Review Article

An Overview of a Versatile Compound: Quercetin

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ABSTRACT

Flavonoids are phytochemical compounds found in a variety of plants, fruits, vegetables, leaves, and barks, it offers a wide range of health benefits. Quercetin is a polyphenolic flavonoid that is found in onions, apples, berries, broccoli, grapes, nuts, cherries and many other food products. Pharmacologically, quercetin has been examined for various disorders and is reported to possess the ability to prevent as well as treat them. It possesses anti-oxidant, anti-allergic, anti-inflammatory, anti-viral and anti-cancer activity as well. Developing suitable formulation for the delivery of quercetin to specific site leads to better compliance and effective treatment of the disease. This review article highlights the beneficiary activities exhibited by quercetin along with the mechanism behind its activity, followed by reporting the different quercetin formulations developed in last few years.

Keywords: Flavonoid, Classification, Quercetin, Potent activities, Formulations.

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INTRODUCTION

Flavonoids are a varying group of phytonutrients (natural substances) that consists of variable phenolic structure, found in fruits, vegetables, stem, bark roots, flowers, tea, grains and wines. Natural products are found to show useful effect on health, prior to the period when flavonoids were segregated for its activities. More than 4000 varieties of flavonoids are found to show colours of flowers, fruits and leaves. Flavonoids comprising more than 8000 compounds exist today.[1,2]

Flavonoids are correlated with a broad range of health promising effects and are necessary component in variety of pharmaceutical, nutraceuticals, medicinal and cosmetic applications. This is observed because of their multidisciplinary activities such as anti-mutagenic, anti-allergic, anti-oxidative, anti-inflammatory, anti-carcinogenic properties combined with their ability to modulate key cellular enzyme functions.[3,4]

Quercetin is an important bioflavonoid present in our daily diet, it manifests a broad range of biological activities and also therapeutic applications that are of interest in the field of pharmaceutical, cosmetic and food industries.[5] The name quercetin was derived from the term quercetum (after Quercus- oak) and is in use since 1857.[6]

The approximate daily intake of quercetin is in between 5-40mg. After the absorption, quercetin is metabolized in intestine and liver. Normally quercetin concentration in the plasma is around nanomolar but can reach to micromolar range when quercetin rich foods are consumed.[7] Quercetin generally occurs as glycosides, ethers and sulphates, the glycosylation of quercetin increases its hydrophilicity, stability, and bioavailability.

It is the most widely found flavonoid through food sources like onions, broccoli, berries, grapes, capers, shallots, tomatoes, cherries, nuts, seeds, various citrus fruits and wine as illustrated in **figure 1.**[8]

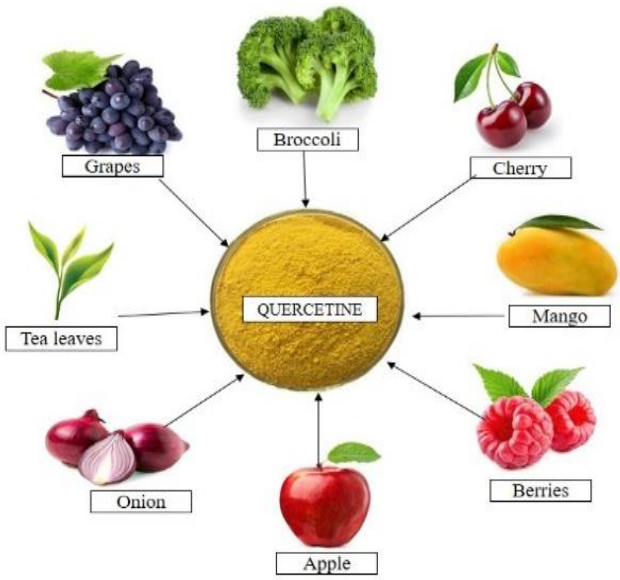

Figure 1: Sources of Quercetin

Chemistry of Quercetin

Quercetin ($C_{15}H_{10}O_7$) is a flavanol, which is one of the subclass from six subclasses of flavonoid compounds. The subclasses are given in **figure 2** [9,10]

