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Natural compounds of plant and animal origin in food and medicines

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ABSTRACT

Evidence of humans using plant or animal medicine goes back 60,000 years. According to the World Health Organization statistics, about 80% of the world's people prefer herbal or animal extracts or hair products for primary health care. They consume their seeds; a medicinal plant is called a plant that has substances. It is a personal effect. Medicinal plants, in addition to general and basic compounds, each have at least one specific secondary effective substance. These special effective materials, which include thousands of species, are called "natural plant-animal materials". Evaluation of these materials is done in two ways: evaluation of biological activity and determining the existence of effective materials. In addition, more than 50% of all new clinical drugs are of natural origin. One of the key advantages of using medicinal plants is their ability to treat bacterial resistance to various types of antibiotics, a significant global health issue. In this article, an attempt has been made to introduce and use natural compounds of plant and animal origin in food and medicines and examine their health and use effects. The results show that due to the less side effects of plant and animal sources, the use of these natural compounds can be effective in the treatment, nutrition and prevention of diseases by following the instructions.

Keywords: Natural compounds, Improving the body's immune system, Medicinal herbs, Nutrition.
Article type: Review Article.

INTRODUCTION

The role of medicinal plants in sustainable management is not just significant, it's growing. These plants play a crucial role in macro dimensions of economic development, environment, health (medicinal self-sufficiency), employment, food security, and genetic resources. This global importance is evident in the deepening and revitalizing role of medicinal plants, especially in the supply of medicines, as one of the key development indicators worldwide. The supply of 25% to 75% of the drugs used in a number of developed countries from 70 to 120 thousand different types of medicinal plants, consumption and exports of one hundred billion dollars of medicine in the world that will be doubled in the next 20 years is proof of this. According to the statistics of the

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World Health Organization, about 80% of the world's people prefer to consume herbal extracts or their effective substances for primary health care (Zhang *et al.* 2020; Nasim *et al.* 2022). Also, their effective compounds exhibied higher diversity. Despite the presence of drugs with the chemical origin of medicinal plants, they are of special importance and properties. Therefore, the trend towards the use of effective substances of medicinal plants is increasing. In many plants, most of the energy and carbon absorbed and analyzed is dedicated to synthesizing organic molecules. These molecules, known as secondary metabolites, are among the most expensive plant chemical compounds (Álvarez Martínez *et al.* 2020). These materials are mostly cyclic molecular compounds that have been used since ancient times as medicine, spice, essential oil, etc. In general, the production of secondary metabolites has taken place to regulate the plant's adaptation to adverse factors and environmental stresses, and it indicates the operation of a kind of defense process to maintain the balance of activity is vital. Most of the products produced, including fruit pulp, seeds, peels, and other extra parts, are not used during food processing. Although these products are usually considered waste, some studies show that these materials contain valuable compounds such as polyphenols, tannins, flavonoids, and other compounds with several properties, including antimicrobial activity. Essential oils and plant extracts are natural compounds derived from plants with distinct characteristics that show good antimicrobial properties. Essential oils (Manessis *et al.* 2020) are complex mixtures of natural, volatile, and aromatic compounds from plants extracted with variable compositions. Essential oils are primarily liquid at room temperature, colorless, and rich in volatile secondary metabolites with low molecular weight. The main compounds of essential oils include terpenes, terpenoids, and phenylpropanoids. Extracts obtained from plants, (PE) are aqueous solutions with high concentrations that can have different compounds depending on the type of plant, extraction method, and solvent used (Diniz do Nascimento *et al.* 2020). PE can have different biological activities, including antioxidant activity, depending on the compounds in them, as well as exhibiting antimicrobial and anti-inflammatory activity, etc. However, they are known mainly for their antioxidant and antimicrobial properties, both used in food preservation. The mechanism of action of these two compounds is derived from plants that have not been fully characterized as antimicrobial and antioxidant compounds. Still, in general, the antimicrobial activity of essential oils can be related to its hydrophobic nature, which allows them to pass through the cell membrane. There are high amounts of polyphenols, and the presence of polyphenolic compounds gives these products the ability to change the permeability of the cell membrane by inhibiting certain enzymes, and through these mechanisms, they can exert their antimicrobial effect (Giannenas *et al.* 2020; Sorokina & Steinbeck 2020).

