

MEDICINAL PLANT EFFLUENTS, A SOURCE OF BIOACTIVE COMPOUNDS AND THEIR APPLICATIONS IN PROCESSED FOODS

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Received: 2024-08-27

Accepted: 2024-09-08

Published online: 2024-09-10

Abstract

The water effluents produced from medicinal plants contain several organic molecules, normally categorized as secondary metabolites, and to a lesser extent, they also include primary metabolites. Utilizing plant extracts as a source of bioactive chemicals is especially intriguing in the development of fortified foods, pharmaceutical formulations, and therapeutic and cosmetic preservatives. The essential oil and polyphenol fractions obtained from the phase of the effluents exhibit distinct profiles. The compounds are utilized as dietary supplements to improve human nutrition status, as feed additives in animal feeding, as biocides for plant protection. Previous studies have documented the antimicrobial properties of plant components against different pathogens, namely those that cause foodborne illnesses. Natural antimicrobials play a vital role in food preservation and health management of bacterial infections in humans and farmed crops. More recently, there has been a significant focus on using essential oils and extracted chemicals to inhibit the growth of harmful microbes.

Various phenolics have been empirically shown to possess strong antioxidant, antiviral, anti-inflammatory, and antidiabetic properties, and are gaining attention in application within cosmetics and medicines. Their substantial significance in the industry underscores the intriguing potential of these water effluents as pharmacologically active components or organic preservatives for the future of natural medicine.

Keywords: Medicinal plants, water effluents, secondary metabolites, processed food.

Introduction

Our ancestors throughout human history developed habits and food diets that directly reflected the geography in which they lived. Since ancient times, beyond the staple food sources, such as seeds and fruits, vital to our diet, herbs and spices, also, have been used to improve food and drink quality. Globally, researchers have identified plant species that possess pharmacological activity, demonstrating varying degrees of effectiveness in treating and preventing illnesses. The estimated range of plant species on Earth vary between 250,000 and 500,000. According to the World Health Organization (WHO), more than 20,000 plants are used in medical application worldwide. Multiple plant species, serve as important assets in the food industry.

Producers frequently apply their oil extracts, phenolic extracts, tinctures, and other formulations to produce extract capsules, culinary additives, health supplements, pharmaceutical drugs, or energy drinks (1).

Two main groups of organic constituents, primary and secondary metabolites, make up plant cells. Their interest relies on the fact that they offer a plentiful supply of bioactive substances. Phenolic fractions derived from the vegetative parts of edible plants like broccoli, cranberry, cocoa, lemon balm, grapeseed, green tea, olive leaves, and pomegranate, exhibit extensive antimicrobial activity when applied for microbe growth control. This is due to their structural characteristics, which allow them to directly interfere with critical stages of microbe cell growth (2). Two stages where bioactive compounds from medicinal plants come from are (i) water effluents that come from different medicinal plants and (ii) vegetable or essential oils that are extracted from water effluents using solvent extraction (3). These compounds have broad-spectrum antibacterial action, effectively attacking various bacteria, yeast, and mould. Nevertheless, it is critical to consider the disparities in their efficacy and amount of bioactivity when employing them (4). These sources are considered very important because of their cost-effectiveness, abundance, ecologically friendly diversity, and lower antimicrobial resistance likelihood than manufactured compounds (5).

The scientific community is conducting extensive research and investigating natural antimicrobial treatments as an alternative to synthetic preservatives to mitigate foodborne pathogen transmission, driven by mounting concerns over the emergence of antimicrobial resistance. Water effluents from medicinal plants offer a rich source of natural compounds that function as antioxidants and enhance the aroma and color of processed meals. These compounds have the potential to enhance the sensory qualities and prolong the shelf life of processed foods, therefore indirectly improving the food safety status. In addition, they enhance the sensory palatability of the food for the consumer and extend the items' shelf life. Furthermore, specialists categorize most water effluents derived from medicinal plants as Generally Recognized As Safe (GRAS) per the Federal Food, Drug, and Cosmetic Act (FFDCA).

The inadequate and excessive use of antimicrobial agents, such as traditional antibiotics, to treat bacterial infections in humans and animals, or the application of chemical biocides in livestock farming with sub-lethal levels, have led to selective pressure on microorganisms. This specific pressure has resulted in the emergence of antibiotic resistance, which poses a significant and widespread risk to world health. The phenomenon has allowed resistant bacteria to persist and spread to antimicrobial agents (5).