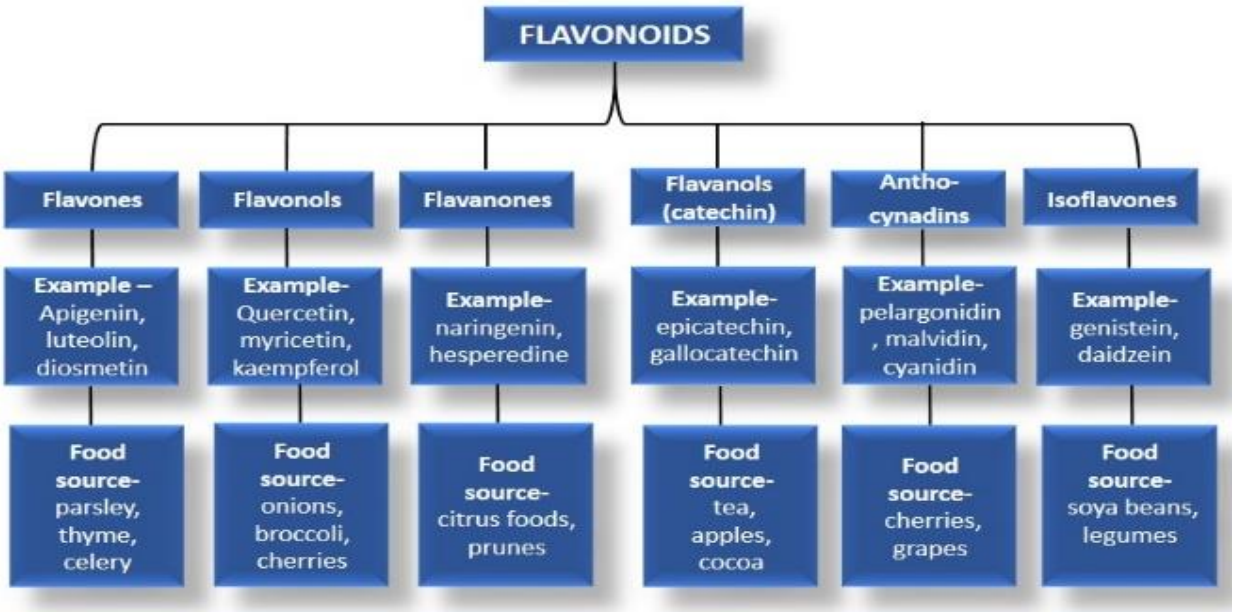

Figure 2: Subclasses of Flavonoid[10]

Flavonoids, a massive family of plant compounds, provide hydroxyl groups (-OH) bound to a three-ring molecule, similar to flavone. The basic structure has two aromatic rings, A and B, as well as a heterocyclic ring, 3-carbon chain C, that connects two rings.[11]

Quercetin is recognized as 3,3′,4′,5,7-pentahydroxyflavone by the International Union of Pure and Applied Chemistry (IUPAC) and has the synonym 3,3′,4′,5,7-pentahydroxy-2-phenylchromen-4-one.[12] Quercetin is a citron yellow flavonoid that seems to be insoluble in cold water, though somewhat soluble in hot water, and highly soluble in alcohol.[13]

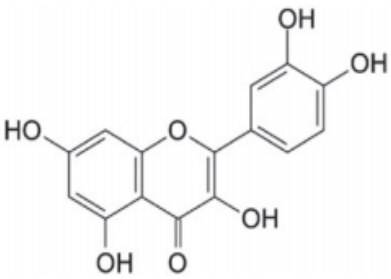

Figure 3: Chemical Structure of Quercetin

POTENT ACTIVITIES OF QUERCETIN

Quercetin is one of the most thoroughly studied flavonoid that show several pharmacological activities such as anti-allergic, anti- bacterial, anti-oxidant, anti-viral, anti-inflammatory, and anti-carcinogenic properties.[14-16]

Anti-allergic activity

Allergic diseases are expanding from last few decades all over the world. There are different reasons for the cause of these diseases such as change in environmental factors, infections, air pollution etc. For major allergic disease, dietary polyphenols are one of the natural therapies which are frequently studied and used in regard of food allergy, atopic eczema, and asthma. Therefore, the main focus is towards the different compounds which possess anti-allergic properties such as flavonoids, like quercetin. It has been shown to have anti-allergic effects in the treatment of respiratory and food allergies.[17]

