effect of herbal bioactive compounds on foods microbial spoilage

M. A. Sahari
Department of Food Science and Technology
Tarbiat Modares University
Tehran, Iran
sahari@modares.ac.ir

S. Asgari
Department of Food Science and Technology
Tarbiat Modares University
Tehran, Iran
Sr_sgr@yahoo.com

Abstract: Extracts of many types of plants that be utilized as flavoring and seasoning agents in foods have been used therapeutically for centuries. Sulphur compounds, terpenes and terpene derivatives, phenols, esters, aldehydes, alcohols and glycosides have shown antimicrobial functions. So far many literatures have been studied the potential use of bioactive phytochemicals in food and pharmacy industries. Thus, this paper reviewed some of the works done to evaluate antimicrobial characteristic of some herbal chemicals, carried out in Tarbiat Modares University.

Keywords: antimicrobial properties, bioactive compounds, microbial spoilage, foodstuff.

1. Introduction

Fruits and vegetables, as biologically active sources, contain phytochemicals with antimicrobial, antioxidant, antimitogentic and anticarcinogenic activities. Phytochemical shaving both antioxidant and antimicrobial properties can be used for preserving foodstuffs and increasing their shelf lives. Essential oils and extracts obtained from plants also contain these active compounds. So, they are used in many foodstuffs as natural additives.

By increasing the consumers demand for green food products with high safety, quality and nutritional values, it seems that using plants and materials of plant origin such as essential oils and extracts is a suitable way to meet this need.

Natural aromatic plants and spices have been widely used in many food products, dairy and bakery products as flavoring and seasoning agents (1) for preserving and for their medicinal value (2), (3).

Naturally occurring compounds in spices such as, sulphur compounds, terpenes and terpene derivatives, phenols, esters, aldehydes, alcohols and glycosides have shown antimicrobial functions (4), (5), (6). The main factors that determine the antimicrobial activity are the type and composition of the spice, amount used, type of microorganism, composition of the food, pH value, temperature of the environment, and proteins, lipids, salts, and phenolic substances present in the food environment (7).

Essential oil from aromatic and medicinal plants has been known to possess potential as natural agents for food preservation, including antibacterial, antifungal and antioxidant (8). Some essential oils are highly inhibitory to pathogens at low levels comparable to organic acid used in food processing. It has to be emphasized that essential oils will probably not be useful as preservatives in foods that will receive heat treatment unit operations after addition of essential oil because it is very likely that the antimicrobial compounds would be evaporative (1). Goynot et al. investigate the effect of volatile fractions of 16 essential oils on the more common fungi causing spoilage of bakery products including, Eurotium amstelodami, E. herbariorum, E. repens, E. rubrum, Aspergillus flavus, A. niger and Penicillium corylophilum. They reported that volatile substances from cinnamon leaf, clove, bay, lemongrass and thym essential oils had good antifungal activity against common fungi causing spoilage in bakery products but these essential oils show poor activity when they were used in a sponge cake. However, comparison of the data obtained by different studies is difficult, because of differences in plants extract compositions, in methodologies followed to assess antimicrobial activity and in microorganisms chosen to be tested. Flavonoids showed anti-microbial activity, and quercetin and other related compound acts essentially by enzyme inhibition of DNA gyrase (9). Rajaei et al. studied antioxidant, antimicrobial and antimitogenic activities of pistachio (Ahmadaghaei variety) green hull extract (crude and purified extracts). The antimicrobial capacity was screened against Gram positive and Gram negative bacteria, and fungi. Aqueous and purified extracts inhibited the growth of Gram positive bacteria; the results of disc diffusion test showed Bacillus cereus was the most susceptible one with minimum inhibitory concentration (MIC) of 1 mg/ml and 0.5 mg/mL for the crude and purified extracts, respectively. In general, Gram negative bacteria are more resistant to polyphenols than Gram positive bacteria, perhaps due to the different cell wall compositions. The results obtained indicate that pistachio green hull may become important as a cheap and noticeable source of compounds with health protective potential and anti-microbial activity (10).