MATERIALS AND METHODS

Herbal treatment for diseases, especially infectious diseases, has become an increasing trend in recent years. Infectious specialists have a great desire to use these drugs for the treatment of infections because the side effects of these drugs are significantly lower compared to chemical drugs (Moulaei *et al.* 2024). It was found in the 1940s and the increased use until the 1980s. Today, with the advances in organic chemistry and significant changes in the methods of extracting, purifying, and determining the structure of natural compounds of plants, the value of medicines obtained from plant sources has become more obvious day by day (Blahova *et al.* 2021). About one-third to half of the medicinal products available in the United States are of plant origin. They are 10 most used medicinal plants in the United States of America. Also in England, many herbal products and supplements have been produced in a safe and healthy form (Abdel Razek *et al.* 2020; Moulaei *et al.* 2024). Studies show that there is a great desire to use these drugs to treat infections because the side effects of these drugs are lower than those of chemical drugs (Moulaei *et al.* 2024). In addition to this growing trend, the lack of medicinal and therapeutic information in a large group of herbal medicine products is a big problem (Dehelean *et al.* 2021). In herbal medicine, essential oils of raw plants in the form of decoctions, tinctures, or herbal essences are traditionally used to treat diseases, including infectious diseases.

The importance of medicinal herbs

Recently, the secondary metabolites of medicinal plants, such as essential oils and plant extracts, have been investigated in terms of their antimicrobial effects. It has been found that most essential oils and extracts extracted from medicinal plants have antifungal, anti-parasitic, antibacterial and antiviruses properties (Zhang *et al.* 2020). For instance, the essential oils of two species of chamomile plants (German chamomile and Nobile chamomile) have the effects of inhibiting the growth of important bacteria such as *Staphylococcus aureus*, *Bacillus* species

and *Listeria monocytogenes*. *Allium jesdianum* had a good effect on seven of the eight important pathogenic bacteria studied, such as *Pseudomonas aeruginosa*, *Streptococcus mutans*, and *Escherichia coli*. In addition, Álvarez Martínez *et al.* (2020) confirmed that, it is effective against bacteria and fungi (Giannenas *et al.* 2020). Other scientists showed that sage plant (4 types of essence) and hydroalcoholic extracts of thyme, eucalyptus and rosemary have antimicrobial and antifungal effects.

Table 1. Herbal drugs for antibacterial properties.

Drug	Compounds	Main planets	Feature
Pelargine	Dry root extract of Pelargonium sidoides and honey	Pelargonium sidoides	Respiratory tract infections - systemic antibacterial
Neurotech	Ascorbic acid - flavonoid - beta carotene - chlorogenic acid	Tanacetum Vulgare, Utrica dioica, Rosa canina	Reducing inflammation - increasing the transmission of nerve signals- systemic antibacterial
URSOLIA	extract of the aerial parts of Salvia officinalis L. with high content of ursolic acid	Vaccinium macrocarpon, Salvia officinalis	anti-inflammatory- systemic antibacterial
Dineh C-Lax	Glycosides of hydroxyanthracene derivatives based on senoside	Senna leaf extract and fennel essential oil	Laxative- Anti-constipation

Medicinal plants not only play a role in the treatment of infectious diseases but, at the same time, reduce a large number of side effects often associated with antibiotic use. Especially in the last decade, hundreds of hectares of arable land in developed countries have been dedicated to cultivating medicinal plants. By looking at the report of the World Food Organization, it is clear that the value of the global trade in medicinal plants in recent years is about 100 billion dollars and will reach 5 trillion dollars by 2050. The most important countries that export medicinal plants internationally are China, India, Canada, America, and Germany. In this century, extensive research has been done on medicinal plants and natural-origin drugs, which have opened new horizons for the community of doctors, pharmacists, and researchers. About one-third of the medicines used by humans are herbal medicines, and this amount is increasing sharply.