Flavonols like quercetin and kaempferol are most abundant aglycones present in tea and generally exist in their glycoside form. They can inhibit the FcεRI receptor by reducing the phosphorylation of various kinases such as spleen tyrosine kinase (Syk), protein kinase C (PKC), and p38 mitogen-activated protein kinase in basophils and mast cells (MAPK).[18] It has been reported that quercetin inhibits the release of histamine and proinflammatory mediators such as tumour necrosis factor–a, interleukin (IL)-1, IL-6 and IL-8 and it suppresses the intracellular calcium influx and protein kinase Cs signalling. Ultimately from this, it can be concluded that quercetin exhibits anti-allergic property in vivo.[19]

Polyphenols may modulate allergic sensitization by interacting with proteins, and its direct impact on allergic cells like mast cells may hinder mediator release, leading in symptom relief. Quercetin prevents the activation of human mast cells by blocking calcium influx, leukotrienes, histamine, prostaglandin release, and proteinkinase activation. As a result, quercetin is efficacious in the treatment of allergic inflammatory disorders caused by mast cells, such as sinusitis, asthma, and arthritis.[17,20] The topical activity and intravenous dosing of quercetin in mouse model was studied for anti-allergic activity and also inflammatory activity which showed positive effect.[21]

Quercetin also inhibits the synthesis and activation of histamine and other allergic and inflammatory chemicals, possibly by stabilising mast cell membranes. Quercetin is already suggested as a possible anti-inflammatory treatment for gout. Gout is one of the common

inflammatory issue in the society, it is caused by the buildup of uric acid crystals in the joints. This can also be cured with the aid of quercetin.

Anti-inflammatory activity

Quercetin inhibits the formation of prostaglandins, leukotrienes and histamine release. This is supportive for asthmatic conditions, as leukotriene B4 is a potent bronchoconstrictor. Chronic inflammatory conditions such as chronic prostatitis and interstitial cystitis can be improved with oral supplementation of quercetin. Anti-inflammatory activity of quercetin is been studied through in vivo animal experiments. The inflammatory reaction caused by carrageenan and a high-fat diet is improved by quercetin.

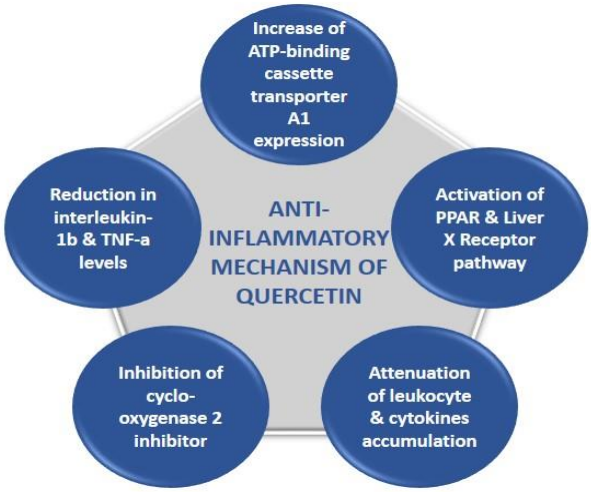

Figure 4: Anti-inflammatory mechanism of quercetin [22]

Mast cells are potent immune system cells that play a major role in allergic reactions and autoimmune diseases. They also have an effect on the release of inflammatory cytokines including IL-8 and necrosis factors (TNF). As a consequence, quercetin is used to treat allergic inflammatory disorders caused by mast cells, such as sinusitis, asthma, and rheumatoid arthritis. [23]

Quercetin also has anti-inflammatory properties, which are attributed to the inhibition of enzymes like lipoxygenase and inflammatory mediators. It affects immunity and inflammation by acting specifically on leukocytes and targeting a variety of intracellular signalling kinases and phosphatases, enzymes, and membrane proteins that are frequently required for cellular function. [24]

Quercetin also holds back the production and the release of histamine and other allergic and inflammatory substances, perhaps by stabilizing the cell membranes of mast cells.[25] Quercetin is considered as potential anti –inflammatory agent for treating gout. It is familiar that gout represents one of the inflammatory problems in the society. Gout is caused by the accumulation of uric acid crystals or their monosodium salts in human joints. Xanthine oxidase is an enzyme that catalyses the sequential hydroxylation of hypoxanthine to uric acid using xanthine as an intermediate. Its inhibition can help assess the severity of gout-related inflammation.[26]

Antioxidant and inhibitory effects of quercetin are responsible for its anti- inflammation activity. It inhibits cyclooxygenase and lipoxygenase enzymes, which in turn inhibits inflammatory mediators including prostaglandins and leukotrienes. TNF, a cytokine that regulates leucocyte formation, proliferation, and differentiation, is also inhibited. According to Bidian et al, quercetin administration has a superior and beneficial impact in the lungs for a short time.[27]

ASTHMA- Asthma is a common chronic condition characterised by mucosal inflammation, bronchial hyperresponsiveness, nasal obstruction, and mucus production. In the initiation and progression of asthma, oxidative damage and other harmful factors of the respiratory tract play a significant role. Antioxidants have been found to be effective in reducing asthma disease process by preventing oxidative damage through several mechanisms.