2. Food Applications

Due to development and use of safer antioxidant from natural sources in food industries, here we emphasize the antimicrobial property focusing on different food types.
I. Meat products and fish

Seyed Abdul Rahman et al. investigated the antimicrobial activity of some food additives used in meat products such as Cumin, Cinnamon, Cloves, Fennel, Red Crushed Pepper, Mustard, Cardamon, Ginger, Poppy and Anise against some microorganisms. They tested the diethyl ether-treated extracts of spice samples in vitro with Staphylococcus aureus, Klebsiella pneumoniae, Pseudomonas aeruginosa, Enterococcus faecalis, Micrococcus luteus, Escherichia coli and Candida albicans as test strains. The disc diffusion method was applied in the trial. Cinnamon was found to be the most effective spice against all the test strains except M. luteus. The weakest antimicrobial activity was displayed by Cloves, cumin, cinnamon and fennel towards this bacterium (11).

Zarringhalami et al. used annatto (Bixa orellana L.) powder (1% norbixin) in two different formulations of sausage (with 55% and 70% meat) as a replacement for 20%, 40%, 60%, 80% and 100% nitrite to decrease the use of nitrite. Microbial contamination owe were compared with the control (without annatto and with 100% nitrite) after 2, 10, 20 and 30 days from production and under refrigerated condition. The statistical comparison showed that in both formulations of sausage, the sample containing 60% annatto did not show any significant differences from the control for microbial contamination. Concerning the effective part in creating antimicrobial effect, literature shows that 9'-cis-norbixin and all transformed of nornorx are capable to create this characteristic. According to these results, annatto extract, as natural additive, is suitable for using in food products (12).

The effect of annatto extract on growth ability and spore germination of selected pathogenic bacteria (Clostridium perfringens, Bacillus cereus, Staphylococcus aureus and Escherchia coli) in chemical medium and sausage sample were studied. Disk diffusion and tube macrodilution techniques were used to determine minimum inhibitory concentration (MIC) and minimum bactericidal concentration (MBC) of annatto extract. The results indicated that annatto has an inhibitory effect on C. perfringens, B. cereus and S. aureus, but no activity was been detected against E. coli. In addition annatto was capable to inhibit spore germination and outgrowth of C. perfringens and B. cereus. Then for decreasing usage of nitrite in sausage, samples with different amounts of nitrite and annatto (nitrite:annatto in ratio of 100:0 contain 120 ppm nitrite as control, 40:60, 40:0 and 0:0 as control for C. perfringens growth ability), were prepared and were kept at different temperature (4, 20 and 37 °C) for 72 h. The results demonstrated that at 20 °C, in samples with 100% nitrite and with annatto and nitrite no germination of spores were observed (31).

Ojagh et al. study examined green tea polyphenols in concentration of 200, 400 and 600 ppm (PP200, PP400 and PP600) on the quality of common kilka (Clupeonella cultriventris caspia) during the storage with ice powder. The free fatty acid (FFA) at 5, 17, 29 and 41 h after fishing were compared with those of the control group (sample without any antioxidant). The Statistical results showed that FFA increased in all the treatment groups during the storage times, the sample with antioxidant as compared with the control group had more significant values (P< 0.05). Overall, the PP200 sample produced the best preservation condition while they did not have any significant difference in their qualitative characteristics (colour, odour, texture, taste and flavour) as well as off-flavour (32).

Tea and sesame seeds oils as two natural preservatives at 5 and 10% levels were added to carp (Cyprinus carpio) and common kilka (Clupeonella cultiventris caspia) oils. Oil peroxide (PV) and thiobarbitoric acid (TBA) values after 13 days at 60 °C were evaluated. The results showed that preservative effect of tea and sesame seeds oils in two mentioned fish oils were the same statistically. (33).

