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A REVIEW OF EFFECTIVENESS OF SPICES AS ANTIMICROBIAL AGENTS IN FOOD PRESERVATION

Mr. Ghadge Amit Babasaheb
Department of Science, Smt. Ratnaprabhadevi Mohite Patil College of Home Science for Women, Akluj
Corresponding Author- Mr. Ghadge Amit Babasaheb
Email: *amitghadge9921@gmail.com*

Abstract
Spices are being used as food preservatives from ancient times. Spice is a naturally occurring compound or a mixture of compounds which can be obtained from the plant parts such as seeds, fruits, trunk skins, roots, leaves or flowers. The spices are considered as safe for human consumption and they are also effective against many pathogens. Spices contain variety of phenolic compounds which give them antimicrobial properties against bacteria, fungi, yeasts and molds. The phenolic compounds in the spices have hydroxyl groups which are believed to be effective in antimicrobial activities. When extracts of spices are used in foods, the concentrations required are very high and this could adversely affect the organoleptic and other properties of the foods. This review deals with various spices that are used as food preservatives, the antimicrobial properties and their mode of action of the active principles of spices, advantages of the use of antimicrobial activities of spices in food and effectiveness of antimicrobial activities of spices in foods.

Key words*: Spices, antimicrobial compounds, active principles, phenolic compounds, food preservatives*

Introduction

Various cultures in the world are using spices to preserve a variety of food, to enhance the taste, flavor, aroma and to impart the color to the foods. The people in ancient era have identified various methods of uses of spices in the preservation of perishable foods. It is believed that they were also aware of the fact that these spices could be used in ailment of many clinical illnesses. Extracts obtained from plants can be used for many years. Some of these have antimicrobial activities and many of them are being used conventionally as functional foods, medicines and supplements in diet.

Spice is a naturally occurring compound or a mixture of compounds which can be obtained from the plant parts such as seeds, fruits, trunk skins, roots, leaves or flowers. For many centuries the products which were derived from the plants were being used for medicinal purposes. In today's scenario, about 80% of the population of the world now relies upon the products obtained from the plants as medicines. Such products are considered as safe for human consumption and they are also effective against many pathogens (Hora and Nair, 1944). The extracts obtained from many spices exhibited bacteriostatic or bactericidal activities. These antimicrobial properties of the spices are due to presence of the volatile oils in their composition ((Arora and Kaur, 1999, Karapınar and Gönül, 1987). The chemotherapy depends upon the development of newer drugs and medicines for treatment. As there is a constant risk of development of resistance in pathogens against a specific or all drugs (Gibbons, 1992) and therefore continuous search for new drugs is needed. Many plants and plant products can be applied to fight against a variety of illnesses (Chopra and Nayar, 1956). These plant products have the essential antimicrobial activities (Mahajan and Arora, 1991, Rusia and Srivastava1988). The antimicrobial properties of these spices is dependent on many factors such as type of spice, composition of the spice, its amount used in the process, types of microorganisms, pH of the medium in which the activity is to be determines, temperature of the environment and composition of the medium (Shelef et al., 1980).

There are many spices which are part of our daily diet. These include ajowain, black pepper, clove, garlic, cumin, ginger, caraway etc. In recent years, there is a great demand for safe and natural preservatives for foods and therefore spices are exploited extensively in this regard. The use of spices in food as natural preservatives has some limitations. The concentration of extracts of spices needed to act as food preservative is very high but this leads to certain

changes in the organoleptic properties of the food. The common methods of food preservation such as use of heat treatment, acids, salts, drying methods and use of some chemical compounds are less invasive methods. Hence such methods should be complemented or replaced by the use of spices (Fernández et al., 2011).

Clove contains eugenol as active principle. Eugenol has anesthetic properties and therefore it can be used in case of toothache (Suresh et al., 1992). It is reported that clove and cinnamon have strong activity against many microorganisms while cumin showed moderate and red pepper showed weak antimicrobial activity (Barbosa-Canovas et al., 1998). The antimicrobial activity of cumin extract against *Micrococcus luteus, Staphylococcus aureus, Pseudomonas aeruginosa* was studied (Çon et al., 1998). Garlic is also used for many infectious diseases due to its antimicrobial properties. Many spices are being used in the pickles and sausages where they act as preservatives for these food items (Meena and Sethi, 1994). Studies have been performed on the antimicrobial activities of many of the spices against microorganisms such as yeasts and bacteria. Effect of cinnamon extracts on *Escherichia coli* and *Klebsiella pneumoniae* were also observed (Ouattara et al., 1997). Comparative studies of antimicrobial activities of some of the spices and that of the different antibiotics have been done to check for the possibility of replacement of antibiotics with extract of spices (Arora and Kaur, 1999). The antimicrobial activity of red pepper was tested on *Staphylococcus aureus (*Nkanga and Uraih, 1981). Clove extracts were also tested on *Enterococcus faecalis, Escherichia coli, Candida albicans, Micrococcus luteus* and *Staphylococcus aureus (*Hammer et al., 1999).

Some advantages of the use of antimicrobial activities of spices in food

Spices and the products obtained thereof are generally recognized as safe (GRAS). They are free of any sort of residues. Spices are used in very less quantities in the preparation of food. They have ability to impart flavor, taste and color to the food in fewer amounts also. Spices are cultivated worldwide (Christaki et al., 2012). Spices contain variety of phenolic compounds which give them antimicrobial properties against bacteria, fungi, yeasts and molds (Adeyinka and Richard, 2015). There are reports indicating the presence of phenolic compounds in spices and the antimicrobial characteristics thereof (Fernández et al., 2011). Spices and phenolic compounds present in them are as follows-

Clove - eugenol,
cinnamon- cinnamic aldehyde,
oregano- carvacrol,
thyme-thymol etc. (Witkowska, 2013).

