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Review Article

FLAVONOIDS: AN ERA OF NUTRACEUTICALS TURNING IN TO MEDICINAL AGENTS

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ABSTRACT

Flavonoids, present in plants, constitute a varied group of naturally occurring compounds well-known for their potential positive effects on health. These molecules present in fruits, vegetables, and beverages such as tea exhibit antioxidant, anti-inflammatory, and other bioactive properties that contribute to their positive impact on human health. In addition, flavonoids act as antioxidants, helping plants combat oxidative stress. Some flavonoids also participate in ultraviolet protection, defense against pathogens, and modulation of plant-microbe interactions. Flavonoids have a different subclass of flavones, flavonols, flavanones, flavan-3-ols, anthocyanins, and isoflavones. The term "bioavailability" describes how well the body absorbs and uses flavonoids, a broad class of plant-based chemicals. The chemical structure of flavonoids, the matrix of foods they are eaten interactions with other dietary components influence their bioavailability. This metabolism can lead to the formation of various metabolites, impacting the compounds' bioactivity. Understanding these aspects is crucial for unlocking the full potential of flavonoids in promoting health and preventing diseases. Patents on flavonoids serve as legal protections for innovations related to these plant compounds. Companies and researchers seek patents to safeguard novel methods of extraction, synthesis, and applications ensuring exclusivity for a specified period. This exclusivity incentivizes investment in research and development, promoting the exploration of flavonoids for pharmaceuticals, food additives, and cosmetics. Ultimately, these legal protections encourage advancements in understanding and harnessing the diverse benefits of flavonoids across various industries.

Keywords: Flavonoids, Bioavailability, Anthocyanins, Polyphenolic.

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INTRODUCTION

Flavonoids, found in plants, are a group of polyphenolic compounds recognized for their biological effects [1]. Flavonoids not only function as unique ultraviolet (UV) filters, protecting plants from diverse biotic and abiotic threats, but they also serve as defense-related signal molecules, allopathic compounds, phytoalexins, and detoxifying agents [2]. Flavonoids protect plants against drought and frost, and they may also help plants become acclimated to high temperatures and cold temperatures [3]. They contribute to the vibrant colors of fruits, vegetables, and flowers, and have antioxidant properties that may offer health benefits. They are a member of a group of phenolic compounds with low molecular weight that are found across the kingdom of plants [4]. Chalcones, flavones, flavonoids, and isoflavones represent various subclasses within the flavonoid category, each originating from distinct primary sources. Two important dietary sources of flavonols and flavones are onions and tea [5]. Common dietary sources of flavonoids include fruits (berries and citrus fruits), vegetables (onions and broccoli), tea, red wine, and dark chocolate. Consuming a variety of these foods can contribute to a well-rounded intake of flavonoids, potentially supporting overall health.

Nowadays, flavonoids are seen as an essential component of many pharmacological, cosmetic, nutraceutical, skin care items, medical uses, and anti-wrinkle treatments for the skin have all employed flavonoids [6,7]. Nonetheless, the medical area is where these polyphenols are most prominently used [8]. Their anti-inflammatory, anti-mutagenic, and anti-carcinogenic qualities can be attributed to their capacity to influence the activity of crucial cellular enzymes [9]. Some studies suggest flavonoids might contribute to cognitive health and have positive impacts on metabolic syndrome.

It is crucial to remember that although the evidence for flavonoids' health benefits is mounting, individual reactions may differ, and further study is required to completely comprehend their processes and their therapeutic uses. Always consult updated and reliable sources for the latest information [10,11].

Ongoing research explores the potential role of flavonoids in cognitive function, metabolic health, and other areas. Flavonoids are being investigated for their impact on gut health, with potential prebiotic effects [12].

Even though several studies have demonstrated the potential health advantages of flavonoids, maintaining a varied and balanced diet is crucial for general well-being. Consultation with health-care professionals is advisable for personalized advice [13].

CLASSIFICATION OF FLAVONOIDS

Flavonoids have a common 15-carbon skeleton consisting of two phenyl rings (A and B) connected by a heterocyclic ring (C). The structural variations within this framework give rise to the different subclasses of flavonoids. They are flavones, flavonols, flavanones, flavan-3-ols, anthocyanin, and isoflavones.

In nature, all of these flavonoids are broadly dispersed (Fig. 1) [14]. Increased consumption of foods high in flavonoids has several health advantages [15]. There is a growing push to separate these natural substances from different plants because of their beneficial benefits on human health. Citrus fruits, for example, are a great source of flavonoids. Citrus fruits and grapes contain two flavonoids: Narigenin and hesperetin [16]. Mulberries include flavonoids called anthocyanin and quercetin glycosides [17].