Mahmoud et al. analysed the microflora of common carp (Cyprinus carpio) skin, gill and intestine and studied the antimicrobial activities of garlic oil and nine constituents of essential oils (allyl isothiocyanate, carvacrol, cinnamaldehyde, citral, cuminaldehyde, eugenol, isoeugenol, linalool and thymol) against the carp isolates to identify compounds that might extend the shelf-life of carp fillet. A total of 90 isolated strains were identified to belong to seven genera: Acinetobacter, Alcaligenes, Bacillus, Flavobacterium, Micrococcus, Moraxella and Pseudomonas, and two families Enterobacteriaceae and Vibrionaceae. The dominant micro-organisms of carp were found to be Flavobacterium (37%) and Vibrionaceae (33%) in skin, Flavobacterium (33%) in gill and Vibrionaceae (63%) and Flavobacterium (37%) in intestine. Against these isolates, thymol, carvacrol and cinnamaldehyde had the strongest antimicrobial activities, followed by isoeugenol, eugenol, garlic oil, and then citral. The antimicrobial properties of the other constituents tested (cuminaldehyde, linalool and allyl isothiocyanate) were low. In tests of mixed compounds, a combination of carvacrol and thymol had the highest antimicrobial activity. Moraxella, Flavobacterium and Vibrionaceae were more sensitive to the compounds, whereas Alcaligenes strains were resistant. Dipping carp fillets in a solution of 0.5% carvacrol and 0.5% thymol before storage at 5°C and 10°C reduced both the total microbial load by about 100-fold and the Volatile Bases Nitrogen (VB-N), as compared with controls. In addition, dipping treatment delayed bacterial growth and extended the shelf-life of the fillets from 4 to 12 days at low temperature (5°C). However, the treated and control fillets showed little difference during storage at 10°C. Data from sensory evaluation showed that dipped fillets in 1% (carvacrol + thymol) extended the shelf-life of carp fillets.
by 8 and 4 days at 5°C and 10°C, respectively. Thus, carvacrol and thymol dipping can improve the microbial stability of fish fillets by removing bacteria and by inhibiting bacterial growth (13).

Mejhlholm and Dalgaard evaluated the antimicrobial effect of nine essential oils (EO) on P. phosphoreum and determine the effect of oregano oil on the shelf-life of modified atmosphere-packed (MAP) cod fillets. The antimicrobial effect of EO was studied in a liquid medium and in product storage trials. Oils of oregano and cinnamon had strongest antimicrobial activity, followed by lemongrass, thyme, clove, bay, marjoram, sage and basil oils. Oregano oil (0.05%, v/w) reduced growth of P. phosphoreum in naturally contaminated MAP cod fillets and extended shelf-life from 11–12 d to 21–26 d at 2°C (14).

Chouliara et al. investigated the combined effect of oregano essential oil (0.1% and 1% v/w) and MAP (30% CO₂/70% N₂ and 70% CO₂/30% N₂) on shelf-life extension of fresh meat stored at 4 degrees C. The parameters that were monitored were microbiological (TVC, Pseudomonas spp., lactic acid bacteria (LAB), yeasts, Brochothrix thermosphaeta and Enterobacteriaceae), physico-chemical (pH, TBA, color) and sensory (odor and taste) attributes. Microbial populations were reduced by 1-5 log cfu/g for a given sampling day, with the more pronounced effect being achieved by the combination of MAP and oregano essential oil. TBA values for all treatments remained lower than 1 mg malonaldehyde (MDA) kg⁻¹ throughout the 25-day storage period. pH values varied between 6.4 (day 0) and 5.9 (day 25). The values of the color parameters L*, a* and b* were not considerably affected by oregano oil or by MAP. Finally, sensory analysis showed that oregano oil at a concentration of 1% imparted a very strong taste to the product (15).

