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Secondary Metabolites in Edible Plants: Hidden Nutraceuticals for Daily Health Management

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Abstract

Edible plants play a vital role in our diet by providing both macronutrients like carbohydrates, proteins, and fats, as well as essential micronutrients such as vitamins and minerals that are necessary for normal growth and development. In addition to these well-known nutrients, these plants contain a variety of secondary metabolites—bioactive compounds that do not directly contribute to growth but have significant health benefits. These compounds, which are often overlooked, help to strengthen the immune system, prevent chronic diseases, and promote overall health. This article explores the main types of secondary metabolites found in everyday edible plants, explains their biochemical roles, and emphasizes their importance in maintaining good health as part of regular nutrition.

Keywords: Secondary metabolites, Edible plants, Nutraceuticals, Phytochemicals, Human health, Functional foods.

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Introduction

Edible plants have traditionally been valued for their primary nutritional components such as carbohydrates, proteins, fats, vitamins, and minerals. which are essential for human growth, energy, and metabolic functioning. However, in recent years, increasing scientific attention has turned toward another important group of plant-derived substances known as secondary metabolites. Unlike primary metabolites, these compounds are not directly involved in the fundamental processes of plant growth and energy generating system. Instead, they often serve ecological roles such as defense against pests, diseases, and environmental stress. Interestingly, many of these compounds also exhibit potent health-promoting properties when consumed by humans. These bioactive compounds, including alkaloids, phenolics, terpenoids, glycosides, and flavonoids, offer significant health benefits ranging from antioxidant activity to chronic disease mitigation (Crozier *et al*., 2006).

Secondary metabolites, also referred to as specialized metabolites. They are organic compounds produced by plants that are not directly involved in the primary growth, development, or reproduction process. Secondary metabolites, as opposed to primary metabolites (e.g., carbohydrates, proteins, lipids, and nucleic acids), which are required for basic cellular functions, are frequently involved in plant defence, ecological interactions, and adaptation to environmental stress (Pichersky and Lewinsohn, 2011). These compounds are derived from primary metabolic intermediates, meaning they originate from compounds such as pyruvate, acetyl-CoA, or intermediates of the shikimate and mevalonate pathways. Despite being non-essential for the survival of the individual plant, secondary metabolites offer evolutionary advantages and contribute significantly to the plant's interaction with its environment, including attracting pollinators, deterring herbivores, and resisting pathogens.

Chemical Diversity of Secondary Metabolites

Secondary metabolites are considered the most chemically diverse group of natural products. Plants generate thousands of structurally distinct secondary metabolites, which are broadly classified into the following major categories based on their biosynthetic origins:

1. Alkaloids

Alkaloids are a broad class of naturally occurring organic compounds with nitrogen-ring structures. These compounds are biosynthesised from amino acids, so they belong to plants' nitrogen-containing secondary metabolites. (Facchini, 2001). The presence of nitrogen is usually in a heterocyclic ring, which contributes to their biological activities.

Alkaloids are typically basic (alkaline) in nature due to their nitrogen atoms and can exist in salt or free base forms. They have a bitter taste and can occur in plants as free bases, salts, or glycosidic conjugates. Their chemical structure is highly variable, which contributes to the diverse range of biological and pharmacological activities seen in this class of compounds (Cordell, 1981).

In plants, alkaloids function primarily as defensive compounds, protecting against herbivores, insects, and microbial pathogens. They may also play roles in growth regulation, pollinator attraction, and allelopathic interactions with other plants. Due to their high toxicity and bioactivity, even small quantities can have significant physiological effects. Alkaloids demonstrate diverse therapeutic potentials including analgesic, stimulant, antimalarial, antitumor, and antimicrobial activities (Wink, 2000). Alkaloids have long been recognized for their potent medicinal properties, and many are used as drugs or precursors in pharmaceutical formulations. Caffeine is a common example of alkaloid found in Coffea arabica (coffee plant), acts as a central nervous system stimulant and is used to reduce fatigue and improve alertness. Nicotine is another example of alkaloid present in Nicotiana tabacum (tobacco), affects the nervous system and has been studied for its psychoactive and addictive properties.

2. Phenolics

Phenolic compounds are a large and diverse group of plant secondary metabolites identified by one or more hydroxylated aromatic rings in their structure. These bioactive molecules are primarily derived from the shikimate pathway, which provides the fundamental building blocks for phenylpropanoid biosynthesis a major metabolic route that produces a diverse range of phenolic derivatives (Dixon & Paiva, 1995; Vogt, 2010). Phenylalanine ammonia-lyase (PAL), an essential enzyme that converts phenylalanine to cinnamic acid, initiates this pathway. Further enzymatic transformations produce a wide range of phenolic compounds, including flavonoids, tannins, lignins, stilbenes, coumarins, and others.

