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Overview of the Chemistry and Bioactive Properties of Flavonoids: Insights into their Diverse Biological Activities

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Abstract

Most recent researches have focused on the health aspects of flavonoids for humans. Many flavonoids are shown to have antioxidative activity, free radical scavenging capacity, coronary heart disease prevention, hepato protective, anti-inflammatory, and anticancer activities, while some flavonoids exhibit potential antiviral activities. In plant systems, flavonoids help in combating oxidative stress and act as growth regulators. For pharmaceutical purposes cost-effective bulk production of different types of flavonoids has been made possible with the help of microbial biotechnology. Flavonoids are a diverse group of plant secondary metabolites that have gained significant attention in recent years due to their wide range of biological activities. These natural compounds are widely distributed in fruits, vegetables, grains, herbs, and other plant-based foods, making them an integral part of the human diet.

Introduction

Flavonoids are not only responsible for the vibrant colors of many plants but also contribute to their aroma and taste. In addition to their sensory properties, these compounds have been extensively studied for their potential health benefits [1]. Chemically, flavonoids belong to a class of polyphenol compounds characterized by a 15-carbon skeleton consisting of two aromatic rings connected by a three-carbon bridge. Based on the oxidation state and the arrangement of the C ring, flavonoids can be further classified into several subclasses, including flavones, flavonols, flavanones, isoflavones, flavanols, anthocyanidins, and others. Each subclass exhibits unique chemical characteristics and biological activities. Flavonoids also act as a secondary antioxidant defense system in plant tissues exposed to different abiotic and biotic stresses [2].

Flavonoids are located in the nucleus of mesophyll cells and within centers of ROS generation. They also regulate growth factors in plants such as auxin. Biosynthetic genes have been assembled in several bacteria and fungi for enhanced production of flavonoids [3]. The chelation of metals could be crucial in the prevention of radical generation which damage target biomolecules. As a dietary component, flavonoids are thought to have health-promoting properties due to their high antioxidant capacity both in vivo and in vitro systems. Flavonoids have ability to induce human protective enzyme systems. The number of studies has suggested protective effects of flavonoids against many infectious and degenerative diseases such as cardiovascular diseases, cancers, and other age-related diseases [4].

Chemistry of Flavonoids

Flavonoids consist of a large group of polyphenolic compounds having a benzo-γ-pyrone structure and are ubiquitously present in plants [5]. They are synthesized by phenylpropanoid pathway .

Chemical formula for flavonoids

The general structure of flavonoids is a 15-carbon skeleton, containing 2 benzene rings connected by a 3-carbon linking chain. Therefore, they are depicted as C6-C3-C6 compounds [6].

Chemical classification of flavonoid

Flavonoids are classified into six subclasses according to their basic structure, including flavonols, flavanones, isoflavones, flavones, flavan-3-ols, and anthocyanin [7].

Biological activities of flavonoids

Antioxidant Activity. Flavonoids possess many biochemical properties, but the best described property of almost every group of flavonoids is their capacity to act as antioxidants. The antioxidant activity of flavonoids depends upon the arrangement of functional groups about the nuclear structure [8].

Flavonoids also exhibit anti-inflammatory properties by modulating the activity of enzymes involved in the inflammatory response, such as cyclooxygenases and lipoxygenases. By inhibiting the production of inflammatory mediators, flavonoids can help alleviate inflammation and associated symptoms [9].

Moreover, flavonoids have shown potential in the prevention and treatment of various cancers. Several studies have reported their ability to inhibit the growth of cancer cells, induce apoptosis and inhibit angiogenesis in tumors. Additionally, certain flavonoids have demonstrated chemo preventive effects by blocking the initiation and progression of carcinogenesis [10].

Conclusion

Flavonoids are a diverse group of natural compounds with a wide range of biological activities. Their antioxidant, anti-inflammatory, anticancer, cardio protective, neuroprotective, and antimicrobial properties make them promising candidates for the prevention and treatment of various diseases. Incorporating a variety of flavonoid-rich foods, such as fruits, vegetables, and herbs. Although numerous studies have highlighted the beneficial effects of flavonoids, it is essential to note that the bioavailability and metabolism of these compounds can vary significantly. Factors such as food processing, gut microbiota,

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and individual variations influence the absorption, distribution, and metabolism of flavonoids in the human body. Therefore, more research is needed to optimize the delivery and utilization of flavonoids for maximum health benefits. In addition to their protective effects against chronic diseases, flavonoids have shown promise in improving cognitive function and reducing the risk of age-related cognitive decline. They exert neuroprotective effects by reducing oxidative stress, modulating neuronal signaling, and enhancing memory and learning.

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