II. Bakery products

Kordsardou et al. studied antifungal properties of Zataria multiflora Boiss essential oil in cake. Zataria multiflora Boiss is one of the important species of Labiatae family. In this study three concentration (500, 1000 and 1500 ppm) of its essential oil was added during cake batter production and a control (without any preservatives) was prepared. Molds in treated samples were counted after packaging and 60 days storage in ambient temperature and rheological characteristics were evaluated after ten day storage. Results revealed that mold counts were reduced significantly in the presence of essence compared with control sample. According to the results, in addition of flavoring, Zataria multiflora Boiss essence may act as antifungal agent in bakery products and antifungal property is retained during baking (16).

Daruge et al. analyzed essential oil of coriander by GC/MS and identified its chemical compositions. Camphor (44.99%), cyclohexanol acetate (cis-2-tert butyl-(14.45%), limonene (7.17%), α-pinene (6.37%), were the main component of coriander essential oil (CEO). Then, antioxidant and antifungal activities of CEO were evaluated in cake during 60 day storage at room temperature. The results indicated that, CEO at 0.15% could inhibit the growth of fungal in the cake. Other studies reported antimicrobial effect of essential oils of Coriandrum sativum L. CEO showed antimicrobial activity against five species of Candida albicans. Also, it is reported that coriander essential oil has pronounced antibacterial activity against both Gram positive (Staphylococcus aureus and Bacillus spp.) and Gram negative (Echerichia coli, Salmonella typhi, Klebsiella pneumonia and Proteus mirabilis) bacteria. In addition, this extract showed anthelmintic activities against Haemonchus contortus. Several researchers have been described the antifungal activity of limonene, a terpenoid hydrocarbon isolated from different plant species including Coriander, against Aspergillus niger. Results showed that this essential oil could be used as natural antioxidant and antifungal in foodstuffs especially those lipid containing (17).

Sabouri et al. used extract of aerial parts of Echinacea purpurea L. instead of synthetic antioxidants in cake. Results showed that Echinacea purpurea L. extract was more effective in controlling growing molds and lipid oxidation during 60 days storage at 25°C and it can be used instead of synthetic antioxidant and preservatives. Results of antymycotic evaluation showed that selected extract at 1000, 1500 and 2000 ppm had an excellent antifungal effect on cake (18).

Lean and Mohamed, 1999 showed that turmeric had antioxidant and antioxidative and antimicrobial activities in butter cake during the 4 weeks storage and this one better than synthetic ones (19).

It has been reported that cinnamon leaf, clove, bay, lemongrass and thyme essential oils have antifungal activity in sponge cake against Eurotium, Aspergillus and Penicillium genus (20). Rizzello et al. reported that the water-soluble extract of Amaranthus spp. seeds has an excellent antifungal activity and large inhibitory against some of the most important bread contaminants such as Penicillium brevicompactum, P. chermesinum and Eurotium herbarioun. Cichoric acid (diamides), polysaccharides, alkanides (alkyl amides) and glycoproteins are considered as the most important compounds of this medicinal plant (21).

Noorolahi et al. added Cinnamon verum essential oil (CVEO; o.o5, 0.1, 0.15%) and Echinacea purpurea
extract (EPE; 0.24, 0.5, 0.75%) to Kolompe (a traditional cookie in Kerman-Iran) and compared their antioxidant and antimicrobial effects with the samples of BHA (100 and 200 ppm) and control (without any antioxidant). The antimicrobial activity of EPE-0.5, EPE-0.75 and all of the three concentrations of cinnamon (CVEO-0.05, CVEO-0.1 and CVEO-0.15) showed very well preventing power on aerobic microorganism, yeast and molds. Strong antimicrobial effect in cinnamon essential oil results from cinnamaldehyde compound. The amount of this compound in essential oil used in this study was 47.25%. This compound shows strong antimicrobial property against many microorganisms. In addition, presence of phenolic compounds in Echinacea extract caused antioxidant and antimicrobial effects. Cinnamon essential oil and Echinacea extract can increase the shelf life of Kolompe, because of the antimicrobial properties. The results of identification and enumeration of E. coli, Enterobacteriaceae, B. cereus, coagulase-positive Staphylococci in days 1, 5, 8, 15, 30, 45, and 60 showed that none of the Kolompe samples contained these bacteria. The reason for this finding may be the effect of cooking temperature, as well as the moisture and low amount of water in the Kolompe samples, which was not adequate for bacterial growing (22).