Phenolic compounds typically feature aromatic rings with hydroxyl (–OH) substitutions, which contribute to their antioxidant activity through the donation of hydrogen atoms or electrons. They may exist in free forms or as conjugated forms (e.g., glycosides or esters), and are often soluble in organic solvents and water. Phenolics play multiple functional roles in plant biology, including:

Antioxidant Activity: Many phenolics scavenge reactive oxygen species (ROS), which protects plant cells from oxidative stress.

UV Protection: Flavonoids and related phenolics absorb harmful ultraviolet (UV-B) radiation, reducing damage to DNA and cellular proteins.

Structural Support: Lignin, a complex phenolic polymer, is deposited in the plant cell wall, particularly in xylem vessels, providing mechanical strength and water transport capacity.

Defense and Pigmentation: Compounds like tannins deter herbivores and pathogens, while anthocyanins and other flavonoids contribute to the coloration of flowers, fruits, and leaves, aiding in pollination and seed dispersal.

Examples of Phenolic Compounds

Quercetin: A widely distributed flavonoid with powerful antioxidant and anti-inflammatory properties. Found in onions, apples, and many leafy vegetables.

Tannins: Astringent polyphenols that bind proteins and deter herbivory; commonly found in tea, grapes, and bark.

Lignin: A major structural polymer in vascular plants; strengthens cell walls and contributes to the rigidity of stems and wood.

Phenolics are extensively researched for their nutraceutical and pharmacological properties, particularly their role in the prevention of chronic diseases such as cardiovascular disease, cancer, diabetes, and neurodegenerative disorders. Their antioxidant capacity, anti-inflammatory effects, and potential to modulate key enzymes make them valuable in functional foods and therapeutic applications (Scalbert *et al*., 2005).

3. Terpenoids (Isoprenoids)

Terpenoids are also known as isoprenoids and they are a large and highly diverse class of natural organic compounds composed of five-carbon isoprene units (CH_5H_8). Plants use two major biosynthetic pathways to build and modify these units:

Mevalonate pathway (MVA pathway) – Operates in the cytosol and primarily synthesizes sesquiterpenes and triterpenes.

Methylerythritol phosphate (MEP) or 1-deoxy-D-xylulose 5-phosphate (DOXP) pathway – Operates in the plastids and it is concerned with the formation of monoterpenes, diterpenes, and tetraterpenes (Rodríguez-Concepción & Boronat, 2002).

These biosynthetic routes produce the universal C_5 precursors isopentenyl pyrophosphate (IPP) and dimethylallyl pyrophosphate (DMAPP), which are polymerised into larger terpenoid structures.

Terpenes are the most abundant secondary metabolites in plants. Terpenes are a simple type of hydrocarbon. Terpenoids and isoprenoids are other terms for modified terpene forms. In technical sense terpenoid have oxygen atom, while terpene does not have oxygen atom. Different types of terpenoids different functional groups which provide them unique characteristics. They are also found in the plant derived essential oils (scented oils). Terpenes are strong-smelling phytochemical found in plants. They are produced by isoprene units. Isoprene is a 5-carbon compound with double bonds. On the basis of Isoprene (5-carbon units), terpenoids are characterized as-C5 (hemiterpenes, one isoprene), C10 (monoterpenes, two isoprene), C15 (sesquiterpenes, three isoprene), C20 (diterpenes, four isoprene), C25 (sesterpenes, five isoprene), C30 (triterpenes, six isoprene), C40 (tetraterpenes, eight isoprene), >C40 (polyterpenes). Terpenoids play a multitude of ecological and physiological roles, including:

Aroma and Flavour: Monoterpenes such as menthol (from Mentha spp.) and limonene (found in citrus oils) contribute to the distinctive smells and flavours of many herbs and fruits.

Defense Mechanisms: Many terpenoids exhibit antimicrobial, antifungal, and insect-repellent properties, serving as chemical defenses.

Signaling Molecules: Some terpenoids act as phytohormones (e.g., gibberellins) and attractants for pollinators or seed dispersers.

Structural Components: Compounds such as sterols are essential components of cell membranes.