Factors affecting the antimicrobial essential oils and extracts

The degree of antimicrobial effect of essential oil depends on the position of the hydroxyl group in the phenolic structure. For instance, the position of the hydroxyl group in the compounds of Thymol and Carvacrol is such that it causes a high antimicrobial effect (Nasim *et al.* 2022). Studies by other researchers confirm the association between chemical compounds (alkaloids, saponin, and phenol) and the antibacterial activity of the extracts (Álvarez Martínez *et al.* 2020). In general, bacteria's sensitivity to the antimicrobial effect of essential oils increases with a decrease in pH, oxygen, and temperature. At low pH, essential oils' hydrophobic properties increase, enabling them to be easily dissolved in the lipid layer of the bacterial cell membrane (Blahova *et al.* 2021). The critical issue is whether or not to use an emulsifier or solvent to dissolve the essential oil or stabilize it in the culture medium. Some of the compounds of these essential oils are effective antibacterial substances, such as carvacrol, thymol, eugenol, perillaldehyde and cinnamaldehyde, and cinnamic acid, which have a minimum inhibitory concentration of 0.05 to 5 μL mL^{-1} in the laboratory. Still, higher concentrations are required to produce the same impact in food. Research on fresh meat, meat products, fish, milk, vegetables, dairy products, fruit, and cooked rice show that the focus required for a significant antibacterial impact in food is 0.5 to 20 μL mL^{-1} and in the washing solution of fruits and vegetables is about -0.1. It is 10 μL mL^{-1}.

Factors affecting the antimicrobial activity of essential oils and plant extracts in foods

Various factors affect the resistance of microbes in food, which can be divided into two categories: internal factors or the characteristics of the food itself (the structure of the food, pH, the amount of free water, fat, protein, carbohydrates, salt and other compounds) and external factors such as temperature, light, the composition of the air around the foodstuff and the type of packaging mentioned (Manessis *et al.* 2020). For instance, low pH increases the hydrophobicity of essential oil, and as a result, it dissolves more easily in the membrane of bacteria, hence it naturally exhibits higher antimicrobial properties. In general, increasing the amount of fat and protein in food requires a higher concentration of essential oil to kill the microbes in the food because the essential oil and

the hydrophobic compounds of the extract are combined with these compounds, and a smaller amount of it with the microbial body. On the other hand, lower amounts of water in food compared to laboratory environments can prevent the progress of antibacterial agents toward the target area in the bacterial cell. Of course, protective effects for bacteria like fats and proteins have not been observed in the case of carbohydrates. In laboratory conditions, it has been proven that the antimicrobial activity of essential oil and extract in liquid culture medium is more than in solid culture medium containing agar. This principle is also true for food, for example, it can be said that the antimicrobial effect of essential oils in liquid foods such as milk is more than in solid foods such as meat products. According to the published articles on the use of essential oils as preservatives in food, the following ranking can be done for some medicinal plants and their essential oil compounds. Antimicrobial activity of different plants: Oregano > Cloves > Cinnamon > Thyme > Mint > Rosemary > Mustard > Coriander. Some of the most important compounds of essential oils include eugenol and carvacrol, cinnamic acid, thymol, cinnamic aldehyde acid, and citral geraniol. Eugenol prevents amylase and protease production by some bacteria, such as *Bacillus cereus*. Destruction of the cell wall and cell lysis is one of its effects. Its hydroxyl group is attached to proteins and prevents the enzyme effect in some bacteria. Carvacrol and thymol can dissolve the outer membrane of Gram-negative bacteria, which leads to the release of LPS and increases the permeability of the cytoplasmic membrane to ATP. Cinnamaldehyde ($C_6H_5CH{=}CHCHO$) also prevents the growth of some bacteria in the same amounts as carvacrol and thymol. This substance does not destroy the outer membrane of Gram-negative bacteria. It does not empty intracellular ATP resources (unlike carvacrol and thymol), but its carbonyl group is attached to proteins and prevents the action of the amino acid decarboxylase enzyme. Antimicrobial properties of various essential oil compounds: Eugenol > carvacrol, cinnamic acid and thymol > cinnamic acid > citral (C10H16O) and geraniol.

RESULTS

Antimicrobial compounds of animal origin

Compounds derived from animals are often used with other preservatives and can maintain target products' quality and shelf life. Some natural compounds derived from animals with antimicrobial properties are lactoferrin, chitosan, and lysozyme.