FLAVONES

Flavones, a noteworthy subgroup of flavonoids, are abundant in leaves, flowers, and fruits as glucosides. Notable sources of flavones encompass celery, parsley, red peppers, chamomile, mint, and ginkgo biloba. Among the flavonoids in this subclass are luteolin, apigenin, and

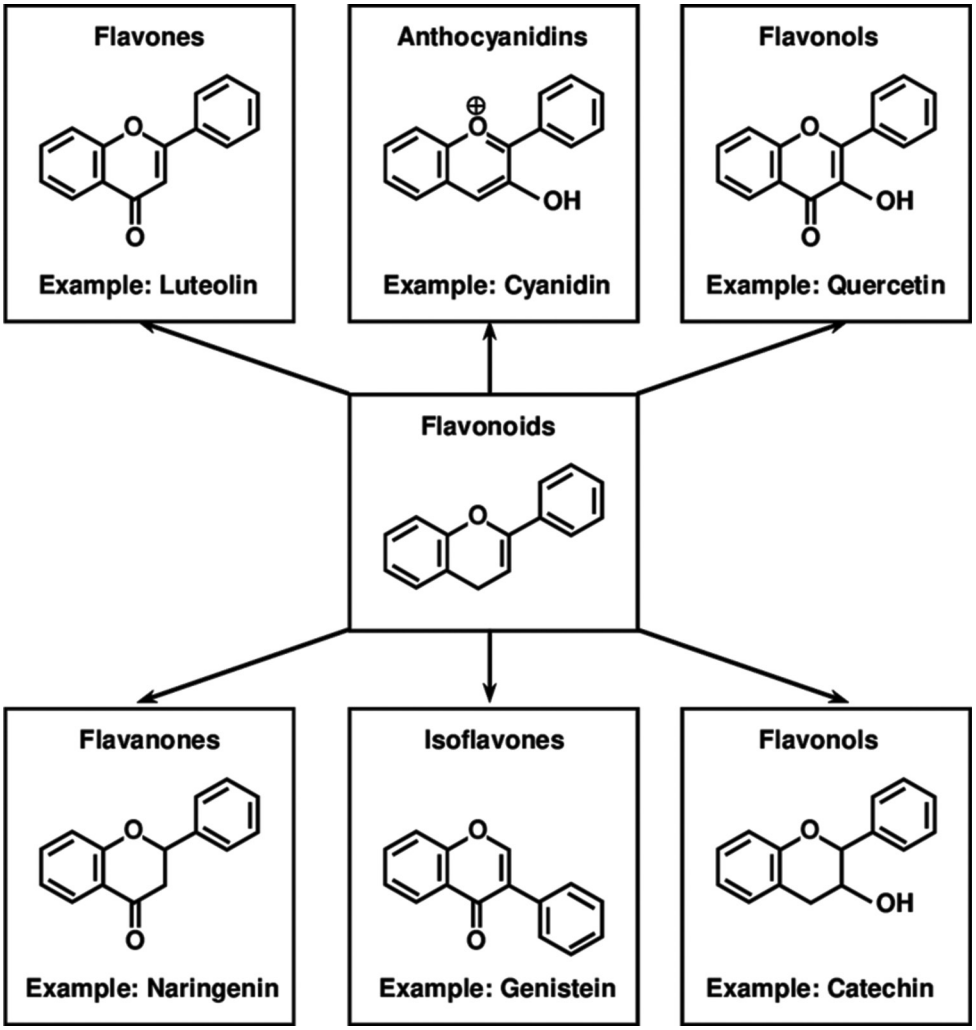

Fig. 1: Sub-classification of flavonoids

tangeritin (Fig. 1). Citrus fruit peels are rich in tangeritin, nobiletin, and sinensetin, four polyethoxylated flavones [18]. They feature a pair of bonding across positions two and three and the ketone at position four, which is in the C ring. According to the taxonomic classification of the particular vegetable or fruit, there might be variations in the hydroxylation at different positions, particularly at position seven of the ring of A or 3′ and 4′ in the B ring. The hydroxyl group at position five of the A ring is present in most flavones.

FLAVONOLS

Flavonols are the ketone groups found on flavonoids. They function as the structural elements of proanthocyanins. Numerous fruits and vegetables are rich in flavonols. Kempferol, quercetin, myricetin, and fisetin are the flavonols that have been investigated the most (Fig. 1). Flavonol-rich foods include onions, kale, lettuce, tomatoes, apples, grapes, and berries. Flavonols are present in fruits, vegetables, tea, and red wine, among other foods. Consuming flavonols has been linked to several health advantages, such as the ability to act as an antioxidant and a decreased chance of heart problems.

The hydroxyl group at the C ring's position three of flavonols differs from that of flavones in that it has the potential to have glycosylation. Since flavonols and flavones have various patterns of methylation and hydroxylation, flavonols may be the most prevalent and biggest subgroup of flavonoids found in fruits and vegetables due to their distinct glycosylation patterns. One example of a plant food that contains quercetin is numerous plant foods [19].