Medicinal value: Taxol (Paclitaxel) is a diterpenoid extracted from Taxus brevifolia (Pacific yew tree) that is widely used as an anticancer agent, particularly in breast and ovarian cancer treatments (Wani *et al*., 1971; Kingston, 2007). Limonene is a fragrant terpene with solvent properties and potential anticancer effects.

4. Glycosides

Glycosides are a class of phytochemical metabolites in which one or more sugar molecules (glycone) are covalently bound to a non-sugar moiety (aglycone or genin). The bond between the sugar and aglycone is typically a glycosidic linkage, and the nature of both components determines the compound's physiological activity (Hostettmann & Marston, 1995). The aglycone may belong to various chemical groups such as steroids, flavonoids, phenolics, or terpenes, thus giving rise to different classes of glycosides like cardiac glycosides, anthraquinone glycosides, flavonoid glycosides, and others. Glycosides are formed through enzymatic glycosylation, in which glycosyltransferases catalyze the attachment of sugar moieties to aglycones derived from primary or secondary metabolism. Some important classes of glycosides include:

Cardiac Glycosides: Found in plants like Digitalis purpurea (foxglove), these compounds (e.g., digoxin, digitoxin) exhibit potent effects on heart muscle contraction and are used in the treatment of congestive heart failure and arrhythmias (Smith & Haber, 2002).

Saponins: These are glycosides with steroidal or triterpenoid aglycones, known for their foaming properties and ability to form complexes with cholesterol in membranes. They possess antimicrobial, anti-inflammatory, and immunomodulatory effects (Sparg *et al*., 2004).

Anthraquinone Glycosides: Found in plants such as Aloe and Senna, used as laxatives due to their effects on the colon.

Flavonoid Glycosides: Widely distributed in edible plants, these are involved in antioxidant defense, pigmentation, and UV protection.

Glycosides have long been used in traditional and modern medicine:

Digoxin: A cardiac stimulant used clinically, isolated from Digitalis purpurea.

Saponins: Used in vaccine adjuvants, natural detergents, and as bioactive compounds in nutraceuticals. They contribute to cardiovascular health and immune resilience (Shi *et al*., 2004).

Stevioside: A natural sweetener derived from Stevia rebaudiana, used as a sugar substitute.

5. Glucosinolates

Glucosinolates are a type of sulphur- and nitrogen-containing secondary metabolite found primarily in the Brassicaceae family (also known as Cruciferae), which includes broccoli (Brassica oleracea var. italica), cabbage (Brassica oleracea var. capitata), mustard (Brassica juncea), and radish (Raphanus sativus) (Fahey *et al*., 2001). Glucosinolates are β-thioglucoside N-hydroxysulfates that originate from amino acids like methionine, tryptophan, and phenylalanine. Each glucosinolate molecule is composed of three parts:

A sulfonated oxime moiety,

A β-D-glucopyranose residue,

A variable side chain (R-group) formed from the amino acid precursor.

During tissue disruption (e.g., chewing, cutting), glucosinolates come into contact with the enzyme myrosinase, which hydrolyses them to produce biologically active breakdown products such as Thiocyanates, Isothiocyanates (ITCs) and Nitriles. Among these isothiocyanates (e.g., sulforaphane) are especially important because of their health benefits (Fahey *et al*., 2001; Bones & Rossiter, 2006).

Health Benefits and Nutraceutical Potential

Research has demonstrated that glucosinolate-derived isothiocyanates offer a wide array of chemoprotective effects. Isothiocyanates such as sulforaphane induce phase II detoxification enzymes, promote apoptosis in cancer cells, and modulate epigenetic regulation (Zhang *et al*., 1992; Clarke *et al*., 2008). One of the most well-studied mechanisms by which isothiocyanates promote health is the activation of the nuclear factor erythroid 2-related factor 2 (Nrf2) pathway. Sulforaphane, a major isothiocyanate in broccoli, is a strong Nrf2 activator. After activation, Nrf2 moves to the nucleus and binds to the antioxidant response element (ARE) in the promoter region of target genes. This upregulates the expression of phase II detoxification enzymes and antioxidant proteins. such as Glutathione S-transferase (GST), Heme oxygenase-1 (HO-1), and NAD(P)H:quinone oxidoreductase 1 (NQO1).