The administration of quercetin is shown to have a beneficial effect on asthma incidence, with increased quercetin intake reducing asthma incidence. According to several epidemiological studies, increasing flavonoid intake is beneficial for asthma.[28,29] Flavonoids have a stronger effect on asthma symptoms in clinical trials.[30] Willers et al. from the Netherlands found that eating apples during pregnancy has a protective effect against the development of asthma and allergic diseases in children.[31]

Quercetin and iso-quercetin both decreases the inflammation caused in murine model of asthma. The results observed has shown that they possess potential for the treatment of allergic diseases and asthma. As a consequence, these two can accompany the progress of effective anti-asthma therapy or can be a mode of identification of novel anti-asthma targets.[32] Quercetin has the ability to control the T helper type 1/ T helper type 2 balance. It was emphasized by Rogerio et al. that quercetin could play a key role in the treatment of respiratory inflammatory diseases like asthma.[33]

RHEUMATOID ARTHRITIS- Rheumatoid arthritis is an autoimmune disease, identified by hyperplasia in the synovial membrane, formation of pannus, infilteration of inflammatory cells and destruction of articular cartilage and bone matrix. Anti-inflammatory agents play an important role in rheumatoid diseases. The in vitro and in vivo animal studies have shown that quercetin can exhibit occurrence and development of inflammation, thus possessing a potent inhibitor for rheumatoid arthritis. [34]

In obese zucker rats, it lowers TNF-a and nitric oxide production in visceral adipose tissue, as well as NOS expression. Quercetin reduced the clinical symptoms of arthritis in chronic rat adjuvant induced arthritis as compared to untreated controls. [35]

It has been studied that anti-inflammatory and joint protective property of quercetin by using C57BL/6 CIA animal model and have reported that quercetin produce better results in comparison to methotrexate for joints protection against arthritic inflammation in mice. Quercetin can relief the arthritis and swelling of paw in CIA mice. It can also lower the impression of inflammatory factors and matrix metalloproteinases in arthritis fibroblast (synoviocytes) [36]

The beneficial and obstructive properties of quercetin in arthritis has been reported by giving quercetin through oral route to rats. Decrease in the clinical signs and symptoms were observed when compared to untreated controls. As a consequence, we can conclude that quercetin lowered the level of interleukin 1b monocyte chemoprotein-1 and also regained the capacity of plasma antioxidant. [37,38]

Anti-oxidant activity

Quercetin is a phenolic compound which possess great antioxidant property. Its flavonoid structure shows radical scavenging. Thus, quercetin possess a structure that is responsible for higher antioxidant activity more than the structure of anthocyanins.[39]

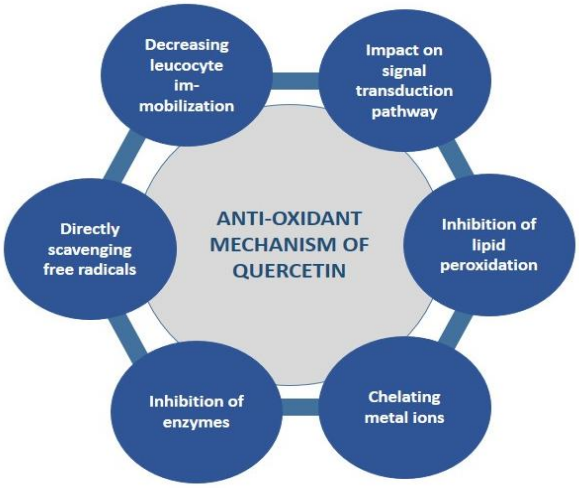

Figure 5: Anti-oxidant mechanism of Quercetin[40]

Quercetin has aglycone flavonoid which have 3-OH groups and are potent inhibitors of the lipid oxidation. Quercetin inhibits the oxidation chain in termination step and thus it prevents the propagation of chain. Quercetin shows antioxidant property because of the catechol group in the ring and also the OH group in the 3rd position of the AC ring. [17,41] Quercetin is an effective flavonoid that prevents the body from reactive oxygen species.

