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ANTIMICROBIAL AND ANTIOXIDANT PROPERTIES OF SPICES

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هذه المقالة تقدم تلخيص موجز لبعض الدراسات التي توضح خواص البهارات من حيث مقاومة الميكروبات ومضادة الأكسدة. وقد ركز المؤلف علي ما تم نشره في جميع أنحاء العالم بخصوص هذه الصفات. وقد ناقش المؤلف مدي استخدام البهارات كمادة حافظة ومادة مضادة للأكسدة وكذلك استخدامها كمكسبات طعم ورائحة.

This article presents a brief summary about the possible antimicrobial and antioxidant properties of some well known and widely used species. The author emphasizes on the previously reported studies which were carried out to reveal the antimicrobial and antioxidant properties of species commonly used throughout the world. In addition, the usefulness of these species as preservatives, antioxidants and aroma as well as flavoring agents is discussed.

INTRODUCTION

Food additives are used to accomplish certain functions as coloring agents, antimicrobials, antioxidants, preservatives, to improve nutrition, to increase emulsification, and to alter flavor. Since ancient times spices have been added to food, not only as flavoring agents but also as preservatives[1].

Spices are defined as "any dried, fragrant, aromatic, or pungent vegetable or plant substance, in the whole, broken, or ground form, that contributes flavor, whose primary function in food is seasoning rather than nutrition, and that may contribute relish or piquancy to foods or beverages"[2]. Why do we use spices in our food ?, this question received much attention in recent years and has generated many hypotheses.

It has been hypothesized that spices act as medicinal treatments, since many primitive societies use spices as pharmaceuticals[3]. Spices have been prescribed for aiding digestion, raising sexual potency, decreasing blood pressure, controlling

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metabolism, and delaying the onset of degenerative diseases[4&5]. However, Sherman and Flaxman[3] suggest that if the role of spices was to cure; spices taken for the purpose of treating an ailment would most likely be taken in larger doses than they are called for in most recipes.

Antimicrobial properties

A well-known early use of plant extracts (i.e. spices and oils) as antimicrobials was attempted by the ancient Egyptians[6]. A study by Sherman and Billing[2] was conducted for analyzing the use of 43 spices in 36 countries worldwide. A total of 4,578 meat-based recipes from 93 traditional cookbooks were involved in this study. The study was restricted to meat-based recipes because meat is more likely to spoil and cause food poisoning than plant products. The inhibitory effects of these spices were tested on 30 species of bacteria. Every spice included in this study displayed inhibitory properties on at least one species of bacteria. Eighty percent of the spices tested inhibited 50 percent of the bacteria, and four spices, garlic, onion, allspice, and oregano, inhibited the growth of every species of bacteria in this experiment.

Herbs and spices have been used for their antimicrobial properties in preventing food deterioration and pathogenic diseases. Ground mustard, clove, and cinnamon as well as their oils are known to be useful in slowing down microbial spoilage of food. In a study of 27 spices, garlic was shown to exert antimicrobial activity against all eight microbials, including *E. coli*, *Salmonella typhosa*, and *Scigella parasysenteria*. Onion, clove, and nutmeg were effective against all except *Bacillus subtilis*. Mace and achiote (annato) have been shown to be especially effective against *Clostridium botulinum*. Also effective as antimicrobials are oregano, marjoram, thyme, sage, rosemary, caraway, wasabi, allspice, pepper, and ginger. Isolated constituents of antimicrobial spices have also been studied for their antimicrobial activity[7].

Additional studies on spices have yielded similar results. A study released by Ross *et al*.[8] analyzed the antimicrobial properties of garlic products. The active ingredient found to be responsible for inhibition of antimicrobials was allicin (allyl 2-propene thiosulfinate). Unique to this study was the discovery that allicin is not present in garlic cloves; instead, allicin is formed by the crushing of the garlic clove. This discovery explains the antimicrobial abilities of garlic powder and garlic oil. Garlic oil and garlic powder displayed the ability to inhibit *H. pylori*, *S. aureus* and *E. coli*[8]. Basil, cumin, caraway, and coriander have been proven to inhibit the growth of *A. hydrophila*, *P. fluorescence*, and *S. aureus*[9].

A study by De *et al*.[10] tested the antimicrobial effects of 35 Indian spices on a Gram-positive and a Gram-negative organism, as well as yeast. The 35 spices were individually mixed into molten agar media at three concentrations. The organisms were then added to the solidified media and their growth was compared with a control group. Results indicated that 20 of the spices had antimicrobial properties. Of the 20 spices with antimicrobial properties, six spices had both antibacterial and antifungal activities.

These results do not come as a surprise. Spices are evolved chemicals produced by plants as a means of defense against their natural predators. This defense can deter insects from eating the plant by giving off a pungent taste and aroma. This defense can also protect the plant from microscopic predators via inhibiting the growth of bacteria and fungi within the plant. Humans, to inhibit microbial growth, add these same chemicals that are used by plants, for preserving food[5].