These enzymes help in reducing oxidative stress and inflammatory responses by neutralizing reactive oxygen species (ROS) and modulating inflammatory pathways (Zhang *et al*., 1992; Kensler *et al*., 2007). Regular consumption of cruciferous vegetables has been epidemiologically linked to reduced risk of cancers, particularly of the lung, colon, breast, and prostate (Traka & Mithen, 2009). Benzyl isothiocyanate and allyl isothiocyanate have been shown to disrupt bacterial membranes, leading to leakage of cellular components. These compounds inhibit growth of pathogens like Helicobacter pylori, Escherichia coli, and Candida albicans, thereby improving gut resilience and reducing inflammation (Dufour *et al*., 2015; Aires *et al*., 2009).

Isothiocyanates influence carcinogen metabolism by acting on the cytochrome $P4_{50}$ (CYP) enzyme system. They inhibit phase I enzymes (such as CYP1A1, CYP1A2, CYP2E1) that activate procarcinogens. Simultaneously, they enhance phase II enzymes responsible for detoxification and excretion of carcinogens. This dual action helps reduce the formation of DNA adducts, limits mutagenesis, and lowers cancer risk, particularly in tissues like the liver, lungs, and colon (Talalay & Zhang, 1996; Myzak & Dashwood, 2006).

6. Carotenoids

Carotenoids are tetraterpenoid class of plant natural products. They have brilliant colorations such as red, orange and yellow pigmentations. Carotenoids have unique coloring properties. Due to their natural colours they are commonly used in food industry, cosmetics and pharmaceuticals. They are also being used as an agent of food fortification as they are the source of provitamin A. They are the organic pigments produced by plants and many algae. They are mainly found in the chromoplast and chloroplasts of plant cells. Carotenoids work as accessory photosynthetic pigment. Carotenoids plays most important and essential role in photoprotection to photosystems in plants. Carotenoids imparts the characteristic colouration to carrots, pumpkins, tomatoes, parsnips etc. Carotenoids are broadly classified in two types –

Xanthophylls: They contain oxygen atom. Xanthophylls acts as photochemical cooling pigments for photosystems. Xanthophylls such as zeaxanthin and lutein are found abundantly in the green and leafy. β-cryptoxanthin is a Xanthophylls found in papaya and pumpkins.

Carotenes: They contain no oxygen atom. They are pure hydrocarbons without oxygen.

Examples of carotenoids and their nutraceutical value:

β-Carotene:

It is an orange coloured thermolabile pigment. β-Carotene are highly sensitive to oxygen and light. They have protective role against cancer and heart disease cancer. β-carotenes inhibit the oxidation of lipoprotein (LDL-cholesterol). LDL-cholesterol oxidation is a critical factor associated with the development of atherosclerosis. Consumption of β-carotene rich vegetables and fruits reduces the risk of lung cancer and coronary heart diseases.

Lycopene:

The lycopene pigments are nonoxygenated carotenoids. Lycopene are the potential biological scavengers of free radicals. Lycopene is reported to be the most effective antioxidants. It donates the electrons for neutralizing the singlet oxygen species and other reactive oxygen species. They have higher antioxidant activity then β-carotenes. Recent researches indicates that consumption of lycopene naturally from tomato fruits is potentially effective in preventing various types of cancers and early onset of ageing.

Zeaxanthin and Lutein:

Zeaxanthin and Lutein are the carotenoid pigments stored in the retina and eye lenses. Recent researches have shown that intake high Zeaxanthin and Lutein reduces the risk of cataract and age-related macular degenerations. Broccoli and spinach are the foods rich in Zeaxanthin and Lutein.

Astaxanthin:-Astaxanthin is a red carotenoid pigment. Astaxanthin occurs naturally in algae, yeast, salmon, lobster, prawns, crab and crayfish. Astaxanthin has 10 times the antioxidant potential of β-carotene and approximately 500 times that of vitamin E (tocopherol). Astaxanthins provide significant protection against free radicals and LDL cholesterol oxidation.

7. Flavonoids-Flavonoids are a class of plant-derived pigments with various phenolic structures. Flavonoids are water-soluble polyphenolic compounds with 15 carbon atoms. In most cases, flavonoids are stored in cell vacuoles. They are typically stored in the form of glycosides. They can be found naturally in many fruits, grains, vegetables, flowers, stem and root bark, tea, coffee, and wine. These plant-based products are most popular because of their health benefits and medicinal properties. Flavonoids have a tremendous antioxidant potential.

Health Benefits of Flavonoids

Antioxidant Activity: Flavonoids scavenge reactive oxygen species and chelate metal ions, which protects lipids, proteins, and nucleic acids from oxidative damage. Their hydroxyl groups are primarily responsible for their strong antioxidant potential (Pietta, 2000). A lesser-known but pharmacologically important plant, Bryonia alba contains saponarin, isoorientin, isovitexin, and lutonarin, all exhibiting antioxidant activity. These compounds contribute to the plant's use in homeopathic treatments for respiratory and inflammatory disorders (Muthu *et al*., 2006).