Nielsen and Rios used a mixture of spice and herbs in active packaging to prevent bread from fungal contamination. The essential oils of cinnamon, mustard, garlic and clove showed the strongest effect. Although oregano oleoresin weakly prevent the growth of most important spoilage fungi of bread, vanilla essential oil had no preventative effect against these fungi (23).

Khaki et al. evaluated the antioxidant and antimicrobial effects of chamomile essential oil in cake preparation during 75 days of storage. Chamomile essential oil as a natural antioxidant and antimicrobial agent can increase shelf-life of food products and due to absence of synthetic agents are safe with no side effect on human health. Results revealed that chamomile essential oil applied to cake was fungicidal and retarded mould growth. With increasing the concentration of chamomile essential oil inhibitory activity would increase but its effect is less than synthetic ones. In conclusion, the sample containing chamomile at 0.15% had better antioxidant and antimicrobial activities than the samples without any synthetic and natural antioxidant and antimicrobial agents. After 75 days, growth of moulds was observed in all samples (24). In another study they investigated Neroli essential oil in cake. Cake samples were produced with three different levels of essence (0.15, 0.1 and 0.05), control samples with synthetic preservatives (industrial cake) and cakes without neither synthetic nor natural preservatives and stored under ambient temperature. The effect of this essence against Escherichia coli, coliforms, Staphylococcus aureus, Enterobacteriaceae, molds and yeasts was evaluated with Iran’s international standard methods. Compared to results of industrial cake samples, this essence had a positive effect on microbial growth retardation (25).

III. Dairy products

Darabi Montaz et al. investigated the antimicrobial effect of Lavandula angustifolia essence on some microbial parameters of butter milk preservation. They screened the antimicrobial of this plant against Staphylococcus aureus, Escherichia coli, coliforms, molds and yeasts. Samples of butter were stored with different levels of L. angustifolia (0.2, 0.25, and 0.15%). Antimicrobial parameters were studied in determined intervals (after 20, 40 and 60 days) during storage. Compared to industrial butter (control sample), the effect of this essence was evaluated positive on microbial (staphylococcus aureus, Escherichia coli, coliforms, molds and yeasts) growth retardation (26).

IV. Sources

Zataria multiflora Boiss. (ZMEO) and Satureja hortensis L. (SHEO) (500, 1000 and 1500) were added to oil of mayonnaise and their preservative effects were compared with BHA synthetic antioxidant (100 and 200 ppm). 15% of linseed oil used as replacer for soybean oil, showed no significant differences in the color, texture, taste, smell, mouth feel and overall acceptability compared with control samples, and this same ratio of 15 percent was used in subsequent tests. The results of preservative effect and sensory properties (showed no significant difference in taste and smell score compared with control sample) of formulated mayonnaise showed that these natural antioxidants in mayonnaise formulation can ameliorate the quality of product as functional food due to advancing the public health (34).

“Tarkhun” and “Babune Shirazi” are the Persian names for Artemisia dracunculus L. and Matricaria chamomilla L., respectively, belonging to the family Asteraceae. The essential oil of Tarkhun is said to be a neuromuscular antispasmodic, anti-inflammatory, is used in aphrophy and spasmodic colitis, antibacterial and antifungal. M. chamomilla L. essential oil has been used commonly in medicine as an anti-inflammatory, antispasmodic, anti-intestinal bloating, anti-pectic ulcer, anti-bacterial and anti-fungal (27).

