil can serve in butter as both a natural antioxidant and aroma agent (Ozkan et al., 2007). Similarly, Cinnamon, cardamom and clove oils inhibit the growth of yoghurt starter cultures more than mint oil; however, in other study mint oil was effective against Salmonella enteritidis in low-fat yoghurt and cucumber salad (Burt, 2004). Again extracts of propolis showed antimicrobial and antifungal activity, especially at low levels against pathogenic microorganisms to protect starter culture strains in fermented products (Kalogeropoulos et al., 2009).

Pires et al. (2009), developed a microbial sachet incorporated with allylisothiocyanate. Its efficiency was tested against yeasts, molds, Staphylococcus sp. and psychrotrophic bacteria in sliced mozzarella cheese stored at 12°C ± 2°C. A reduction of 3.6 log cycles was observed in yeasts and molds counts in the mozzarella packed with the antimicrobial sachet over 15 days of storage time. The sachet also showed an antibacterial effect on Staphylococcus sp.; however, psychrotrophic bacteria were very resistant. A new dairy product “Karishcum” obtained by adding Curcuma Longa (Curcumin or Turmeric) to classic Karish cheese at a rate of 0.3% (w/v) was realized in a study conducted by Hosny et al. (2011). A primary experiment was done to determine the correct percentage of Curcumin addition to cheese milk to get a good taste and a long shelf life. The behavior of pathogenic bacteria in the artificially contaminated product during cold storage for 14 days, revealed that addition of the extract (0.3%) determined a reduction of bacterial counts of about 1 log of *S. typhimurium* and two log of *P. aeurogenosa* and *E. coli* 0157:H7.

2.3. Meat and poultry products

It has been shown that plant extracts are useful for reduction of pathogens associated with meat products. Combination of 1% cloves and oregano in broth culture showed inhibitory effect against *L. monocytogenes*, however, the same concentration was not effective in meat slurry (Lis-Balchin et al., 2003). Survival and growth of both susceptible and antibiotic-resistant Campylobacter strains have been inhibited effectively on agar plates and in contaminated ground beef by application of roselle (Yano et al., 2006; Yin and Chao, 2008).

Chitosan (0.5% and 1%) added individually or in combination with nitrites (150 ppm) as ingredients was tested to protect fresh pork sausages from microbial spoilage. Its application as active coating was demonstrated (Bostan and Isin-Mahan, 2011). Soultos et al. (2008) found chitosan active against total viable count, lactic acid bacteria, Pseudomonas spp., B. thermosphacta, Enterobacteriaceae, yeasts, and molds. Krisch et al. (2010)

conducted comparative study to investigate the antimicrobial effect of commercial herbs, spices and essential oils (fresh and dried garlic, onion, thyme, marjoram, and oregano) in minced pork. While fresh spices showed weak or no inhibition on viable cells of minced pork, some effects of essential oils were observed. Best shelf life values were obtained for pork meat added with garlic and marjoram oil. A relevant preservation effect for fresh chicken breast meat, stored at 4°C, was obtained by dipping meat in oregano oil, prior to packaging under MAP (Chouliara et al., 2007). Fratianni et al. (2010) also proposed use of thyme and balm essential oils to decrease the natural microflora of chicken breast meat. In particular, balm essential oil significantly limited growth of Salmonella sp., whereas thyme essential oil effectively inhibited growth of E. coli. In particular, use of clove oil along with lactic acid provided synergistic antioxidant and antimicrobial effects; the inclusion of vitamin C also stabilized product color (Naveena et al., 2006). Ntzimani et al. (2010) highlighted that combined use of EDTA, lysozyme, rosemary, and oregano oil extended shelf life of semi-cooked coated chicken fillets stored under vacuum packaging at 4°C to more than 2 weeks.