Lactoferrin

Lactoferrin is an 80 kDa glycoprotein bound to iron in milk. These proteins are found in tears, saliva and specific granules, especially neutrophils. Lactoferrin is a multifunctional protein widely studied in the past decades. Its biological properties include regulation of iron absorption in the intestine, anti-inflammatory properties, regulation of the body's immune system, antibacterial, antiviral, and antitumor activity (Sauter 2020). This compound is known more for its ability to bind to iron, which ultimately leads to its antibacterial activity, which has been discovered (Abdel Razek *et al.* 2020). As mentioned, the main physiological function of lactoferrin is to create a connection with iron, and this issue has been raised as a protein characteristic that helps its antibacterial activity, which is the reason for the essential need of pathogenic microorganisms for iron as an important nutritional factor and required for cell growth. Studies conducted on the antimicrobial properties of lactoferrin have shown that lactoferrin could destroy some *Streptococcus* mutants through a process independent of the mechanism of reaction with iron (Moulaei *et al.* 2024). Crystal structure studies of lactoferrin show that these proteins have large cationic connections on the surface, which facilitates direct communication with anionic lipid A except for lipopolysaccharide of Gram-negative bacteria. This interaction can damage the inner membrane of the cell, change the outer membrane's permeability, and lead to the release of intracellular compounds.

Chitosan

Among several natural antimicrobial compounds, chitosan has significant commercial applications in the food industry. It is a biopolymer composition found naturally in animals' skeletons, especially crustaceans and endodontics. Chitosan is very effective in food preservation, but it is insoluble at neutral and higher pH (pH > 6), which can improve its solubility and be used as a food preservative (Manessis *et al.* 2020). Chitosan is a hydrophilic polysaccharide derived from chitin, which has a broad antimicrobial spectrum against Gram-positive and Gram-negative bacteria. Chitin and chitosan were studied as antimicrobial compounds against a wide range of target microorganisms such as algae, bacteria, and fungi in various forms. Although its exact mechanism has not been fully determined, recent data have tried to introduce chitin and chitosan as a compound that inhibits the growth of bacteria rather than a bactericide.

Lysozyme

Lysozyme or muramidase are two glycoside hydrolase protein enzymes. Lysozyme is an enzyme that plays an important role in destroying bacteria in the mouth. Lysozyme destroys and breaks the cell walls of many bacteria. Lysozyme is an enzyme naturally present in bird eggs, mammalian milk, etc., and is recognized as a safe substance for direct use in food. The antimicrobial activity of lysozyme is mainly related to the breakdown of beta 1 and 4 bonds between -N-acetylmuramic acid and -N-acetylglucosamine in the peptidoglycan of the cell wall of microorganisms. It has been reported that lysozyme in egg white acts as a bacteriolytic agent and is considered an antimicrobial for food preservation. These compounds have been used to preserve food such as meat products, dairy, fruits, vegetables, and fish.

Table 2. Animal origin proteins with antibacterial features.

Animal Source	Major Component	Antibacterial	Major Formula
Dairy protein	Bioactive peptides	Casein and whey	Fast digesting proteins
			E. coli DPC5063, *S. aureus*, *Listeria monocytogenes*, *S. typhimurium*, *B. subtilis*
Salmon, Fisheries	Bioactive peptides anticoagulant	Protamine	*L. monocytogenes*, coliforms
Egg	Glutamic acid, aspartic acid	Lysozyme	*Bacillus*, N-acetyl-muramylhydrolase
Crabs, shrimps and other shellfish	Polycationic biopolymer	Chitosan	*E. coli*, *S. aureus*, *Pseudomonas* spp., and *L. monocytogenes*
Raw milk, colostrum, saliva and other biologicalsecretions	Glycoprotein	Lactoperoxidase	*Salmonella*, *E coli*, *Staphylococcus*
Dairy	Glycoprotein Iron	Lactoferrin	*Pseudomonas*, *E. coli*, *Salmonella*