Arora and Kaur[11] mentioned that spices have been shown to possess medicinal value, in particular, antimicrobial activity. They compared the sensitivity of some human pathogenic bacteria and yeasts to various spice extracts and commonly employed chemotherapeutic substances. Of the different spices tested only garlic and clove were found to possess antimicrobial activity. The bactericidal effect of garlic extract was apparent within 1 hour of incubation and 93% killing of *Staphylococcus epidermidis* and *Salmonella typhi* was achieved within 3 hours. Yeasts were totally killed in 1 hour by garlic extract but in 5 hours with clove. Some bacteria showing resistance to certain antibiotics were sensitive to extracts of both garlic and clove. Greater anti-candidal activity was shown by garlic than by the topical antifungal agent nystatin.

Antibacterial activity of extracts of Allium sativum (garlic), Myristica fragrans (nutmeg), Zingiber officinale (ginger), Allium cepa (onion) and Piper nigrum (pepper) has been evaluated against 20 different serogroups of *E. coli*and 8 serotypes of Salmonella, *L. monocytogenes* and *A. hydrophila*. Garlic extract showed excellent antibacterial activity against all the test organisms, except *L. monocytogenes*. Nutmeg showed good anti-listerial activity, although activity against *E. coli* and Salmonella were serotype dependent. Both garlic and nutmeg extracts were effective against *A. hydrophila*. Extracts of ginger showed inhibitory activity against two serogroups of *E. coli*: as O8 (enterotoxigenic *E. coli*) and O88 only. Extracts of onion and pepper did not show any antibacterial activity against the test organisms[12].

Garlic had been used worldwide to fight bacterial infections as it exhibited a broad antibiotic spectrum against both Gram-positive and Gram-negative bacteria. Sivam[13] summarized results published as follows : i) raw juice of garlic was found to be effective against many common pathogenic bacteria including intestinal bacteria responsible for diarrhea in humans and animals; ii) garlic was effective even against those strains that have become resistant to antibiotics; iii) the combination of garlic with antibiotics leads to partial or total synergism; iv) even toxin production by micro-organisms was prevented by garlic.

Preservatives

Spices have an antimicrobial properties that act as a natural preservative in foods[2]. Kumar and Berwal[14] measured the inhibitory activity of garlic (*Allium sativum*) against *Staph.aureus*, *S.typhi*, *E.coli* and *L.monocytogenes* by the turbidity method. These researchers revealed that all bacterial pathogenic strains tested were inhibited by garlic. In addition, they observed that *E.coli* was the most sensitive to the effect of garlic. In contrast *L. monocytogenes* was less sensitive. Finally, these investigators emphasized that garlic was a potent inhibitor of food pathogens and that it's use would increase the shelf-life of processed foods.

Hammer *et al.*[15] studied the antimicrobial activity of 52 plant oils and extracts against several microorganisms (*E.coli, Acinetobacter baumanii, Aeromonas veronii biogroup sobria, C. albicans, Enterococcus faecalis, K. pneumoniae, Ps. aeroginosa, S. typhimurium, S. marcescens,* and *Staph. aureus)* using an agar dilution method. These investigators found that oregano (*Origanum vulgare*), lemongrass and bay inhibited all microorganisms at concentrations of = 2.0% (v/v). Moreover, these scientists investigated twenty of the plant oils and extracts using a broth microdilution method for activity against *E. coli*, *Staph.aureus* and *C. albicans*, and found that the lowest inhibitory concentrations (MIC) were 0.03 % (v/v) thyme oil against *E. coli* and *C. albicans*. Thus, they concluded that these results support the idea that plant essential oils and extracts might have a role as pharmaceuticals and preservatives.

Fathi *et al.*[16] investigated the effect of two concentrations of both potassium sorbate (0.1 and 0.2%) and ground black cummin (Nigella Sativa) (1% and 3%) on the survival of 4 strains of *Yersinia enterocolitica* (two standard straina, American serotype 0:8 and European serotype 0:9, and other two locally isolated strains from sausage) inoculated into minced meat. These researchers found that 0.1 and 0.2% potassium sorbate and 1% and 3% Nigella Sativa induced a decrease in numbers of *Yersinia enterocolitica* and higher concentrations of them exhibited more inhibition of counts of this organism than low concentrations.