FLAVANONES

Flavanones are a class of flavonoid compounds present in all citrus fruits. Among the flavonoids in this class are hesperetin, naringenin, and eriodictyol. The many health benefits of flavanone are associated with its capacity to scavenge free radicals. These compounds give citrus fruit peels and juices their bitter taste. Citrus flavonoids have interesting pharmacological effects as medications that lower blood lipids, which are inflammation, cholesterol, and antioxidants. The primary structural distinction between the two distinct flavonoid groupings is that dihydroflavones, also known as flavanones, have a pair of bonds between positions 2–3 that is saturated, but the C ring of flavones is not. There have been a lot more flavanones discovered in the last 15 years [19].

ISOFLAVONOIDS

Among the many different subgroups of flavonoids are isoflavonoids. Within the kingdom of plants, isoflavonoids are confined to a small range of species, with the majority of them being found in legumes such as soy. In addition, it has been reported that microorganisms contain a number of isoflavonoids [20]. In addition, it has been demonstrated that they are crucial as precursors for the synthesis of phytoalexins during interactions between plants and microbes [21,22]. Isoflavonoids have a lot of potential for treating many diseases. Because isoflavones have estrogenic activity in some animal models, such as daidzein and genistein, they are also referred to as phyto-estrogens (Fig. 2). Szkudelska and Nogowski investigated the effects of genistein on hormonal and metabolic balance. These impacts may have an impact on multiple disease pathways [23].

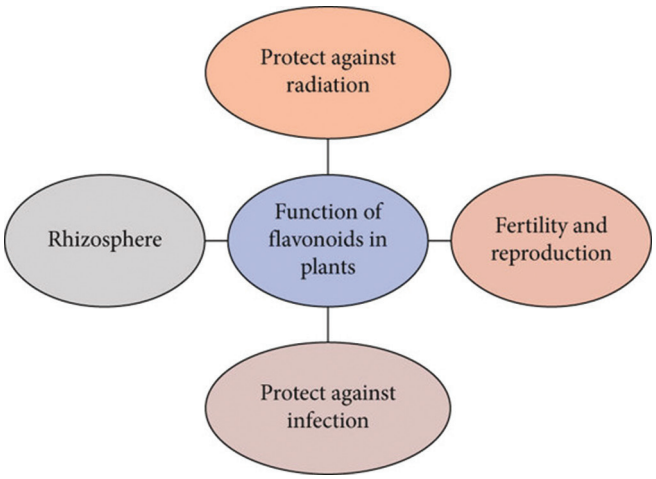

Fig. 2: Function of flavonoids in plants

ANTHOCYANINS

Plant, floral, and fruit hues are attributed to pigments called anthocyanins. The most often researched anthocyanins include cyanidin, delphinidin, malvidin, pelargonidin, and peonidin. They are usually present in the outer cell layers of several fruits, such as red and merlot grapes, raspberries, strawberries, blueberries, bilberries, blackberries, and cranberries. Because of these compounds' durability and health benefits, the food industry may use them for a variety of applications [24]. The anthocyanin's color is influenced by the pH and the methylation or acylation of the hydroxyl group on both the A and B rings [19].

FLAVAN-3-OLS

The 3-hydroxy derivatives of flavanones are referred to as catechins or dihydroflavonols. They form a very varied and multi-substituted subgroup. Because the hydroxyl group is still bound to position three on the C ring, flavonols are also known as flavan-3-ols. There does not appear to be a pair of connections between positions two and three, in contrast to many flavonoids. Rich sources of flavanols include bananas, pears, peaches, blueberries, and apples [25].

APPLICATIONS OF FLAVONOIDS:[26-28]

1. Antioxidant supplements: Flavonoids, with their strong antioxidant properties, are used in dietary supplements to support overall health and combat oxidative stress
2. Anti-inflammatory medications: Certain flavonoids, such as quercetin and kempferol, have anti-inflammatory properties and may be explored for developing pharmaceuticals targeting inflammatory conditions
3. Skin care products: Flavonoids, particularly those found in green tea and chamomile, are incorporated into skin care products for their potential to protect the skin from oxidative damage and inflammation
4. Natural food colorings: Anthocyanins, a type of flavonoid, are used as natural colorants in the food industry for products such as beverages, jams, and confectionery
5. Flavors enhancers: Some flavonoids contribute to the taste and aroma of foods, enhancing flavors in various culinary applications
6. Plant growth regulators: The function of flavonoids in the growth and development of plants is being investigated. They may be used in agriculture as natural plant growth regulators or enhancers
7. Potential chemo-preventive agents: Certain flavonoids, such as those found in fruits and vegetables, are investigated for their potential role in preventing or inhibiting the development of cancer
8. Functional foods: Foods high in flavonoids, including dark chocolate and berries, are included in functional foods that promote cardiovascular health
9. Cognitive health supplements: Flavonoids, particularly those with neuroprotective properties, are studied for their potential role in cognitive health and may be incorporated into supplements
10. Research and development: Flavonoids are investigated for their antiviral properties, and ongoing research explores their potential use in developing medications against viral infections
11. Wound healing: Some flavonoids exhibit properties that may aid in wound healing, and their application is explored in dermatological formulations

It is crucial to remember that even if flavonoids appear promising in these uses, further research is needed to fully understand their mechanisms and optimize their use in specific contexts. Always consult scientific literature and professionals in the respective fields for the latest information and guidance.