2.4. Fresh fish and fish products

Fresh fish is one of perishable product due to its biological composition. The main cause of deterioration is the activity of spoilage seafood microorganisms that provoke loss of essential fatty acids, fat-soluble vitamins and protein functionality, production of biogenic amines, and formation of off-odors (Gram and Dalgaard, 2002). Application of essential oils on the surface of whole fish or as coating for shrimps inhibited Salmonella enteritidis, L. monocytogenes and natural spoilage flora (Burt, 2004; Hayouni et al., 2008). Shelf life of carp fillets was extended fourfold by application of combined carvacrol + thymol with some other additives, compare to sterile 0.2% agar solution as a control (Mahmoud et al., 2007). Antimicrobial activity studies of garlic oil against bacterial isolates from carp showed that, it had the strongest antimicrobial activities, followed by iso-eugenol, eugenol, garlic oil, and then citral for increasing the shelf life of carp fillets, respectively (Mahmoud et al., 2004). On the other hands, essential oils of Aloysia sellowii were successfully screened against a variety of Gram-positive and -negative micro-organisms and two yeasts in brine shrimp (Simionatto et al., 2005). Basil, clove, garlic, horseradish, marjoram, oregano, rosemary, and thyme have been used successfully to implement hurdle technology for protecting seafood from the risk of Vibrio parahaemolyticus contamination (Yano et al., 2006). A synergistic effect of treatment with anodicelectrolyzed NaCl solution, combined with eugenol and linalool, has been found to enhance shelf-life extension of coated semi-friedtuna (Abou-taleb and Kawai, 2008). Ojagh et al. (2010) reported that the use of a coating with chitosan and cinnamon essential oil improved trout fillet shelf life (16 days vs 10 days of the control) and in particular it enhanced texture, odor, and color. Similar results were also obtained for trout fresh fillets coated with gelatin enriched with cinnamon oil (1%, 1.5%, and 2%). In particular, experimental data indicated that the active coating can be suitable for preserving the fillets and maintain quality to an acceptable level (Andevari and Rezaei, 2011).

2.5. Cereal-based products

Among strategies aimed to improve quality of bread, some effects were reported by using different natural compounds. In particular, it was reported that chitosan coating improved bread quality by inhibiting microbial growth and retarding oxidation and staling. A reduced microbial proliferation was obtained for bread coated with chitosan during storage at room temperature (No et al., 2007). Rehman et al. (2007) reported different applications of citrus peel essential oils in bread. Results demonstrated that the oils influenced sensory characteristics and delayed microbial growth. Maximum inhibitory effect against moulds and bacteria was achieved by spraying peel essential oil. The combination of MAP and mustard oil was proposed for wheat and rye bread artificially inoculated with moulds (Suhur and Nielsen, 2005). The different combination of the three selected natural additives improved bread shelf life. In particular, lower cell loads of yeasts and moulds were observed for bread with lecithin and ascorbic acid (Latif and Masud, 2006). An active packaging with cinnamon essential oil combined with MAP was tested to increase the shelf life of gluten-free sliced bread. Results showed that the active packaging is better than MAP to increase product shelf life because it inhibited microbial growth while maintaining the sensory properties of the gluten-free bread (Gutiérrez et al., 2011). Del Nobile et al. (2009a) proposed the use of different natural antimicrobial compounds such as thymol, lemon extract, chitosan, and grapefruit seed extract at different concentrations (2000 mg/kg and 4000 mg/kg) to improve the microbiological stability of refrigerated amaranth-based fresh pasta. Results pointed out that chitosan were the most successful among the investigated compounds in slowing down the spoilage, whereas lemon extract was the less effective. In a subsequent work, the antimicrobial activity of chitosan in combination with different MAP was tested. It was found that among the tested MAP conditions, the combination of 30:70 N_2:CO_2 extended the shelf life beyond two months (Del Nobile et al., 2009b). The antimicrobial activity of chitosan against the main microorganisms of fresh pasta was also reported by Costa et al. (2010). In particular, statistically significant differences were found between the shelf life of pasta with chitosan packaged under MAP conditions in a low barrier film made up of polypropylene and in a multilayer high barrier film made up of polyethylene terephthalate, ethylene-vinyl alcohol, and polyethylene.