Quercetin has been discovered to take an active part in scavenging free radicals that can damage DNA and cell membranes, resulting in cell death. Quercetin has indeed been linked to a reduction in the synthesis and release of histamine and other mediators involved in allergic reactions.[42] It was reported that quercetin's methylated metabolites have significant antioxidant property in comparision to quercetin alone. Quercetin exhibit antioxidant activity as it can scavenge the reactive oxygen species. [43,44]

Quercetin is an antioxidant that prevents the development of a fibrils and reduces oxidative stress. Polysorbate 80 and quercetin were combined to create nanocomposites with high aqueous solubility and excellent radical scavenging activity.[45] The antioxidant properties of quercetin and the quercetin-DNA complex have been investigated both theoretically and experimentally for their ability to scavenge free radicals. In comparison to quercetin alone, the quercetin-DNA complex showed higher antioxidant activity.[46]

Quercetin is a powerful natural compound that is used to treat skin conditions caused by oxidative, inflammatory, or other factors. Quercetin nanocrystals were created and demonstrated the potential to inhibit the oxidative impact of hydrogen peroxide on cells, indicating that they could be used to treat skin disorders. [47]

Anti- viral activity

Quercetin exhibits anti-viral activity and this is because of its potential to bind the viral protein and interfere with the viral nucleic acid synthesis. As methyl quercetin was observed to block the polio virus replication by interfering with the single- stranded RNA replicative intermediate in association with a block in cellular protein synthesis. [48] Chiang et al. found that the aqueous extract of C. pulcherrima, as well as its associated quercetin, has broad antiviral activity against herpesviruses (HSV-1, HSV-2) and adenoviruses (ADV-3, ADV-8, ADV-11).[49] Porcine epidemic diarrhoea virus (PEDV) is the primary cause of major entero-pathogenic diarrhoea in swine. It is found that quercetin, apigenin, luteolin and catechin show moderate anti-PEDV activity by inhibiting the PEDV replication. [50]

Influenza virus are important pathogens that give rise to respiratory infections in humans and animals. Polyphenols derived from plant are connected with antioxidant activity, neuroprotective, cardioprotective activity and anticarcinogenic activity. Some of the polyphenols like resveratrol and epigallocatechin gallate show remarkable anti-influenza activity in vivo and in vitro. Quercetin and iso-quercetin are found to show antiviral effect as they reduced the duplication of influenza viruses. The antiviral effect of iso-quercetin was found to be more in comparison to quercetin. [51] Quercetin inhibits hepatitis C virus replication by preventing viral genome translation through the NS5A-driven internal ribosomal entry site.[52]

Mayaro fever is caused by the arthropod-borne Mayaro virus (MAYV), which is a medically significant disease that mostly affects people who are in constant contact with forested areas in South America. It was discovered that quercetin has a high antioxidant ability. [53] The in silico and in vitro anti influenza effect study for quercetin derivatives were done by targeting PB2 subunit viral RNA polymerase. Total 410 compounds were tested for in silico study by virtual screening, five quercetin derivatives were selected as possible drug targeting employ in vitro inhibition of

influenza virus strains A and B. Thus, quercetin derivatives can be highly affordable and easily available drug candidate as anti-influenza inhibitor. [54]

Quercetin and other flavanols have shown to be effective against influenza virus infection as well as SARS-CoV-2, a human corona virus. In silico and computational studies have shown that a variety of natural products and phenolic compounds are effective against SARS-CoV-2, with quercetin being one of the most effective compounds. Quercetin binds to the virus's spike protein receptor and has a higher potency than hydroxychloroquine. [55-57]

Cardioprotective activity

Quercetin possesses advantageous effects on cardiovascular diseases such as atherosclerosis, hypertension, ischemia-reperfusion injury, cardiotoxicity which are associated with anti-oxidant and anti-inflammatory effects. [58-59] The protective mechanism that quercetin shows for cardiovascular system are given in **figure 6.** [60]