ROLE OF FLAVONOIDS IN PLANTS

In plants, flavonoids serve a myriad of essential functions, contributing to their survival, development, and interaction with the environment. Primarily recognized for their role in UV protection, flavonoids act as natural sunscreens by absorbing and dissipating UV-B and UV-A radiation, shielding plant tissues from potential damage. These compounds furthermore perform a crucial part of defense mechanisms, serving as phytoalexins to deter herbivores and pathogens. Furthermore, flavonoids contribute to plant pigmentation, influencing flower coloration to attract pollinators [29]. In addition to their defensive and esthetic roles, flavonoids participate in signal transduction pathways, regulating plant growth, development, and stress responses. Their antioxidant properties help plants cope with oxidative stress induced by environmental factors. Overall, flavonoids exemplify the adaptability of plants, providing multifunctional benefits that contribute to their ecological success and resilience [30].

ANTI-INFLAMMATORY ACTIVITIES OF FLAVONOIDS

Plants contain a class of polyphenolic chemicals called flavonoids, which, through a variety of processes, have strong anti-inflammatory properties. These bioactive molecules exert their effects by modulating inflammatory pathways and cellular responses (Figs. 3-6). First, flavonoids can inhibit the activity of pro-inflammatory enzymes, such as cyclooxygenases and lipoxygenases, thereby suppressing the production of inflammatory mediators such as prostaglandins and leukotrienes. In addition, flavonoids act as antioxidants, scavenging free radicals and reducing oxidative stress, which is closely linked to inflammation. Moreover, these compounds can interfere with signal transduction pathways involved in inflammatory responses, inhibiting the activation of transcription factors such as NF-κB. Through the reduction of inflammatory gene expression, flavonoids help regulate the immune response. Furthermore, flavonoids demonstrate anti-inflammatory effects by modulating immune cell function, influencing the release of cytokines, and attenuating the adhesion of immune cells to endothelial cells. Overall, the multifaceted anti-inflammatory activities of flavonoids make them promising candidates for therapeutic interventions in various inflammatory conditions [31-34].

ANTI-TUMOR ACTIVITIES OF FLAVONOIDS

Known for their potential anti-tumor properties, flavonoids are a broad collection of naturally occurring chemicals that are prevalent in fruits, vegetables, and beverages such as tea. One of their primary mechanisms is rooted in antioxidant properties, as flavonoids combat oxidative stress and mitigate cellular damage caused by free radicals. Moreover, these compounds exhibit anti-inflammatory effects, crucial in impeding the chronic inflammation associated with tumor development. Flavonoids also have an effect on the proper course of division of cells and prevent aberrant growth by controlling the cell cycle. Some members of this group demonstrate a remarkable ability to induce apoptosis, prompting programmed cell death in cancer cells and hindering their uncontrolled proliferation. In addition, certain

flavonoids contribute to anti-tumor effects by inhibiting angiogenesis, the process of new blood vessel formation crucial for tumor growth [35]. Furthermore, these compounds may modulate the immune system, enhancing the body's natural defense mechanisms against cancer. Finally, flavonoids can interfere with key enzymes involved in various cellular processes, disrupting signaling pathways essential for tumor survival and progression. While research continues, these multifaceted mechanisms highlight the potential of flavonoids in the development of anti-tumor therapies [36].

ANTI-BACTERIAL ACTIVITY OF FLAVONOIDS

Because of their complex interactions with bacterial structures and processes, flavonoids, a broad collection of naturally occurring polyphenolic chemicals in plants, exhibit a wide spectrum of antibacterial properties. One prominent mechanism involves their ability to disrupt bacterial cell membranes. Flavonoids can insert themselves into the lipid bilayer, altering membrane fluidity and permeability, ultimately leading to cell membrane destabilization and lysis.

Moreover, flavonoids interfere with crucial bacterial enzymes, such as DNA gyrase and RNA polymerase, vital for bacterial replication and transcription. By disrupting these processes, flavonoids impede bacterial growth and reproduction. In addition, flavonoids often demonstrate metal-chelating properties, sequestering essential metal ions required for bacterial survival. This action further disrupts bacterial functions dependent on metal cofactors [37].