Furthermore, a study conducted by Abd EL-Malek[17] tested the activity of four spices (garlic, oregano, thyme and black cumin seed) with different concentrations (0, 0.5, 1.0, 3.0, 5.0, 7.5, 10.0, 12.5, 15.0 and 17.5%) against *E. coli* O157:H7 in MacConkey sorbitol agar (MSA). The obtained results showed that garlic had the strongest inhibitory action, followed by oregano and thyme, which had medium inhibition; while black cumin seed had the weakest inhibitory activity. Aqueous extract of garlic and essential oils of oregano, thyme and black cumin seed were tested for their inhibitory activity against *E. coli* O157:H7. The MIC of garlic extract against *E. coli* O157:H7 was 1.56% (w/v), while the minimum lethal concentration (MIC) was 3.12% (w/v). The inhibitory effect of various Essential oils (EO) concentrations indicated that oregano EO followed by thyme EO had the highest inhibitory effects. Spices and spice extracts which had the best inhibitory effects against *E. coli* 0157:H7 in the laboratory medium and in-vitro study, should be chosen and tested for the food model study. The obtained results showed that garlic 3% has the highest inhibitory effect against *E. coli* 0157:H7 at the 3rd day of storage with reduction rate of 100%. The results obtained in this study suggests that garlic, oregano EO and thyme EO has a potential application as natural food preservative and can be used in meat product formulations for controlling the growth of *E. coli* 0157:H7.

Zaika[18] has released a list of spices with a known inhibitory effect against specific microbes. This list includes cinnamon, cloves, and mustard as strong inhibitors; allspice, bay leaf, caraway, coriander, cumin, oregano, rosemary, sage, and thyme as medium inhibitors; black pepper, red pepper, and ginger as weak inhibitors.

From the above evidence, it is clear that spices have great potential as preservatives in a society that prides natural ingredients. It is obvious that more work is necessary to determine the practicality of spices as preservatives.

Antioxidant action

Many spices are known to exert antioxidant activity and are useful for preventing lipid oxidation in living organisms as well as in foods. Of 78 common spices tested, 32 showed antioxidant activity in lard[18]. Rosemary and sage were found to be "remarkably effective" and by far the strongest antioxidants, with oregano, thyme, nutmeg, mace, and turmeric next in line. When the spices were tested in an oil-in-water emulsion, clove was found to exert the strongest antioxidant activity, followed by turmeric, allspice, mace, rosemary, nutmeg, ginger, cassia, cinnamon, oregano, savory, and sage. Aniseed, basil, cardamom, marjoram, as well as black and white pepper have also been reported to have some antioxidant activity. These results have prompted studies of various constituents of some of these spices to determine whether the isolated compounds produce antioxidant effects.

Zaika *et al.*[19] emphasized that the antimicrobial compounds in spices and herbs were mostly in the essential oil fraction. They revealed that besides their significant antimicrobial activities, spices have antioxidant properties that were effective in retarding rancidity during frozen storage of ground meat.

Spice extractives, such as oleoresin of rosemary, can provide inhibition of oxidative rancidity and retard the development of "warmed-over" flavor in some products. Thus, some spices not only provide flavor and aroma to food and retard microbial growth, but are also beneficial in prevention of some off-flavor development. These attributes are useful in the development of snack foods and meat products[20].

Aroma and flavoring properties

In modern food processing, spices were added to foods primarily as flavoring agents. The functional properties (i.e. major flavor and aroma compounds and antimicrobial fractions) of a spice reside in its essential oil[6].

Culinary spices have also been grown and used to flavor foods since antiquity. In most of these spices, the flavor is provided by the aromatic ingredients in their essential oils and oleoresins. Government agencies and some, but not all, health professionals recommend that for optimal health we should reduce our salt intake. This can be achieved by flavoring our meals to a greater degree with culinary herbs and spices such as basil, caraway, cilantro, coriander, cumin, dill, oregano, rosemary, sage, thyme, and other herbal seasonings[21].

Also, Subbulakshmi and Naik[22] pointed out that spices were vital culinary addendums enhancing oreganolyptic characteristics of foods. In addition, they had various preservative and antimicrobial properties and nutritional benefits, which make them an inevitable food accessory. The aroma and flavoring properties of the spices were related to their EO contents. These authors declared that the use of EO had covered one of the major objections to the use of ground spices i.e. flavor variability both in strength and character. Most of the EO were constant in their flavoring effects and the danger of microbial contamination was eliminated.

A study conducted by Skandamis and Nychas[23] found that oregano oil inhibited the microbial growth of spoilage organisms in minced meat and also improved physicochemical properties of meat. These researchers pointed out that the aroma of oregano oil was found to be acceptable up to 1 % (v/w) in minced meat. Oregano (*Origanum vulgaris L.*) was used medicinally in the Greek, Roman, and Arab Civilizations and it proved to be an excellent culinary herb both in terms of the aroma and flavor which it gives to foods[24].

More research must be done to assess the value of spices and garlic as an alternative to chemical food preservatives, especially in foods in which the spices or garlic flavor would be an added bonus and there was potential use for garlic by itself or in combination with other herbs or spices to extend the shelf-life of raw meat products[13].

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