V. Cereals

Lopez et al. investigated toxic compounds in essential oils of coriander, caraway and basil active against stored rice pests. Essential oils, distilled from seeds of Coriander sativum and Carum carvii and from leaves of five different varieties of Ocimum basilicum, were fractionated by column chromatography and tested in the laboratory for volatile toxicity against three stored rice pests (Sitophilus oryzae, Rhyzopertha dominica and Cryptoles pesillus). The active fractions were analyzed
by GC–MS. Coriander contained linalool (1617 ppm of the oil) as the main product active against the three pests. Camphor-rich fractions (over 400 ppm) were very toxic to R. dominica and C. pusillius. The caraway profile included carvone and limonene as expected but (E)-anethole, generally regarded as a minor product in the essential oil of this species, was also a major component, being present at 365 ppm. Carvone was the most effective (972 ppm) monoterpene against S. oryzae. In addition, (E)-anethole at 880 ppm was toxic to R. dominica while vapors of limonene (1416 ppm) and fenchone-rich (554 ppm) fractions killed adults of C. pusillius only. Three major essential oil profiles were present in the five varieties of O. basilicum analyzed: methyl eugenol/estragole, estragole and estragole/linalool chemotypes. The abundance of components had a strong influence on the outcome of the bioassays. Fractions, where combinations of products occurred with or without other minor compounds, were often more toxic than any one compound alone (28).

VI. Fruits and Vegetables
Carvacrol and cinnamaldehyde were very effective at reducing the viable count of the natural flora on kiwifruit when used at 0.15 μl ml⁻¹ in dipping solution, but less effective on honeydew melon. It is possible that this difference has to do with the difference in pH between the fruits; the pH of kiwifruit was 3.2–3.6 and of the melon 5.4–5.5. The lower the pH, the more effective EOs and their components generally are (29).

It appears that, in vegetable dishes just as for meat products, the antimicrobial activity of EOs is benefited by a decrease in storage temperature and/or a decrease in the pH of the food. Vegetables generally have a low fat content, which may contribute to the successful results obtained with Eos (29).

All EOs and their components that have been tested on vegetables appear effective against the natural spoilage flora and food borne pathogens at levels of 0.1–10 μl g⁻¹ in washing water. Cinnamaldehyde and thymol are effective against six Salmonella serotypes on alfalfa seeds when applied in hot air at 50 °C as fumigation. Increasing the temperature to 70 °C reduced the effectiveness of the treatment. This may be due to the volatility of the antibacterial compounds. Oregano oil at 7–21 μl g⁻¹ was effective at inhibiting Escherichia coli O157:H7 and reducing final populations in eggplant salad compared to the untreated control. Although the salad recipe appears to have a high fat content, the percentage of fat was not stated (29).

VII. Food packaging
Basil (Ocimum basilicum L.) is a popular culinary herb, and its essential oils have been used extensively for many years in food products, perfumery, and dental and oral products. Basil essential oils and their principal constituents were found to exhibit antimicrobial activity against a wide range of Gram-negative and Gram-positive bacteria, yeast, and mold. The present paper reviews primarily the topic of basil essential oils with regards to their chemical composition, their effect on microorganisms, the test methods for antimicrobial activity determination, and their possible future use in food preservation or as the active (antimicrobial), slow release, component of an active package (30).

3. Conclusion
Natural antioxidants and antimicrobials can increase shelf-life of food products and due to absence of synthetic agents are safe with no side effects on human health. Antimicrobial activity of plant extracts is frequently due to the essential oil fraction or to sulfur-containing compounds in the aqueous phase. The composition, structure as well as functional groups in oils play an important role in determining their antimicrobial activity. Results of different studies indicate that herbal bioactive compounds can act as good replacers of synthetic antioxidant and preservatives.

4. References


