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REVIEW ARTICLE

Naturally Occurring Preservatives in Food and their Role in Food Preservation

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ABSTRACT

Preservative agents are required to ensure that manufactured foods remain safe and unspoiled. Antimicrobial properties of essential oils reveal that Gram-positive bacteria are more vulnerable than Gram-negative bacteria. A number of EO components have been identified as effective antibacterial, e.g. carvacrol, thymol, eugenol, cinnamaldehyde and cinnamic acid, having minimum inhibitory concentrations at higher dilutions *in vitro*. Essential oils comprise a large number of components and it is likely that their mode of action involves several targets in the bacterial cell. The potency of naturally occurring antimicrobial agents or extracts from plants, ranges of microbial susceptibility and factors influencing antimicrobial action and their anti-oxidative properties, aimed at food preservation, are reviewed in this article. Methods employed for estimation of inhibitory activity, mode of action and synergistic and antagonistic effects are evaluated. The potential value of these agents as natural and biological preservatives is considered.

Key words: Essential oils, food safety, natural antimicrobials, toxicity.

INTRODUCTION

Many food products are perishable by nature and require protection from spoilage during their preparation, storage and distribution to give them desired shelf-life. Because food products are now often sold in areas of the world far distant from their production sites, the need for extended safe shelf-life for these products has also expanded. The development of food preservation processes has been driven by the need to extend the shelf-life of foods. Food preservation is a continuous fight against microorganisms spoiling the food or making it unsafe. Several food preservation systems such as heating, refrigeration and addition of antimicrobial compounds can be used to reduce the risk of outbreaks of food poisoning; however, these techniques frequently have associated adverse changes in organoleptic characteristics and loss of nutrients. Within the disposable arsenal of preservation techniques, the food industry investigates more and more the replacement of traditional food preservation techniques by new preservation techniques due to the increased consumer demand for tasty, nutritious, natural and easy-to-handle food products. Improvements in the cold distribution chain have made international trade of perishable foods possible, but refrigeration alone cannot assure the quality and safety of all perishable foods. The most common classical preservative agents are the weak organic acids, for example acetic, lactic, benzoic and sorbic acid. These molecules inhibit the outgrowth of both bacterial and fungal cells and sorbic acid is also reported to inhibit the germination and outgrowth of bacterial spores. In the production of food it is crucial that proper measures are taken to ensure the safety and stability of the product during its whole shelf-life. In particular, modern consumer trends and food legislation have made the successful attainment of this objective much more of a challenge to the food industry. Firstly, consumers require more high quality, preservative-free, safe but mildly processed foods with extended shelf-life. For example, this may mean that foods have to be preserved at higher pH values and have to be treated at mild-pasteurization rather than sterilization temperatures. As acidity and sterilization treatments are two crucial factors in the control of outgrowth of pathogenic spore-forming bacteria, such as *Clostridium botulinum*,