Anticancer Properties: Hesperidin (from citrus fruits) and Aurone are flavonoids with proven efficacy in inhibiting abnormal cell proliferation. Quercetin, besides being a potent antioxidant, also suppresses growth of colorectal cancer cells by affecting Wnt/β-catenin signaling and inducing apoptosis (Murakami *et al*., 2008).

Anti-inflammatory and Immunomodulatory Effects: Flavonoids inhibit key enzymes such as COX-2 and LOX and downregulate pro-inflammatory cytokines (IL-6, TNF-α), which reduces inflammation and modulates immune responses (Middleton *et al*., 2000).

Antibacterial and Antiviral Activity: Flavonoids exhibit broad-spectrum antimicrobial properties by disrupting microbial membranes, inhibiting DNA/RNA synthesis, or interfering with microbial enzyme systems (Cushnie & Lamb, 2005).

Cardioprotective, Hepatoprotective, and Neuroprotective Roles: Flavonoids like those found in dark chocolate (cocoa) improve endothelial function, reduce LDL oxidation, and regulate blood pressure, contributing to cardiovascular health. They also protect neurons against oxidative stress and support hepatic detoxification enzymes (Manach *et al*., 2004). Dark chocolate is rich in catechins and epicatechins, flavonoids that improve vascular elasticity, reduce platelet aggregation, and lower blood pressure, thereby offering protection against cardiovascular diseases (Engler & Engler, 2006).

8. Anthocyanins

Anthocyanins are a class of brilliantly coloured, water-soluble phenolic pigments that are stored predominantly in the vacuoles of plant cells. These compounds belong to the flavonoid group of secondary metabolites and are biosynthetically derived from flavonols through the phenylpropanoid pathway (Gould *et al*., 2009). Anthocyanins are commonly found in the petals of flowers and the pericarps of fruits, although they are also reported in roots, stems, leaves, and even seeds of certain plant species (Khoo *et al*., 2017).

Structurally, anthocyanins are glycosylated pigments, with sugar moieties enhancing their solubility and stability in aqueous cellular environments. Among the various anthocyanins identified, cyanidin-3-glucoside is one of the most widespread and well-studied across the plant kingdom. Other commonly occurring anthocyanins include delphinidin, peonidin, pelargonidin, petunidin, and malvidin, each contributing to specific coloration depending on their hydroxylation and methylation patterns (Andersen & Jordheim, 2006).

The vivid red, purple, and blue hues observed in many fruits, vegetables (e.g., purple cabbage, black carrot, red radish), cereal grains (e.g., pigmented rice and maize), and tubers (e.g., purple potato) are primarily due to the accumulation of anthocyanin pigments (He & Giusti, 2010). Their colour expression is sensitive to environmental factors such as pH, temperature, and light. Notably, anthocyanins display red coloration at low (acidic) pH, but transition to blue or violet in more alkaline environments (Castaneda-Ovando *et al*., 2009).

Applications of Anthocyanins in health management

Medicinal Value and Pharmacological Potential: Anthocyanins are pharmacologically active secondary metabolites with broad-spectrum biological functions. Studies have demonstrated their roles in combating chronic diseases due to their antidiabetic, anti-inflammatory, anticancer, antimicrobial, anti-obesity, and cardioprotective properties (Tsuda, 2012; Wallace, 2011). Their free radical scavenging ability is attributed to their polyphenolic structure, which contributes to reduced oxidative stress.

Appetite Stimulation: Anthocyanins, as bioactive phytochemicals, have been reported to modulate metabolic processes and can function as appetite stimulants, particularly through their influence on satiety-related hormones and gut microbiota (Scalbert *et al*., 2005).

Cardiovascular Benefits: Anthocyanin consumption has been linked to decreased platelet aggregation, which plays an important role in lowering the risk of atherosclerosis and coronary heart disease. Regular consumption of anthocyanin-rich foods has been linked to improved endothelial function and lower arterial stiffness (Cassidy *et al*., 2013).

Eye Health and Vision Protection: Anthocyanins have neuroprotective properties for ocular tissues. They help to prevent retinal degeneration, improve night vision, and protect the retina from oxidative stress and light-induced injury (Matsumoto *et al*., 2003). This has resulted in their inclusion in nutraceuticals designed to maintain visual health, particularly in ageing populations.