Such phenolic compounds present in the spices are lipophilic in nature. Due to this lipophilic nature of these compounds, they can easily damage the microbial cells as they disrupt the cells by interfering with osmotic pressure and membrane permeability (Prakash et al., 2015). Damage to the cell membrane results in leakage of vital ions, amino acids, proteins, nucleic acids and ATP molecules out of the cell and at the same time it leads to disturbances in nutrient uptake, synthesis of biomolecules and biochemical pathways of the cells (Bajpai et al., 2012). The active principles present in the spices also function in the food and they prevent the rancidity and off-flavor development in the food. This effect is due to the reducing properties and chemical structures of these molecules. They can neutralize the free radicals in foods. These molecules can exhibit this antioxidant activity either as pure molecules or due to the synergistic effect in the foods (Carocho et al., 2014). This ability of the active principles in spices is also observed in biological systems and it was reported to protect the body from damage due to free radicals thereby helping fight many diseases like diabetes, cancer and heart problems (Opara and Chohan, 2014). The phenolic compounds in spices are found to be important for the microorganisms in the intestine. The spices contain many dietary nutrients and therefore intake of spices in any forms can benefit the living systems by providing many such nutrients like polyphenols (Pérez-Jiménez et al., 2010). These polyphenols are utilized by the gut micro-flora and then converted into other metabolites which are with more effective biological activities (Valdés et al., 2015).

Details of antimicrobial activities of spices

The specific modes of action of the antimicrobial substances in the spices are not clearly understood due to the presence of a variety of components in the spices. The microbial cell components on which the effects are targeted are also varied. Mostly, the phenolic compounds in the spices have hydroxyl groups which are believed to be effective in antimicrobial activities **(**Gyawali and Ibrahim, 2014). These hydroxyl groups can impart their effects at cellular membranes causing cell damage. Due to this membrane damage, there is outflow of essential cellular components such as nucleic acids, ions and amino acids. The phospholipid bilayer of the cell membrane is the target for

eugenol. Damage to the cell membrane causes alteration in the cellular activities, changes in the osmotic pressure and salt imbalance. The permeability of the cell membrane increases and ATP levels in the cytoplasm are decreased. All these changes cause cell death. These phenolic compounds also cause damages to the enzymatic machinery in the microbial cells. In some cases mesosomes formation in the cells and coagulation of the cytoplasmic proteins were also observed (Prakash et al., 2015). It was reported that the active principles of spices containing phenolic compounds are more effective on Gram positive bacteria as there is direct contact of these compounds with the cell membrane. Gram negative bacteria have lipopolysaccharides in the outer membrane which prevent the lethal effects of such compounds **(**Gyawali and Ibrahim, 2014).

Effectiveness of antimicrobial activities of spices in foods

The active principles in the spices are found to possess antimicrobial activities at acceptable level when the in vitro studies are performed. But it was reported that when they are used in foods, the concentrations required are very high and this could adversely affect the organoleptic and other properties of the foods. Also the other components like proteins, fats, carbohydrates, salts etc. present in the foods could also affect the antimicrobial activity of spices in the foods (Casaburi et al., 2015). In in vitro studies, nutrient media used contains lesser variety and concentrations of the nutrients as compared to the nutrients in the foods.

This fact affects the repair of the damaged microbial cells. A solution to this type situations can be obtained by using combination of different types of extracts in the foods. This will also induce the synergistic activity of different active principles in the foods (Prakash et al., 2015). Another cause for lesser activity of active principles of spices in the food is processing of the food. Due to many operations in the food processing, the natural composition and structure of these biomolecules could be altered resulting in lesser activities (Chan et al., 2015). The heat treatments of the food like dry heating, pasteurization, sterilization etc. may also alter the activities. Temperature maintained at the storage places in also important factor in such cases. While using the spices for food preservation due to their antimicrobial activities, it is important to consider the factors which are related to the spices itself. These factors include methods of extraction, age of the plant, stages of harvesting, bio-geographical and climatic conditions of the cultivation etc. (Weerakkody et al., 2010). Spices are grown in natural environment. Various processes are involved in their cultivation, harvest, storage and transport. At each stage, they are vulnerable to be infected or contaminated by certain microorganisms and hence they may possess their own typical micro-flora. This micro-flora may have some microbes which are pathogenic to human. This poses risks for using such spices in food as the pretreatment of cooking may not destroy all such pathogens and they may grow at storage temperature and cause cases of food poisoning (Sagoo et al., 2009).

Conclusion

It is very clear that extracts of many of the spices such as clove, cinnamon, ginger, ajowain, black pepper, garlic, cumin, caraway etc. possess the antimicrobial properties. These antimicrobial activities are distinctly observed in vitro studies. But while applying them in the food as preservatives, there are some issues regarding their use due to various complexities involved. The chief issue involved is the higher concentrations required for their desired effects in the food and consequential changes in the organoleptic properties of the food. Therefore further studies regarding the choice of the spices, concentrations to be used, synergistic effects, composition of the food, various physic-chemical characteristics of the environment etc. should be studied in detail to enhance the use of spices as food preservatives. In today's modern age, there is always constant need for the safe and quality products especially in the food industries. The use of natural products is always promoted as the chemicals pose problems of pollution and waste disposal. The health problems associated with the use of synthetic food preservatives are also a matter of concern these days. Spices and their extracts can be good alternatives as food preservatives.

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