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addressing this consumer need calls for innovative approaches to ensure preservation of products. Secondly, legislation has restricted the use and permitted levels of some currently accepted preservatives in different foods. This has created problems for the industry because the susceptibility of some microorganisms to most currently used preservatives is falling. An increasing number of consumers prefer minimally processed foods, prepared without chemical preservatives. Many of these ready-to-eat and novel food types represent new food systems with respect to health risks and spoilage association. Against this background, and relying on improved understanding and knowledge of the complexity of microbial interactions, recent approaches are increasingly directed towards possibilities offered by biological preservation. Throughout the development of both Western and Eastern civilization, plants, plant parts, and derived oils and extracts have functioned as sources of food and medicine, symbolic articles in religious and social ceremonies, and remedies to modify behavior. Taste and aroma not only determine what we eat but often allow us to evaluate the quality of food and, in some cases, identify unwanted contaminants. The principle of self-limitation taken together with the long history of use of natural flavor complexes in food argues that these substances are safe under intended conditions of use. Originally added to change or improve taste, spices and herbs can also enhance shelf-life because of their antimicrobial nature. Some of these same substances are also known to contribute to the self-defense of plants against infectious organisms (Kim *et al*. 2001). In spite of modern improvements in food production techniques, food safety is an increasingly important public health issue (WHO 2002a). It has been estimated that as many as 30% of people in industrialized countries suffer from a food borne disease each year and in 2000 at least two million people died from diarrheal disease worldwide (WHO 2002a). There is therefore still a need for new methods of reducing or eliminating food borne pathogens, possibly in combination with existing methods. At the same time, Western society appears to be experiencing a trend of 'green' consumerism (Smid and Gorris 1999), desiring fewer synthetic food additives and products with a smaller impact on the environment. Furthermore, the World Health Organization has already called for a worldwide reduction in the consumption of salt in order to reduce the incidence of cardio-vascular disease (WHO 2002b). If the level of salt in processed foods is reduced, it is possible that other additives will be needed to maintain the safety of foods. There is therefore scope for new methods of making food safe which have a natural or 'green' image. One such possibility is the use of essential oils (EOs) as antibacterial additives. Based on rich histories of use of selected plants and plant products that strongly impact the senses, it is not unexpected that society would bestow powers to heal, cure diseases, and spur desirable emotions, in the effort to improve the human condition. The perception that these products are "natural" and have a long history of use has, in part, mitigated the public's need to know whether these products work or are safe under conditions of intended use. Until recently, EOs have been studied most from the viewpoint of their flavor and fragrance only for flavoring foods, drinks and other goods. Actually, however, EOs and their components are gaining increasing interest because of their relatively safe status, their wide acceptance by consumers, and their exploitation for potential multi-purpose functional use (Ormancey 2001). It has long been recognized that some EOs have antimicrobial properties (Boyle 1955) and these have been reviewed in the past (Shelef 1983; Nychas 1995) as have the antimicrobial properties of spices (Shelef 1983) but the relatively recent enhancement of interest in 'green' consumerism has lead to a renewal of scientific interest in these substances (Tuley 1996). These characteristics are possibly related to the function of these compounds in plants (Mahmoud and Croteau 2002). The antibacterial properties of EOs and their components are exploited in such diverse commercial products as dental root canal sealers (Manabe *et al*. 1987), antiseptics (Cox *et al*. 2000) and feed supplements for lactating sows and weaned piglets (van Krimpen and Binnendijk 2001; Ilsley *et al*. 2002). It is therefore scientifically sound to evaluate the impact of Eos on food and food products safety. Natural flavor complexes (NFCs) are mixtures of mainly low molecular weight chemical substances separated from plants by physical means such as distillation, extraction, and cold pressing. The most common NFCs are EOs. The EO is typically obtained by steam distillation of the plant or plant parts. With few exceptions, plants are dependent on their EO content for their unique aroma and gustatory profile. In other words, the volatile constituents of the plant isolated in the EO are primarily

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responsible for aroma and taste of the plant. For economic reasons, crude EOs are often produced via distillation at the source of the plant raw material and subsequently further processed at modern flavor facilities. EOs also called volatile or ethereal oils, are aromatic oily liquids obtained from plant flowers, buds, seeds, leaves, twigs, bark, herbs, wood, fruits and roots. They can be obtained by expression, fermentation, effleurage or extraction but the method of steam distillation is most commonly used for commercial production of EOs (van de Braak and Leijten 1999). The term 'essential oil' is thought to derive from the name coined in the 16th century by the Swiss reformer of medicine, Paracelsus von Hohenheim; he named the effective component of a drug *Quinta essentia* (Guenther 1948). An estimated 3000 EOs are known, of which about 300 are commercially important – destined chiefly for the flavors and fragrances market (van de Braak and Leijten 1999). Distillation as a method of producing EOs was first used in the East (Egypt, India and Iran) (Guenther 1948) more than 2000 years ago and was improved in the 9th century by the Arabs. By the 13th century EOs were being made by pharmacies and their pharmacological effects were described in pharmacopoeias (Bauer *et al*. 2001). The greatest use of EOs in the European Union (EU) is in food (as flavorings), perfumes (fragrances and aftershaves) and pharmaceuticals (for their functional properties) (van de Braak and Leijten 1999). EOs and fractions are also formulated in shampoos, toothpaste, disinfectants, topical ointments and cosmetics. However, when used in foods, highly volatile plants EOs are sometimes lost during processing operations. Microencapsulation technology is one way these losses of EOs by volatilization can be prevented. This technique is being widely used in the pharmaceutical industry for controlled delivery of drugs. It is also currently used in the food industry for flavor stabilization. By encapsulating antimicrobial EOs, not only can they be protected from heat, but they also can be released in products at a controlled rate to deliver effective inhibitory concentrations over extended periods and thereby extend shelf-life. This review presents the current understanding of the mode of action of these compounds and their possible applications in food protection.