We have used multiple methods of food preservation, such as chilling, freezing, lowering water activity, limiting nutrients, fermentation, and pasteurization, to prevent

microbial decay (8). Many countries have approved and extensively used synthetic antimicrobials, but a new focus has emerged on medicinal plant water effluents as natural preservatives. This shift is mainly due to the harmful health effects of synthetic organic compounds as alternatives. Consumers are increasingly looking for food products that are minimally processed, contain fewer artificial chemicals, and prioritize food safety. Therefore, it is crucial to investigate alternative sources of natural preservatives that are safe, effective, and widely accepted. We can use organic acids, essential oils, and medicinal plant water effluents as effective natural antimicrobials to ensure food safety. Plant extracts, whether in their pure form or as engineered, provide several benefits for controlling the growth of microbes. Water effluents can be used in eco-friendly ways by preventing and eradicating biofilms in food and medical settings, as well as storage compounds. This can enhance food quality and reduce biofilm-related problems (5).

Moreover, people use medicinal plant species as functional foods, nutritional supplements, and in human health applications like traditional medicine and recombinant proteins. The diverse range of uses for water effluents derived from medicinal plants, such as their antioxidant, antibacterial, antidiabetic, anti-carcinogenic, flavouring, beverage, and detergent properties, makes them highly versatile and ideal for a variety of fascinating applications in the food production industry.

Medicinal plants, spices, and herbs

Medicinal plants are a significant source for discovering new pharmacological substances to treat severe disorders (11). Many plants, including thyme (*Thymus vulgaris*), chili (*Capsicum annuum*), cloves (*Syzygium aromaticum*), coriander (*Coriandrum sativum*), cumin (*Cuminum cyminum*), fenugreek (*Trigonella foenumgraecum*), garlic (*Allium sativum*), ginger (*Zingiber officinale*), mustard (*Brassica juncea*), and saffron (*Curcuma longa*), possess diverse nutritional properties and compositions (1). Essential oils can impede bacteria growth and eliminate germs, including Gram-positive aerobic Bacillus genus, e.g., *Bacillus cereus*, and Gram-negative, facultative anaerobic bacteria. *Aeromonas* genus, e.g., *Aeromonas sobria* (6).

Saffron flowers are commonly used in food, tea, and cosmetic formulations. Several cosmetic, pharmaceutical, and flavouring formulations employ *Mentha sp.*, *Ocimum sanctum*. Various applications such as dietary supplements, culinary items, cosmetics, pharmaceuticals, and oral treatment use extracts from the Panax ginseng plant. People have used other plants, such as *Azadirachta indica*, as biopesticides or treatments for diabetes and tuberculosis (1).

The chemistry of medicinal plant extracts

Plant tissues contain a variety of secondary metabolites, including flavonoids, tannins, alkaloids, alkenyl phenols, saponins, lactones, and terpenoids, which have antibacterial properties. Biochemical pathways broadly categorize secondary metabolites into three main groups: phenolic compounds, terpenoids, and nitrogen-containing compounds (12).

Terpenoids are molecules containing isoprene units (5-C atoms), and according to the isoprene units, they are classified as monoterpenoids (two units of isoprene), sesquiterpenoids (three units of isoprene), diterpenoids (four units of isoprene), and so on. Terpenoids are mainly involved in the defensive role of the plant.

Phenolic compounds comprise a wide range of secondary metabolites, with a main skeleton of benzene rings. They are responsible for the color, taste, and flavour of many plant fruits and their extracts. Phenolic compounds exhibit a wide array of pharmacological activity. They are responsible for the color, taste, and flavour of many plant fruits and their extracts. Exhibit a wide array of pharmacological activity in single cells and high organisms.

Nitrogen-containing compounds comprise various classes, such as alkaloids or cyanogenic compounds. Alkaloids are present in plants and play several functions: growth promoter, plant protection, and nitrogen storage. They are also used to treat several diseases, such as cancer, diabetes, or cardiac diseases.

Medicinal plant water effluents as antibiotics

The primary goal of using antibiotics is to cure microorganism-caused illnesses effectively. Recent studies indicate that the increasing resistance of bacteria to antibiotics might potentially reduce the effectiveness of traditional food preservation methods, such as drying, thermal processing, and acidification. The extensive utilization of chemical preservatives in food has played a key role in the heightened resistance of microorganisms to antibiotics. As a result, bacterial populations resistant to antibiotics are emerging and spreading rapidly. Providing novel antimicrobials is critical to combating them. Plant-derived antimicrobial substances serve as effective and safe substitutes for controlling microorganisms resistant to conventional antibiotics, particularly those that cause foodborne diseases.

When combined with antibiotics, plant extracts can work as adjuvants to make the antibiotics more effective against diseases that are resistant to antibiotics by lowering the Minimum Inhibitory Concentration (MIC) of that antibiotic. (13). Certain parts of thyme (*Thymus vulgaris*) essential oil work well to make *Salmonella*

typhimurium less resistant to antibiotics like ampicillin, bacitracin, erythromycin, novobiocin, penicillin, and tetracycline. Carvacrol and thymol demonstrate effectiveness against *Staphylococcus aureus*. We classify them as phenol monoterpene derivatives (2). Both conventional and unconventional methods are used in plant extraction.