9. Coumarins

Coumarins are a class of colourless, polyphenolic secondary metabolites widely distributed in the plant kingdom and also produced by some fungi and bacteria. They were first isolated from the seeds of *Dipteryx odorata* (Tonka bean), a member of the family Fabaceae (Venugopala *et al*., 2013). Chemically, coumarins are known as 2H-1-benzopyran-2-one, comprising a fused benzene ring and a lactone-containing α-pyrone ring, forming a heterocyclic structure. Their unique aromaticity and fnctional versatility contribute to diverse biological activities.

Coumarins are oxygenated crystalline heterocyclic compounds classified under the broader group of benzopyrones. Naturally occurring coumarins are found in various dietary and plant sources, including leafy vegetables, seeds, nuts, fruits, tea, coffee, and red wine (Lake, 1999). Their biosynthesis primarily occurs via the phenylpropanoid pathway.

These compounds are especially abundant in plant species from several families such as Umbelliferae (Apiaceae), Rutaceae, Oleaceae, Mimosaceae, Clusiaceae (Guttiferae), Caprifoliaceae, and Nyctaginaceae (Borges *et al*., 2005). Higher levels of coumarins are reported in the fruits of Bael (*Aegle marmelos*), tonka beans seeds (*Dipteryx odorata*), roots of Ferulago campestris and leaves of *Murraya paniculate*.

Health benefits

Coumarins are pharmacologically significant, with a wide range of biological and therapeutic effects. They possess antioxidant, anticoagulant, antiviral, antifungal, antibacterial, anticancer, anti-inflammatory, antihypertensive, antihyperglycemic, antiadipogenic, cardioprotective, and neuroprotective properties (Venugopala *et al*., 2013; Borges *et al*., 2005). Some important health benefits include:

Anti-inflammatory Activity: Coumarins are known to stimulate phagocytosis and proteolysis in inflamed tissues, enhancing the body's natural immune response and reducing inflammation. They modulate key inflammatory pathways and enzymes such as cyclooxygenase and lipoxygenase (Bourgaud *et al*., 2001).

Anticoagulant Activity: One of the most well-known coumarin derivatives is dicoumarol, a natural anticoagulant isolated from spoiled sweet clover (Melilotus spp.). It acts as a vitamin K antagonist, interfering with the synthesis of vitamin K-dependent clotting factors in the liver, thus reducing blood coagulation. Synthetic derivatives such as warfarin are extensively used in clinical settings for thromboembolic disorders (Hirsh *et al*., 2003).

Antimicrobial Properties: Coumarins show antimicrobial activity against a variety of bacteria, viruses, and fungi. They disrupt microbial cell walls, inhibit synthesis nucleic acids, and interfere with key metabolic enzymes thus, limiting microbial growth (Zhou *et al*., 2016).

Antihypertensive Activity: Certain coumarin derivatives such as dihydromammea, isolated from the seeds of Mammea africana (Family: Guttiferae), have demonstrated vasodilatory and antihypertensive effects. These effects are likely due to modulation of calcium channels and nitric oxide pathways (Ngameni *et al*., 2009).

Antitubercular Properties: Coumarins have also shown promise in tuberculosis treatment. Umbelliferone, a simple coumarin isolated from members of the Umbelliferae, has exhibited inhibitory effects against Mycobacterium tuberculosis in vitro, suggesting its potential as a lead compound in anti-TB drug development (Sahu & Padhy, 2013).

Conclusion

Secondary metabolites, once considered mere by-products of plant metabolism, are now recognized as potent nutraceuticals with immense relevance for human health. Edible plants harbour a wide array of these bioactive compounds—including flavonoids, alkaloids, phenolic acids, terpenoids, coumarins, anthocyanins, and glucosinolates—which not only contribute to the plant's defense and adaptive strategies but also provide therapeutic health benefits to the human body. A growing body of evidence highlights the antioxidative, anti-inflammatory, anticancer, antimicrobial, cardioprotective, neuroprotective, antidiabetic, and hepatoprotective roles of these compounds. Regular consumption of secondary metabolite-rich fruits, vegetables, herbs, and spices is strongly correlated with reduced risk of chronic diseases and improved metabolic balance. In conclusion, edible plants serve not only as sources of nourishment but also as reservoirs of natural therapeutic agents. Promoting dietary diversity with an emphasis on plant-based foods can be a sustainable and effective strategy for daily health management and disease prevention in the modern lifestyle.

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