ANTIOXIDATIVE PROPERTIES

Lipid peroxidation is a complex process occurring in aerobic cells and reflects the interaction between molecular oxygen and polyunsaturated fatty acids. Radicals are known to take part in lipid peroxidation, which causes food deterioration, aging organisms and cancer promotion (Ashok and Ali 1999). Antioxidants act as radical-scavengers, and inhibit lipid peroxidation and other free radical-mediated processes: therefore, they are able to protect the human body from several diseases attributed to the reactions of radicals (Takao *et al*. 1994). Use of synthetic antioxidants to prevent free radical damage has been reported to involve toxic side effects (Cornwell *et al*. 1998), to serve the processing of natural products. Free radicals provoked by various environmental chemicals as well as endogenous metabolism are involved in a number of diseases like tumors, inflammation, shock, atherosclerosis, diabetes, infertility, gastric mucosal injury, and ischemia due to the oxidative damage to DNA, lipids, and proteins and which can result in failure of cellular functions (Kasai et al. 2000). Consumption of antioxidants from plant materials that inhibit free radical formation or accelerate their elimination has been associated with a lowered incidence of these diseases as a consequence of alleviating the oxidative stress of free radicals (Leong and Shui 2002); accordingly, antioxidants have recently garnered increased research interest. Free radicals can result in food sourness, oil rottenness, and most industrial product aging. Many experiments have indicated that free radicals are necessary to support life, though they are also dangerous in biological tissues. Under normal physiological conditions, free radicals in the body will undergo a process of production and continuous scavenging so as to sustain physiological equilibrium. Even when the free radicals generated in the body are in low concentrations, the body metabolism may be disordered and some diseases can be caused (Pietta 2000). Synthetic antioxidants have been used in the food industry since the 1940s, but trends in many health-related industries tend to shift preferences to natural sources. Therefore, investigation of natural antioxidants has been a major research interest for the past two decades as many research groups and institutions have been screening plant materials for possible antioxidant properties. Food composition data, necessary for epidemiological and nutritional studies, are merely representative of foodstuffs consumed in the raw state. Many food composition databases never take into consideration the fact that concentrations of nutrients and their activity may

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change through cooking practices such as blanching. This is of great importance, considering that only a small amount of vegetables is consumed in the raw state, whilst most need to be processed for safety and quality. Overwhelming scientific data, from epidemiological studies, indicate that diets rich in fruit, vegetables and grains are associated with a lower risk of several degenerative diseases, such as cancers (Steinmetz and Potter 1996) and cardiovascular diseases (Rimm *et al*. 1996). This association is often attributed to different antioxidant components, such as vitamin C, vitamin E, carotenoids, lycopenes, polyphenols and other phytochemicals. The most widely used synthetic antioxidants in food (butylated hydroxytoluene BHT, butylated hydroxyanisole BHA, propyl galate PG and tertiary butyl hydroquinone TBHQ) have been suspected to cause or promote negative health effects (Pokorny 1991). Antioxidants have been widely used as food additives to provide protection against oxidative degradation of foods by free radicals. Since ancient times, spices in different types of food to improve flavors are well known for their antioxidant capacities (Madsen and Bertelsen 1995). In recent decades, the EOs and various extracts of plants have been of great interest as they have been the sources of natural products. In order to prolong the storage stability of foods, synthetic antioxidants are used for industrial processing. But according to toxicologists and nutritionists, the side effects of some synthetic antioxidants used in food processing such as butylated hydroxytoluene (BHT) and butylated hydroxyanisole (BHA) have already been documented. For example, these substances can exhibit carcinogenic effects in living organisms (Baardseth 1989). For this reason, governmental authorities and consumers are concerned about the safety of the food and also about the potential effects of synthetic additives on health (Reische *et al*. 1998). Hence, there is a growing interest in studies of natural additives as potential antioxidants. Many sources of antioxidants of plant origin have been studied in recent years. Among these the antioxidant properties of many aromatic plants and spices have shown to be effective in retarding the process of lipid peroxidation in oils and fatty foods and have gained the interest of many research groups. The use of EOs as functional ingredients in foods, drinks, toiletries and cosmetics is gaining momentum, both for the growing interest of consumers in ingredients from natural sources and also because of increasing concern about potentially harmful synthetic additives (Reische et al. 1998). Within the wide range of the above-mentioned products, a common need is availability of natural extracts with a pleasant taste or smell combined with a preservative action, aimed to avoid lipid deterioration, oxidation and spoilage by microorganisms. Those undesired phenomena are not an exclusive concern of the food industry, but a common risk wherever a lipid or perishable organic substrate is present. In fact, they induce the development of undesirable off-flavors, create toxicity and severely affect the shelf-life of many goods (Hirasa and Takemasa 1998). EO compounds, such as carvacrol and thymol, will both prevent the microbial and chemical deterioration when added to food (Ultee *et al*. 1999; Burt 2004; Mahmoud et al. 2004a, 2004b). The antimicrobial and antioxidant effect of these phenolic compounds can be enhanced by combining with other natural preservatives (Ramanathan and Das 1992; Yamazaki et al. 2004). The antioxidant activity found in the fractions of Citrus sinensis, is attributed to the presence of flavonoids and other phenolic compounds (Maria *et al*. 2006). The synthesis of several phenylpropanoid compounds (flavonoids, isoflavonoids, psoralens, coumarins, phenolics acids, chlorogenic acid, lignin and suberin) is induced in plants by biotic and abiotic stress, factors such as wounding, low temperature and attack of pathogens (Dixon and Paiva 1995). Phenolic compounds are known to constitute one of the most important groups of natural antioxidants, owing to their diversity and extensive distribution. They possess biological and chemical properties in common: reducing character, capacity of sequestering reactive oxygen species (ROS) and several electrophiles, for chelating metallic ions, tendency to self-oxidation and capacity for modulating the activity of some cell enzymes (Robards *et al*. 1999). Functions of diverse phenolic antioxidant in the diet have already been discussed (Astley 2003; Trewavas and Stewart 2003). The biological activity of phenylpropanoids and their function as antimicrobial agents are well recognized, as are their antiallergenic and anti-inflammatory properties, along with their antimutagenic action (Rice-Evans et al. 1996). The number of antioxidant compounds synthesized by plants as secondary products, mainly phenolics, serving in plant defense mechanisms to counteract reactive