Properties of medicinal plants

Many plants have a remarkable ability to fight against human bacterial and fungal pathogens. Due to people's disinclination to consume foods with chemical preservatives, plant sources are used as flavorings and antimicrobial agents (Dehelean *et al.* 2021). These are effective for infectious diseases, but at the same time, they reduce the number of side effects that are often associated with antibiotics (Manessis *et al.* 2020). The results of studies show that the composition of medicinal plants can be greatly influenced by the conditions of the relevant tissue and growth stage as well as closed antimicrobial mechanisms. The composition of the plant is very different. Since the antibacterial effect of medicinal plants depends to a significant extent on the phytochemical characteristics of the family. Sub-family, it is not surprising that the difference in the antibacterial effect of the samples taken from the same plant from two different regions can be observed (for example, in the study (Abdel Razek *et al.* 2020), the hydroalcoholic extract of Falcaria vulgaris had 5.62 MIC and 125 mg/ml and MBC 25.31 and 5.2 mg/ml respectively for E. coli and Staphylococcus aureus bacteria, but in the study of (Giannenas *et al.* 2020) that the said plant with the same method obtained 240 MIC and 120 mg/ml for E. coli and 240 and 240 mg/ml for Staphylococcus aureus (Nasim *et al.* 2022). Research has shown that the antimicrobial and antioxidant properties of medicinal plants have a direct relationship with the total amount of phenolic compounds, and usually plants that have high antimicrobial properties also have good antioxidant properties. Among plant antioxidants, phenolic compounds are more widespread. The antioxidant properties of these phenolic compounds are mainly related to their reductive properties and chemical structure, which can neutralize free radicals, combine with metal ions, and quench single and triple oxygen. Phenolic compounds stop the oxidation reaction by giving electrons to free radicals. Studies have shown that phenolic compounds play an important role in the antimicrobial properties of plants. These compounds kill microorganisms by destroying cell walls and proteins, disrupting membrane and enzyme function, and influencing DNA and RNA replication (Diniz do Nascimento *et al.* 2020). Clinical investigations have shown that various plant products are effective in treating immune system disorders and balancing the function of the immune system in is effective in chronic infections, poisoning and preventing the entry of microorganisms into the body.

CONCLUSION

In recent years, the attention to natural preservative compounds of different origins has increased greatly, increasing the level of people's awareness of the health-giving properties of these compounds, awareness of the direct and indirect negative effects that synthetic or chemical preservatives cause on human health and consumers It has led researchers to increase efforts to replace natural compounds instead of chemical and synthetic

compounds. Nowadays, most of the studies indicate that one or several compounds should be used as preservatives in order to have the most effect at a low concentration without causing any change in the qualitative and sensory characteristics of the product. Of course, we remind that before using natural antimicrobial compounds in food, we must ensure the safety and health of that compound. By observing and paying attention to the aforementioned points, natural compounds can be used as a safe and valuable alternative to chemical and synthetic compounds in maintaining and guaranteeing the quality of food products.

Table 3. Properties of antibacterial herbal medicines.

Name	Active part	Feature
Matricaria chamomilla	Bisabolol and Camazolen	Anti-inflammatory, anti-allergic, anti-itching and skin congestion and anti-spasm
Pimpinella anisum	Antol	Antispasmodic, antiflatulent, diuretic and cardiac stimulant
Cedrus libani	limonene	Strong diuretic, blood regenerator, astringent, scalp tonic, anti-fungal, anti-mosquito, anti-congestion, anti-willow and anti-mosquito and respiratory disinfectant.
Anethum graveolens	Caron	Antispasmodic in disorders of the digestive system, fluidity of bronchial secretions
Syzygium aromaticus	Eugenol and eugenyl acetate	Anti-viral, anti-microbial, anti-fungal, stimulant, aphrodisiac, anti-bloating and anesthetic
Cinnamomum cassla	cinnamaldehyde	Energetic, anti-microbial, anti-fungal, anti-viral, anti-parasitic, uterine tonic, anti-coagulant and insecticidal
Eucalyptus globulu	Cineol	Expectorant, antimicrobial and virus
Lavandula officinalis	Linalool and linalyl acetate	Antispasmodic, sedative, analgesic, anti-inflammatory and antimicrobial
Citrus limonum	limonene	Strengthening natural immunity, regulating the body's metabolism, strengthening the nervous system, anti-microbial, anti-viral, anti-flatulent and laxative
Melaleuca alternifolia	Terpenin	Anti-microbial, anti-virus, anti-congestion and anti-spasm

Compounds obtained from medicinal plants play a central role in the food and cosmetic industries and have broad and diverse applications. Therefore, the economic importance of essential oils is undeniable and debatable. According to scientific research, essential oils have many uses in the pharmaceutical and food industries. They also have special biological, pharmacological, and therapeutic potential. For instance, essential oils interfere with microbial activities and, in many cases, destroy microbes without adverse effects on the consumer's health.

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