Beyond direct effects on bacterial structures, flavonoids can modulate the host's immune response. They may enhance the activity of immune cells, such as macrophages and neutrophils, promoting a more effective defense against bacterial infections. Furthermore, flavonoids can inhibit the formation of bacterial biofilms – protective matrices bacteria create for increased resistance to antibiotics and the immune system.

The vast array of antibacterial mechanisms exhibited by flavonoids underscores their potential as natural agents for combating bacterial infections. Research in this field continues to unveil the specific flavonoid structures and bacterial targets, offering valuable insights to create new antimicrobial treatments [38].

ANTI-VIRAL ACTIVITIES OF FLAVONOIDS

Through a variety of processes, flavonoids, a broad class of polyphenolic chemicals found in numerous plant sources, have demonstrated considerable anti-viral action. One key aspect of their antiviral effects involves interference with viral penetration of host cells. Flavonoids can inhibit viral attachment and fusion by interacting with viral envelope proteins or cellular receptors, thus preventing the initial stages of infection. In addition, they may impede viral replication within host cells by targeting essential viral enzymes. For instance, flavonoids can inhibit the activity of viral proteases and polymerases, critical for viral protein synthesis and genome replication.

Furthermore, flavonoids exhibit immunomodulatory properties, influencing the host's immune response to viral infections. They can enhance the activity of immune cells, including natural killer cells and T lymphocytes, contributing to a more effective antiviral defense. Moreover, flavonoids possess anti-inflammatory effects, which can be beneficial during viral infections by mitigating excessive immune responses that may contribute to tissue damage [39].

Some flavonoids also show virucidal activity, directly inactivating viruses outside host cells. This action can be particularly relevant for preventing the spread of viruses in the extracellular environment. In addition, flavonoids may interfere with viral maturation and release, limiting the production of infectious viral particles.

The diverse and multifaceted anti-viral properties of flavonoids highlight their potential as natural agents in the development of antiviral strategies. Understanding the specific mechanisms and interactions involved provides valuable insights for exploring flavonoids as potential components of antiviral therapies [40].

ROLE OF FLAVONOIDS IN OXIDATIVE STRESS

A broad class of polyphenolic substances found in many plant-based foods, flavonoids are essential for preventing oxidative stress, which is defined as an imbalance between reactive oxygen species (ROS) and the body's antioxidant defense systems. These compounds exhibit potent antioxidant properties, serving as effective reactive oxygen species and free radical scavengers. Moreover, certain flavonoids can chelate metals, preventing them from catalyzing reactions that generate harmful radicals. Beyond their direct antioxidant effects, flavonoids modulate cellular signaling pathways, influence gene expression related to antioxidant defenses, and stimulate the activity of endogenous antioxidant enzymes. This multifaceted approach helps protect cellular components, including lipids and DNA, from oxidative damage. Flavonoids also demonstrate anti-inflammatory effects, contributing to overall cellular resilience. Notably, their impact extends to mitochondrial function, neuroprotection, and cardiovascular health. Incorporating flavonoid-rich foods into the diet thus offers a comprehensive strategy for mitigating oxidative stress and promoting overall well-being [41-43].

BIOAVAILABILITY AND METABOLISM OF FLAVONOIDS

Bioavailability of flavonoids

A complicated and dynamic process, the bioavailability of flavonoids is regulated by a number of circumstances. Flavonoids are a broad collection of polyphenolic substances that are plentiful in fruits, vegetables, and beverages such as tea and wine. Flavonoids undergo digestion in the gastrointestinal tract, where they are subject to enzymatic breakdown and structural modifications. The type of flavonoid significantly impacts its bioavailability, with variations in absorption rates observed among different subclasses. The presence of other dietary components, such as fats or sugars, can affect flavonoid absorption, as some may enhance or inhibit their uptake [44].

In addition, the matrix of the food source plays a crucial role; for instance, consuming flavonoids within whole fruits may enhance their bioavailability compared to isolated supplements. Cooking methods and food processing can also influence flavonoid content and bioavailability. Furthermore, the gut microbiota plays a pivotal role in metabolizing flavonoids, generating bioactive metabolites that may contribute to their health benefits. While the overall bioavailability of flavonoids tends to be relatively low, these compounds potential health effects may be attributed to their interactions with various biological processes, even at lower concentrations [45].

Metabolism of flavonoids

The metabolism of flavonoids is a multifaceted process involving absorption, transformation, and elimination within the body. On consumption, flavonoids undergo digestion in the gastrointestinal tract, where they may be broken down by enzymes into smaller, more absorbable compounds. Absorption occurs primarily in the small intestine, with the absorbed flavonoids entering the bloodstream. However, the bioavailability of flavonoids is often limited, and a significant portion reaches the colon undigested. In the colon, gut microbiota plays a crucial role in metabolizing these compounds, leading to the formation of various microbial metabolites. These metabolites, such as phenolic acids, are thought to contribute to the health benefits associated with flavonoid consumption [46-50].