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oxygen species (ROS) in order to survive, is currently estimated to be between 4000 and 6000 (Wollgast and Anklam 2000; Havsteen 2002). The phenolic content and composition of plants and the products produced from them depend on genetic and environmental factors, as well as post-harvest processing conditions (Cowan 1999). The antioxidant activities of phenolics are related to a number of different mechanisms, such as free radical-scavenging, hydrogen-donation,singlet oxygen quenching, metal ion chelation, and acting as a substrate for radicals such as superoxide and hydroxyl. A direct relationship has been found between the phenolic content and antioxidant capacity of plants (Al-Mamary *et al*. 2002). Proestos *et al*. (2006) linked the phenolic fraction of plant extracts to their antioxidant capacity. The use of plants, herbs as antioxidants in processed foods is becoming of increasing importance in the food industry as an alternative to synthetic antioxidants (Madsen and Bertelsen 1995). They tend to be water soluble, because they frequently occur combined as glycosides and they are usually located in the cell vacuole (Harborne 1998). Phenolics are antioxidants with redox properties, which allow them to act as reducing agents, hydrogen donators, and singlet oxygen quenchers (Pietta 2000). They also have metal chelation properties (Kahkonen *et al*. 1999). Their significance for the human diet and antimicrobial activity has been recently established (Rauha *et al*. 2000; Nychas *et al*. 2003). The antioxidant properties of these compounds are often claimed for the protective effects of plant-based beverages against cardiovascular disease, certain forms of cancer and photosensitivity reactions (Bravo 1998). It was also found that they inhibit human immunodeficiency viral replication (HIV), human simplex virus (HSV), glucosyl transferases of Streptococcus mutans (dental carries), ascorbate auto-oxidation (green tea), cytotoxic effects, tumor promotion and xanthine, monoamine oxidases (Mattila *et al*. 2000; Middleton *et al*. 2000; Havsteen 2002). These studies provide the basis for the present rapidly increasing interest for the use of natural antioxidants as functional food ingredients and/or as food supplements. Extraction procedures to obtain active principles are mainly focused on the use of methanol or ethanol as solvents. Since active compounds in plants exhibiting biological activity are in low concentrations, selective extraction methods should be used. Activity may be varied when different solvents are used for conventional extraction. Extraction with non-polar solvents, such as hexane, petrol ether, provided better antioxidant properties than did methanol or acetone (Chen et al. 1992; Chevolleau *et al*. 1992). Presence of antioxidant component in plant materials is determined by many methods since the antioxidants act by different mechanisms. They play an important role for the scavenging of free radicals and chain-breaking and these types of compounds have been called primary antioxidants and act as deactivators of metals, inhibitors of lipid hydroperoxide breakdown, regenerators of primary antioxidants and quenchers of singlet oxygen (Koleva *et al*. 2002). On the other hand, fatty acid decomposition is one of the main causes of food spoilage and inhibition of fatty acid oxidation is an important issue in the food industry. Food preservers or antioxidants are mainly used as inhibitors of the oxidation of fatty acids. Therefore, the inhibition of linoleic acid oxidation can be measured in the presence of ƒÀ-carotene that is used as a marker (Dapkevicius *et al*. 1998). Radical-scavenging and antioxidant properties of EOs from Rosemarinus officinalis and Cuminum cyminum were tested and compared to those of Thymus x-porlock EO. The radical scavenging performance of the rosemary oil was better than that of Cuminum cyminum (Gachkar *et al*. 2006). Owlia *et al*. (2007) reported antioxidant activity of EO from Matricaria chamomilla L. The antioxidant activity of Ruellia tuberosa L. (Acanthaceae) was investigated by Chen *et al*. (2006). The methanolic extract (ME) and its four fractions of water (WtF), ethyl acetate (EaF), chloroform (CfF), and n-hexane (HxF) were prepared and then subjected to antioxidant evaluation. The results revealed that R. tuberosa possesses potent antioxidant activity. The antioxidant activities of the different fractions tested decreased in the order of EaF > CfF > ME > WtF > HxF according to the hydrogen peroxide-induced luminal chemiluminescence assay, and results were the same with the exception of the rank order of HxF and WtF according to the DPPH free radical-scavenging assay. Total antioxidant activity of water-soluble components in raw spinach was in the order of BI . BM . BPG > BP, whereas free radical-scavenging activity was in the order of BI > BPG > BM > BP (Amin *et al*. 2006). Kartal and co workers (2007) examined the in vitro antioxidant properties of the EO and various extracts prepared from the herbal parts of Ferula orientalis A. (Apiaceae). Bektas *et al*. (2005) compared the antioxidant potentials of

