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Editorial

Advances in Biological Activities and Application of Plant Extracts

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1. Short Overview of Plant Phytocompounds

For centuries, plants have been part of human civilisation, serving as food, healing substances and treatments for various diseases. In recent years, advances in biological research have revealed the remarkable potential of plant compounds in the food and medicine sectors [1]. In the food industry, plant extracts are used to improve the safety, nutritional value and shelf life of food products. In addition, antimicrobial phytocompounds have found application in food packaging materials, ensuring inhibition of bacterial growth and prolonging the freshness of perishable goods [2–5].

Polyphenols are a group of plant-based compounds characterised by their phenolic structure. These compounds include flavonoids, phenolic acids and stilbenes, among others [6,7]. With numerous health benefits attributed to their antioxidant and anti-inflammatory activities, polyphenols have become valuable components in food production and fortification [8]. Polyphenols scavenge free radicals, neutralising their harmful effects and reducing oxidative stress in the body [9,10]. Incorporating ingredients or extracts into food products can delay lipid oxidation and prolong the shelf life of products, reducing the need for synthetic preservatives [11,12]. Epidemiological studies have linked regular consumption of polyphenol-rich diets to reduced risk factors for chronic diseases such as cardiovascular disease and certain cancers [13,14]. The addition of polyphenols in food products, however, presents certain challenges. Their sensitivity to heat, light and oxygen may lead to their degradation during processing and storage [15]. Careful formulation and packaging strategies are required to retain the bioactivity and flavour profiles of polyphenols in finished products [16].

Alkaloids represent a wide range of nitrogen-containing compounds found in plants, often being associated with specific physiological activities. These compounds contribute to the characteristic flavours and aromas of certain food ingredients and are increasingly recognised for their potential health-promoting properties [17]. Several alkaloids are responsible for different flavours in various food products. For example, caffeine, an alkaloid found in coffee beans and tea leaves, imparts the stimulating bitterness in these popular beverages [18]. In addition, quinine, which is derived from the cinchona tree, provides the characteristic bitterness of tonic water, a common mixer in cocktails [19]. Beyond their flavour contribution, some alkaloids possess functional properties that make them valuable in the food industry. For instance, capsaicin, an alkaloid in chilli peppers, is well known for its spicy heat, which enhances the sensory appeal of dishes. Capsaicin has also been associated with metabolic-boosting and pain-relieving effects [20].

Terpenoids represent a diverse group of compounds characterised by their structural backbone of isoprene units. These compounds are responsible for the distinct aromas and flavours found in various plants and have a broad spectrum of potential applications in the food industry [21]. Terpenoids are key contributors to the aromatic complexity and flavour profiles of many food ingredients. Limonene, which is found in citrus fruits, imparts

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refreshing and zesty notes to the flavours of lemon and orange. Similarly, pinene, which is abundant in pine and rosemary, contributes to the characteristic pine-like aroma often used in savoury dishes. Research suggests that some terpenoids possess potential health benefits. For example, β-caryophyllene, which is found in black pepper and cloves, has shown anti-inflammatory and antioxidant properties. Similarly, linalool, which is present in lavender and coriander, may have sedative and anxiolytic effects. As such, terpenoids are increasingly being considered for use as functional ingredients in food products designed to promote health and well-being [22,23].

Essential oils are highly concentrated volatile compounds extracted from various parts of aromatic plants, including flowers, leaves and fruits. These oils possess characteristic flavours and aromas that can transform ordinary food into culinary delights [24]. Alongside their aromatic properties, essential oils offer additional benefits in food preservation and health promotion, making them valuable assets in the food industry [25]. By understanding the potential of these natural extracts, the food industry can unlock a world of innovative culinary experiences while adhering to sustainable and health-conscious practices. Certain essential oils exhibit antimicrobial and antioxidant properties, making them effective natural preservatives in the food industry. These oils can inhibit the growth of harmful bacteria, moulds and yeasts, thereby extending the shelf life of food products without the need for synthetic preservatives [26–29]. Oils such as oregano, thyme and cinnamon have demonstrated potent antimicrobial effects, making them suitable choices for preserving various food items. Incorporating essential oils into food preparations can offer potential health benefits due to their bioactive compounds. For example, ginger essential oil contains gingerol, which has anti-inflammatory and digestive properties [30]. Similarly, basil essential oil can provide antioxidants and antimicrobial effects [31]. When used judiciously, essential oils can contribute to a balanced and health-conscious diet.