The liver further metabolizes absorbed flavonoids through processes such as glucuronidation and sulfation, converting them into water-soluble compounds for excretion. Some metabolites retain bioactivity and may exert antioxidant, anti-inflammatory, or other physiological effects. The interplay between digestive enzymes, gut microbiota, and hepatic metabolism influences the overall metabolic fate of flavonoids,

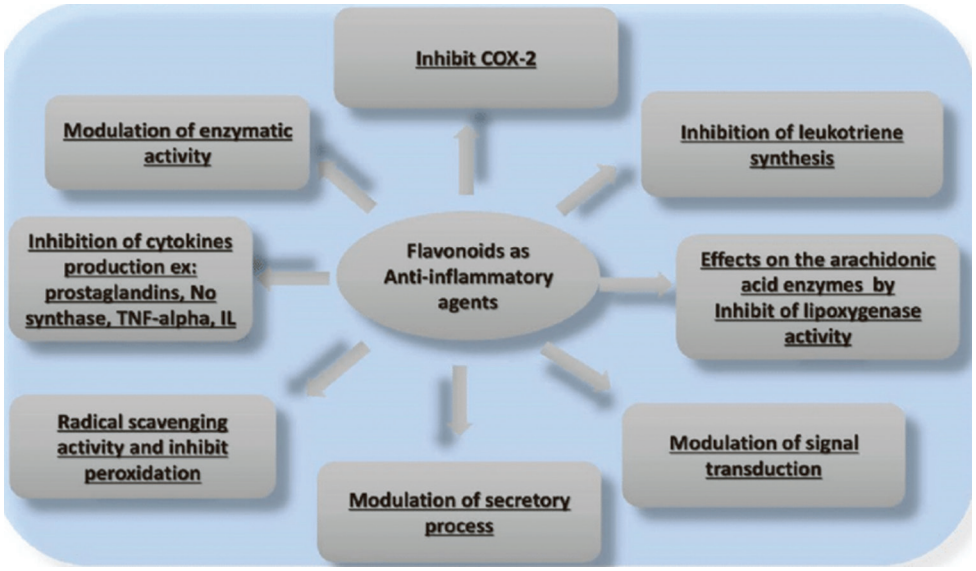

Fig. 3: Anti-inflammatory activities of flavonoids

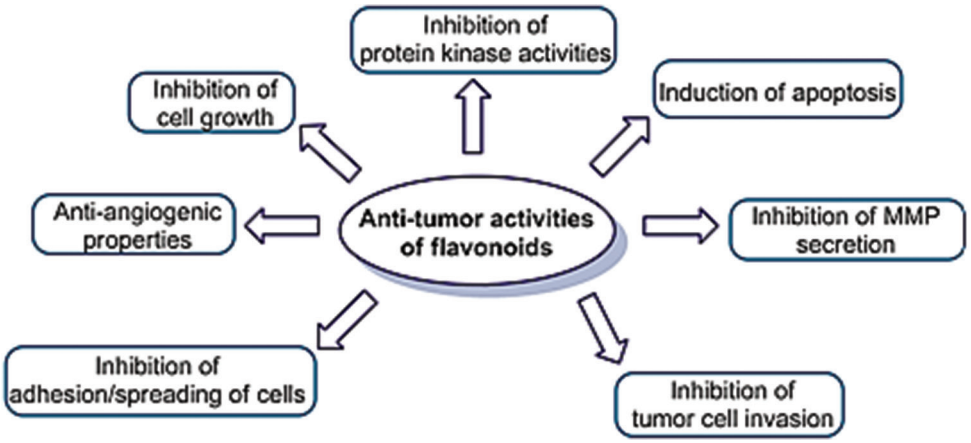

Fig. 4: Anti-tumor activities of flavonoids

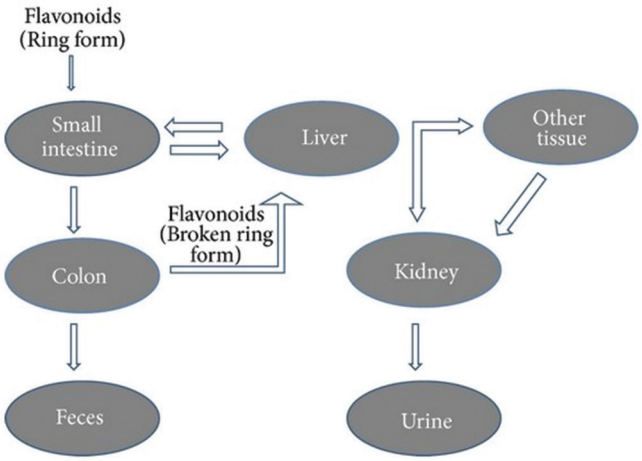

Fig. 5: Metabolism of flavonoids

contributing to their diverse and potentially beneficial effects on human health [51].