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two Thymus species on the basis of the chemical compositions of EOs obtained by hydrodistillation. It was reported that oxidative stress is associated with the pathogenesis of Alzheimer□fs disease (AD) and cellular characteristics of this disease are either causes or effects of oxidative stress (Vina *et al*. 2004). These evidences clearly show that oxidative stress, an early event in AD, may play a key pathogenic role in the disease (Zhu *et al*. 2004). Interestingly, intake of polyphenols through diets rich in fruits, vegetables and beverages such as red wine was stated to reduce incidence of certain age-related neurological disorders including macular degeneration and dementia (Commenges *et al*. 2000). Herbs and spices have been used for many centuries to improve the sensory characteristics and to extend the shelflife of foods. As a result, considerable research has been carried out on the assessment of the antioxidant activity of many herbs, spices and their extracts when added in a variety of foods and food model systems. Mate (Ilex paraguariensis) leaves contain many bioactive compounds, such as phenolic acids, which seem to be responsible for the antioxidant activity of green mate infusions, both in vivo and in vitro (Filip *et al*. 2000; Bracesco *et al*. 2003; Markowicz-Bastos *et al*. 2006). The antioxidant effect of two plant EOs (sage and rosemary EOs) and one synthetic antioxidant (BHT) on refrigerated stored liver pate (4□‹C/90 days) was evaluated. Pates with no added antioxidants were used as controls. Plant EOs inhibited oxidative deterioration of liver pates to a higher extent than BHT did (Estevez *et al*. 2007). Oxidative reactions in foodstuffs are enhanced after cooking and refrigerated storage through the increase of their oxidative instability due to the degradation of natural antioxidants and the release of free fatty acids and iron from the haeme molecule (Kristensen and Purslow 2001; Estevez and Cava 2004). Sage (*Salvia officinalis*) and rosemary (*Rosmarinus officianalis*) are popular Labiatae herbs with a verified potent antioxidant activity (Dorman *et al*. 2003). The antioxidant activity of sage and rosemary EOs is mainly related to two phenolic diterpenes: carnosic acid and carnosol which are considered two effective free-radical scavengers (Dorman *et al*. 2003; Ibanez *et al*. 2003). The antioxidant activity of these molecules has been compared to that from other recognized antioxidant substances, and Richheimer *et al*. (1999) indicated that the antioxidant potential of the carnosic acid was approximately seven times higher than that of BHT and BHA.There was a strong correlation between the rosmarinic acid level and antioxidant activity potential. Honey has been reported to contain a variety of phenolics and represents a good source of antioxidants, which makes it a good food antioxidant additive and increases its usability potential in ethnomedicine (Al-Mamary *et al*. 2002; Aljadi and Kamaruddin 2004; Beretta *et al*. 2005; Kucuk *et al*. 2007). Several methods have been developed, in recent years, to evaluate the antioxidant capacity of biological samples (Rice-Evans *et al*. 1997; Schlesier *et al*. 2002). The total phenolic content of natural samples, such as plants and honey, reflects, to some extent, the total antioxidant capacity of the sample (Beretta *et al*. 2005). The most widely used antioxidant methods involve the generation of oxidant species, generally radicals, and their concentration is monitored as the present antioxidants scavenge them. Radical formation and the following scavenging are applied in 2,2-diphenyl-1-picrylhydrazyl (DPPH)- and superoxide radical-scavenging activity measurements (Gulcin *et al*. 2003). In radical-scavenging activity, the higher extract concentration required to scavenge the radicals means the lower antioxidant capacity. Ferric-reducing/antioxidant power (FRAP) is another widely used antioxidant activity measurement method, which has been used for the assessment of antioxidant and reducing power of many different samples, including honey (Aljadi and Kamaruddin 2004) and plant exudates (Gulcin *et al*. 2003).