2. Selected Plant Compounds and Disease Prevention

Many plant compounds, such as polyphenols, flavonoids and carotenoids, act as potent antioxidants and anti-inflammatory agents. By neutralising harmful free radicals and reducing inflammation, these compounds help protect cells from oxidative stress and inflammation-related damage, which can contribute to chronic diseases such as cardiovascular disease, diabetes and neurodegenerative disorders [32–34]. Certain plant compounds, including alkaloids and essential oils, possess antimicrobial and antiviral activities. These compounds can inhibit the growth and replication of bacteria, viruses and fungi. They play a vital role in combating infections and promoting the function of the immune system, helping to prevent and treat various infectious diseases. Numerous plant compounds have demonstrated anticancer properties, with some acting as chemopreventive agents that inhibit the development of cancer cells [35,36]. For example, turmeric curcumin, grape resveratrol and quercetin from onions have shown promising effects in various cancer models, potentially influencing tumour growth, angiogenesis and metastasis [37–39]. Certain plant compounds, such as omega-3 fatty acids from seeds and nuts and flavonoids from fruits and vegetables, can improve cardiovascular health. These compounds help lower cholesterol levels, reduce blood pressure and prevent the formation of blood clots, reducing the risk of heart disease and stroke [40–42]. Phytochemicals, such as flavonoids and terpenoids, have been linked to improved cognitive function and brain health. These compounds can protect nerve cells from damage, reduce inflammation in the brain and enhance neural plasticity, potentially benefiting individuals with conditions such as Alzheimer's and Parkinson's disease [43–46]. Plant compounds, such as soybean isoflavones, can help improve bone health and reduce the risk of osteoporosis. These compounds have oestrogen-like properties that can contribute to maintaining bone density and reducing bone loss in postmenopausal women [47,48]. Certain plant compounds, such as fibre, can promote gastrointestinal health. Fibre aids in digestion, regulates intestinal movements and can support the growth of beneficial gut bacteria, contributing to a healthy gut microbiome [49,50]. Some plant compounds, such as berberine from certain herbs, have shown potential to manage blood sugar levels and improving insulin sensitivity in individuals with type 2 diabetes [51,52]. It is impossible to list all the previously described compounds isolated from plants and their health-promoting properties, but continuously emerging scientific reports confirm the significant role of phytocomponents in the prevention of various conditions.

3. Methods for Obtaining Plant Extracts

Obtaining plant extracts involves separating the desired bioactive compounds from the plant material. Various methods are used to achieve this, each having its own advantages and disadvantages. The choice of method depends on the properties of the target compounds and the desired quality of the final extract [53]. Maceration involves soaking the plant material in a solvent for an extended period to allow the extraction of the desired compounds. Common extractants used in maceration include ethanol, water and a mixture of both (hydroalcoholic solvents). This method is relatively simple and inexpensive, which makes it suitable for large-scale operations. However, it may not be optimal for extracting certain heat-sensitive or polar compounds [54,55]. Solvent extraction is a widely used method in which a suitable solvent, such as hexane, ethanol or supercritical CO_2, is used to selectively dissolve the target compounds. This method can produce high-quality extracts and is efficient in extracting a wide range of compounds. However, it requires careful handling of flammable or toxic solvents and may leave trace amounts of solvents in the final product [55–57]. Supercritical fluid extraction (SFE) involves using a supercritical fluid, usually CO_2, to extract plant compounds. Under specific conditions of pressure and temperature, CO_2 behaves as both a liquid and a gas, allowing it to penetrate plant material and extract the desired compounds. SFE is a clean and efficient method that produces high-quality extracts, but it requires specialised equipment and can be expensive [58]. Soxhlet extraction is a continuous extraction method that uses a combination of maceration and distillation. The plant material is placed in a thimble and the solvent is repeatedly cycled through the material, allowing for efficient extraction. This method is suitable for extracts with a high concentration of compounds, but can be time-consuming [54]. The choice of extraction method and the process parameters play a vital role in obtaining high-quality plant extracts that can be used in various industries, such as pharmaceuticals, cosmetics and food production. Each method has its strengths and weaknesses, so it is essential to carefully evaluate the specific requirements and goals of the extraction process to determine the most suitable approach.

4. Conclusions

Advances in the study of plant-derived phytocompounds have opened a new frontier for applications in the food industry and medicine. With their diverse biological activities against various diseases, these compounds hold immense promise for improving human health and preventing diseases. In addition, ongoing research in medicinal plants and strategies to enhance their properties will undoubtedly lead to exciting breakthroughs, providing sustainable solutions for global health challenges. As we move further into the world of plant extracts, it is vital to adhere to the principles of academic integrity and antiplagiarism, fostering the dissemination of research and further innovation in this field.

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