Patent on flavonoids

Patents related to flavonoids cover a broad spectrum of innovations, ranging from their extraction and isolation methods to their applications in various industries. For example, a patent might be granted for a novel process of extracting flavonoids from specific plant sources, optimizing yield and purity. These patents often detail unique techniques, such as innovative extraction solvents or equipment, aimed at improving the efficiency of flavonoid isolation.

In addition, patents may focus on the formulation of flavonoids for pharmaceutical, nutraceutical, or cosmetic purposes. Companies and researchers seek protection for specific compositions that enhance the stability, bioavailability, or targeted delivery of flavonoids. This could involve encapsulation methods, combination with other bioactive compounds, or unique formulations to improve the overall efficacy of flavonoid-based products [52].

In the pharmaceutical sector, patents may cover the use of flavonoids for treating specific medical conditions. These could include neuroprotective effects, anti-cancer properties, or applications in cardiovascular health. The patent documentation typically includes detailed descriptions of pre-clinical and clinical data supporting the therapeutic efficacy of flavonoids for the specified conditions.

It is important to note that the patent landscape is continually evolving as new research emerges. As of my last knowledge update in January 2022, the specifics of flavonoid patents would require current search results to provide the most accurate and up-to-date information. Researchers, pharmaceutical companies, and food industries actively

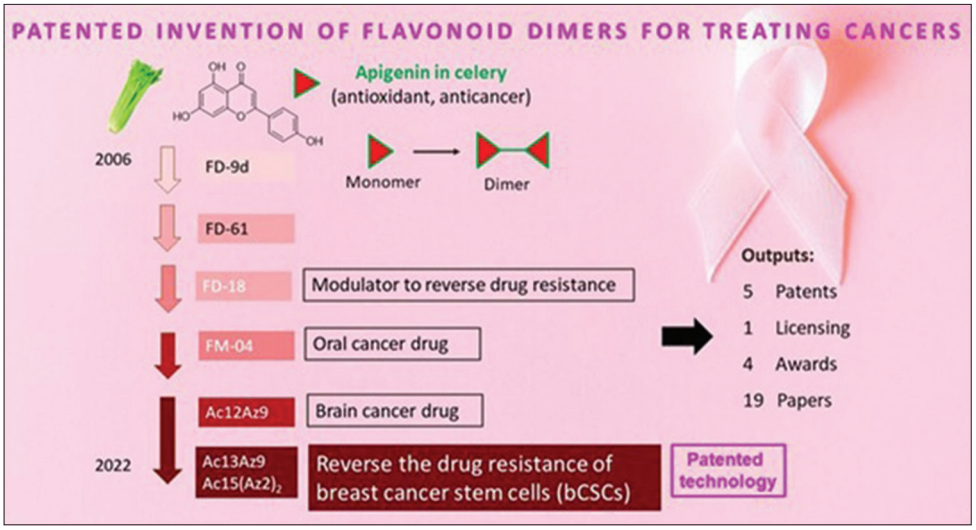

Fig. 6: Patented inventions of flavonoids in cancer treatment

Table 1: Plant family on their flavonoid

Plant (Family)	Representative flavonoids
Aloe vera (Asphoelaceae)	Luteolin
Acalyphaindica (Euphorbiaceae)	Kaempferol
Azadirachtaindica (Meliaceae)	Quercetin
Betulapendula (Betulaceae)	Quercetin
Buteamonodpermea (Fabaceae)	Genistein
Cannabis sativa (Compositae)	Quercetin
Citrus medica (Rutaceae)	Hesperetin
Glycyrrhizaglabra (Leguminosae)	Liquitrin
Menthalongifolia (Lamiaceae)	Luteolin
Mimosa pudica (Minosoideae)	Isoquercetin
Oroxylumindicum (Bignoniaceaea)	Chrysin

engage in patenting to protect their innovations and commercial interests related to flavonoids [26].

Immune pharmacological properties of flavonoids

Flavonoids are a broad class of polyphenolic chemicals that are widely distributed in fruits, vegetables, tea, and other beverages. Their immunological pharmacological qualities have drawn a lot of interest. Primarily recognized for their potent antioxidant capabilities, flavonoids scavenge free radicals and mitigate oxidative stress, thus fortifying immune cells against damage. Moreover, these compounds exhibit pronounced regulating important mechanisms of inflammation to produce anti-inflammatory actions, restraining the release of pro-inflammatory cytokines and enzymes. Beyond their anti-inflammatory action, flavonoids act as immunomodulatory substances by altering the immune cells and signalling pathways to fine tune the immune responses. They influence the activation and function of macrophages, T cells, and B cells, contributing to a balanced immune system. Some flavonoids showcase antiviral activities by impeding viral replication, bolstering the body's defense against infections. In addition, these compounds can stimulate antibody production by B cells, enhancing the adaptive immune response. The regulation of immune signaling pathways, interaction with gut microbiota, and potential anti-cancer properties further underscore flavonoids' multifaceted impact on immune health. While promising, ongoing research aims to elucidate specific mechanisms and optimal dosages for leveraging flavonoids in immune-related therapeutic strategies [27].