FUTURE RESEARCH

Foods preserved with natural additives have become popular due to greater consumer awareness and concern regarding synthetic chemical additives. This has led researchers and food processors to look for natural food additives with a broad spectrum of antimicrobial activity (Marino *et al*. 2001). We have little doubt that the aroma compounds can represent a useful tool to increase the shelf-life and the safety of processed foods and fruits. evertheless, in relation to the composition of foods and fruits, further investigations are necessary to identify the conditions that maximize their activity without detrimental effects on the organoleptic properties of the product. The antimicrobial molecules in complex mixture of EOs' compounds and their eventual interactions should be addressed. This will lead to increase in control of microbial

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growth, to minimize the impact of these substances on the flavor of food products and to avoid fluctuations in Eos activity due to meteorological, seasonal and geographical factors, as well as different compositions due to the plant type. The stability of EOs during food processing will also need to be studied. Standardization of test methods for testing antibacterials for use in food. This is a field where a selection of standard methods would accelerate the study of promising antibacterial components and their synergistic or antagonistic action with each other and with food ingredients. Synergistic effects could be exploited so as to maximize the antibacterial activity of EOs and to minimize the concentrations required to achieve a particular antibacterial effect. Antagonism between EO and food ingredients is undesirable and research is needed so it can be avoided in practical applications. Interactions between EOs and their components and other food ingredients and food additives need to be investigated. Clove and oregano oils can acquire a dark pigmentation when in contact with iron (Bauer *et al*. 2001); this may impose limitations on the public acceptability of the food products or preservatives. Further elucidation of the mechanisms of antimicrobial actions of EOs would provide insights that may prove useful for technological applications. Setting up specific active packaging able to release slowly over time in the headspace the selected molecules. The activity would be enhanced by a calibrated increase of EO vapor pressure in order to enhance its capacity to interact with the microbial cell membrane (Guerzoni *et al*. 1994; Gardini *et al*. 1997; Lanciotti *et al*. 1999). The interaction between antimicrobials and packaging materials, rather than the food itself need research. Development of microbial resistance to the presence of EOs in foods is important. Disadvantageous effects of addition of EOs on the safety of the food, such as influencing the stress tolerance of pathogens need special attention. Possible consequences such as toxicity or other unwanted side effects on the human health of the use of Eos would need to be explored.

CONCLUSION

The potency of naturally occurring antimicrobial agents or extracts from plants ranges of microbial susceptibility and factors influencing antimicrobial action and their anti-oxidative properties, aimed at food preservation. These naturally occurring chemical preservatives are safe for preservation.

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