To effectively separate and use natural antimicrobials on food, you must be able to remove and clean them. Most of the time, we use steam distillation and hydro-distillation to extract the material. Recently, researchers have employed a new supercritical fluid extraction method to enhance solubility and mass transfer (3).

Using traditional methods to get essential oil from plants takes a long time and energy. Most extraction methods also require a variety of solvents. Many solvents, like ammonium chloride, methanol, ethanol, and hydrochloric acid, are dangerous. Chemical or heat processes, along with other common methods of extracting plants, have the potential to alter the natural qualities, amount of active ingredients, or usefulness of the plant, and even create dangerous chemicals (6). It appears more effective to use an extraction method that requires minimal processing, such as straight mechanical extraction, to prevent any alteration or destruction of the active ingredients. Water effluents made from medicinal plants fight food diseases by killing germs.

Applications for medicinal plant effluent in processed foods

Studies have demonstrated the exploitation of water effluents and their essential oils from medicinal plants and food industry by-products contributes to combating foodborne pathogens, making them valuable in the food and medicine sectors. Food systems use antimicrobial chemicals from plants to kill biofilm and create edible coats. The biofilms and edible layers slowly spread through the food packages, which helps the antibacterial effect last longer.

This is because discarding the waste generated by the wine industry can harm the environment, necessitating its reuse. Therefore, we can transform these waste materials into innovative products that benefit the planet, society, and economy (14). Scientists have found that grapeseed extracts show several biological effects. For example, they stop the growth of harmful bacteria that could contaminate food and kill fungi to keep meals fresh. Water effluent extracts are generally considered safe (GRAS) (7). With the addition of ground beef and further vacuum treatment, *Clostridium perfringens* cells are more likely to die from the heating process. The study's results have helped restaurants and catering services figure out exactly how long and at what temperature to heat vacuum-cooked beef, which keeps food safe by killing germs (15). Applying water extracts from different medical plants improves refined olive oil's shelf life and organoleptic characteristics (2, 16).

Pharmaceutical and cosmetic formulation applications

Grouped into primary and secondary metabolites, some of which are sugar molecules called glycosides, plants are a factory of potentially thousands of natural organic compounds (NOCs). Glycosides are essential for secondary metabolite synthesis, which plants involve in many vital processes, e.g., plant protection. These features of glucoside molecules, which prevent them from reaching the target healing site, confer upon them the status of pro-drug formulations. Pro-drugs have utilized glycosides in the form of bioactive compound nanoparticle formulations. Sometimes, these chemicals can give rise to customized versions that work well to reach treatment targets (19). It is intriguing to extract bioactive substances, mostly polyphenols, from olive oil wastewater and use them to produce nutraceuticals and cosmetic formulations (20, 21, 22).

The cosmetics and drug industries use by-products from the wine industry, such as grape stems and seeds, to create water effluents from *Vitis vinifera L.*, a medicinal plant (17). The beauty business has always paid much attention to ensuring its products are safe from microbes. The reason for this is that microbial pollution could cause the goods to go bad and pose a health risk to customers. Microorganisms can alter the chemical and physical properties of cosmetics, leading to the separation of different stages, lightening of color, and release of odour compounds.

When it comes to killing bacteria, the products work very well against Gram-positive bacteria that cause foot wound sores. Not only that, but the extracts also help reduce inflammation by stopping lipopolysaccharide-stimulated macrophages from making nitric oxide, with a 35.25% success rate. These researchers have found a new way to slow aging by stopping anti-tyrosinase activity (about 54%) and elastase activity (almost 98%). Because of this, grape curbs have shown much biological promise, making them appealing to the food, medicine, and skincare industries (14).

The pharmacy industry frequently uses PSO in various situations. According to reports, PSO can help fight cancer, protect the liver, lower blood sugar, protect the kidneys, and reduce inflammation. It also helps boost the defence system and keep fat metabolism in check. Punic acid is the primary active natural substance. It has many positive benefits, such as lowering cholesterol, fighting obesity, reducing inflammation, lowering blood sugar, protecting the kidneys from damage, and preventing diabetes (9). Numerous instances demonstrate the application of healing plant water effluents and essential oils in alternative medicine.

Conclusion

Researchers have identified medicinal plant water effluents as a promising and sustainable source for the extraction of bioactive compounds. Biophenolics have found applications as nutritional supplements, phytopharmaceuticals, preservation additives, adjuvants, edible coating components, and antibiotics. Biophenolics have gained significant attention due to their biological activity and awareness of the environmental implications. The increased human activity worldwide and the increased population have stressed the world's resources. Numerous arguments support the idea that a sustainable economy can ensure, advance, and improve global well-being. Exploiting the effluent extracts from the medicinal plant industry to apply in processed foods with improved bio-phenolic profiles and using these extracts as pharmaceutical supplements, nutraceuticals, and cosmetics is highly significant.

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