FLAVONOIDS IN SKIN DISEASES (PSORIASIS)

Psoriasis is a persistent chronic skin inflammation disorder with a prevalence rate of 125 million or 2–3% of the world population. Inflammation and uncontrolled proliferation of keratinocytes are the major symptoms [28,53-56]. The current treatment available for psoriasis is high in cost and causes several adverse effects. In psoriasis treatment drugs may play a key role, due to long-term utilization and development of resistance to the desired action. Plant products such as flavonoids have lesser side effects and low-cost natural compounds [57-62].

Several compounds related to flavonoids are reported in the treatment of psoriasis but not as such. Regular intake of these plant products is already reported by maintaining a sufficient quantity of this product we can manage the oxidative stress. This is the major reason for causing several autoimmune and inflammatory disorders [63-66].

Compounds such as quercetin, naringenin, apigenin, Grinstein, luteolin, and delphinidin are reported in psoriasis treatment because of their anti-inflammatory, anti-oxidative and anti-proliferative activity [67,68].

FLAVONOIDS IN NEURODEGENERATIVE DISORDERS

When neurons are affected by any pathological condition of the human body, it is implicated as a neurodegenerative disorder [69-72]. Disorders are named after without any causative organism to treat that particular disease. Neurological dysfunctions are the implications of this disorder. Some of the diseases are genetical implications to comply with the symptoms. Plant products are secondary metabolites of the plant and they are not required by the plants. A higher intake of flavonoids may reduce the risk of Parkinson's disease [73-78]. These diseases are majorly caused by age-related factors and toxic pathways which are controlled by the flavonoids [79,80].

IMPLICATIONS FOR THE FUTURE

Over the past 10 years, flavonoids have drawn a lot of interest from researchers and a number of their possible advantages have been clarified. Nevertheless, as the majority of the study included *in vitro* experiments, it is challenging to make firm judgments regarding the nutritional value of flavonoids [81-84].

Due to the lack of information on bioavailability and the variety of the many molecular structures, the research of flavonoids is complicated. In addition, there are currently insufficient techniques for quantifying oxidative damage *in vivo*, and measuring objective endpoints is still challenging. To enable the collection of further information on the long-term consequences of consuming flavonoids on excretion and absorption and are particularly limited – better analytical techniques are required [85,86]. As above mentioned, flavonoids are the primary food source of human beings in their food such as veggies and tea. It

will play a key role in immune-related disorders and neurodegenerative disorders. By applying the nanotechnology principles, the formulators can deliver the flavonoids in a targeted drug delivery form [87,88].

The current stressful lifestyle is caused by their regular working styles and sedentary lifestyles. The generation of oxygen free radicals causes damage to the cells involved in the major functions. Hydroxyl groups present in the flavonoids have the capacity to hold the radicals which are leading to stress conditions. Flavonoids have shown the potential to treat pregnancy-induced disorders [89-92]. Anti-allergic nature of flavonoids used as alternative medicine in the coming future [93]. These plant products have applications in the management of obesity and infectious diseases [94]. Cytokine production in the cascade of inflammatory conditions plays a key role in the propagation of the signaling mechanism [95-101].

As per the present study, flavonoids are versatile compounds to overcome the disease caused by stress. However, the major problem occurred with the efficacy and bioavailability of the flavonoids at the site of action. To overcome these issues the formulators, need to explore the various targeted drug delivery systems to increase the accumulation of active compounds at the site of action.

CONCLUSION

Flavonoids, abundant in fruits, vegetables, and beverages such as tea showcase a diverse array of bioactive properties. Their antioxidant, anti-inflammatory, and potential anticancer effects contribute to the growing interest in their health benefits. While research continues to unveil their intricate mechanisms and therapeutic potential, incorporating flavonoid-rich foods into a balanced diet remains a prudent choice for overall well-being. The patent for flavonoids represents a significant advancement in the field of pharmaceuticals and nutrition. With their diverse biological activities and potential health benefits, flavonoids hold promise for various applications, ranging from medicinal treatments to dietary supplements. This patent not only protects the innovative aspects of utilizing flavonoids but also opens avenues for further research and development in harnessing their therapeutic properties. Overall, the flavonoid patent stands as a valuable contribution to science and technology with the potential to positively impact human health and well-being.

CONFLICTS OF INTEREST

The authors declare no conflicts of interest.

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