3. Combined technologies for food preservation

The ability to produce a safe food product with extended storage life which is acceptable to the consumer according to the relevant food standard guidelines is the objective of food preservation. This is achieved through designing processing steps specific to different products. The goal is to combine a range of processes, for example, mild heat stress and a low concentration of preservatives to give a safe and quality food product. There is renewed interest in using minimal/non thermal processing technologies such as High Pressure Processing (HHP) and Pulsed Electric Field (PEF), active and modified atmosphere packaging (Cutter, 2006; Gurtler, 2010; Diez, 2009).

4. Challenges of using plant extracts in food systems

It is clear from the literature that a range of plant extracts are needed to inhibit the natural microbiota that is found in different types of food. This is quite different to the traditional preservatives where the same preservatives such as metabisulphites, sodium benzoates, sorbates etc., are used in different food systems. The challenges of using plant antimicrobials are:

- Some plant extracts have flavors associated with them that may be a problem, therefore it is important to match the food and the plant extract flavor or understand the synergies to decide on the concentration used.
- Type of microorganisms present in the food that can cause spoilage and disease is critical to understand the antimicrobial effect of plant extracts as it is not the same for all microorganisms.
- Incorporation of plant antimicrobials in food can give rise to the growth and virulence of certain pathogens due to the changes in microbial ecology. It is critical to understand the effect of plant extracts on the behavior of these microbial population in complex food systems.
- The growing environment of the source plants influences the levels of antimicrobial compounds in them. In addition, the period of harvest, storage and extraction procedures used will have an effect on the levels of active components responsible for antimicrobial activity and this would be a challenge in using it as a functional food ingredient.

5. Concluding and future perspectives

Most food products require protection against microbial spoilage during storage, especially in food industry and consumers demand safe natural products. Thus why it needs search of food authorities and researchers for mild preservation techniques to improve microbial quality and safety without causing nutritional and organoleptic losses that more satisfy consumers. Therefore, application of natural compounds from traditional medicinal plants as biological food preservatives are gaining a great interest from research and industry, due to the potential to provide quality and safety benefits, with a reduced impact on human health. Natural antimicrobials are gaining interest among food technologists for their use as alternatives to physical- and chemical-based antimicrobial treatments. However, there are many constraints in the application of natural antimicrobials in foods that require further research on their antimicrobial efficacy, consumer acceptability, and cost. Some of the major research issues that need to be addressed include development of microbial resistance to natural antimicrobials, homogeneously mixing of some antimicrobial compounds in food matrices, large-scale production of these compounds from their natural sources without losing their functional activity, and the approval of their use by regulatory agencies. Antimicrobial resistance could develop if the antimicrobials applied are not applied at their effective doses for the target microbial population. Injured or stressed cells could recover in the presence of suboptimal doses of antimicrobials by resistance adaptive mechanisms. The greatest challenge that remains is consumer acceptability of various natural antimicrobials, such as herbs and essential oils. When applied at the concentrations needed to achieve the desired level of antimicrobial potency, these antimicrobials can adversely affect the organoleptic properties of food beyond consumer acceptance.

Many of the natural antimicrobials are categorized as GRAS for specific food applications, but their use in other commercial applications requires regulatory approval. Natural antimicrobials can provide a tremendous opportunity for advancing the field of food preservation and safety; however, additional research is needed to optimize their applications. Further studies are also necessary with regard to the association and different combinations of various antimicrobial compounds and plant extracts as well as with other ingredients, aiming to characterize the type of interaction concerning synergistic, antagonistic or additive effects. It is also necessary to enhance knowledge of the influence of plant, post-harvest, and agro-industrial management in the composition and final content of the chemical components, in order to minimize undesirable variation or the low effectiveness of these compounds in the products. Finally, it is necessary to broaden and deepen the sensory studies related to the utilization of individual and combined antimicrobial compounds and plant extracts in different types of food industry in order to better understand the possible impacts on consumer acceptance.

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