Figure 6: Mechanism of quercetin on cardiovascular system

Quercetin possess anti-inflammatory properties that help it to reduce cardiovascular disease. In vitro experiments on isolated rat arteries have shown that quercetin aglycon acts as a vasodilator. In a study, it is reported that mortality occurring due to heart related disease decreases with the increase in consumption of quercetin.[61] Edward et al reported that patients with stage 1 hypertension, who have consumed 730mg quercetin daily for 28 days, showed decrease in systolic, diastolic and also mean arterial pressure. [62] Quercetin can lower the blood pressure by lowering the oxidative stress and improving the renin angiotensin- aldosterone system (RAAS), and also improving the vascular function. [63]

Consumption of quercetin in small quantity, protects from coronary heart disease that is caused due to oxidized low-density lipoproteins. Quercetin also shows antiplatelet effect by inhibiting the thromboxane A2. Antihypertensive effect is due to the decrease of oxidative stress by inhibition of superoxide generating enzymes or direct superoxide anion scavenger effect. Quercetin conjugate mainly -glucuronide tends to shows protective effect on smooth muscles. Flavanols reduces cardiovascular risk by their vasodilator mechanism and antihypertensive effect. Cardiovascular diseases are one of the major causes of death worldwide. [64]

Serban et. al has reported that quercetin when taken at the dose of 500mg/day and above it shows significant anti-hypertensive effect.[65] In the regulation of blood pressure, cardiac output, blood volume, angiotensin system and nervous system plays a vital role. [66] Quercetin shows inhibiting effect on LDL oxidation and endothelium dependent vasodilation and it reduces the effect of adhesion molecules and other inflammation markers. [67] Wei et al has demonstrated that quercetin has the capability for treating heart diseases as it reduces the LPS-induced cardiac abnormalities in mice. [68]

Quercetin lowers the excess production of ROS, and damage caused by trauma, it also improves TNF- α, prevents the myocardial cell injury caused due to Ca2+ overload. Therefore, quercetin have the potential to prevent the injury caused by oxidative stress. [69]

Anti-cancer activity

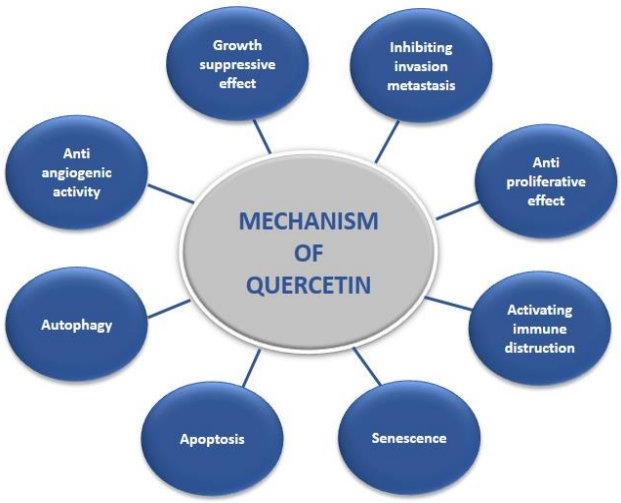

Figure 7: Mechanism of quercerin for Anti-cancer activity[70]

Quercetin is considered as a paradigm of naturally occuring chemopreventive agent because of its biological activities like antioxidant, anti-proliferative, anti-inflammatory, pro-apoptotic and anti-angiogenic. It may lead through all the stages of carcinogenesis from activation to initiation and metastasis and act on different biological, genetic and immunological aspects that aid the development and maintenance of tumours. Quercetin is likely to interact with the various targets known as "hallmarks of cancer," acting as a multi-target inhibitor with pleiotropic and synergistic effects in tumour cells when combined with many other phytochemicals.

The anti-proliferative activities of quercetin, as well as its potential apoptosis and antioxidant properties, can all impact the formation of cancer-related diseases. Quercetin effectively treats cancer by stimulating cell death or arrest of cell cycle in cancer cells over normal cells via a process involving the downregulation of selective oncogenes or the upregulation of tumour suppressor genes, both of which improve the selective pathways leading to cancer cell removal. [71]

Since quercetin can inhibit cell proliferation and angiogenesis while also inducing apoptosis and cellular senescence, quercetin has been considered a potential anticancer agent. [72]

Quercetin can activate cancer cell death and cell cycle progression by downregulating oncogenesis genes such as Mc1, Bcl-2, Ras, MEK, and PI3K, or upregulating tumour suppressor genes such as p53 and p21. [73,74] Quercetin blocks the spread of several cancers like liver, colon, prostate, lung, cervical and breast cancers.

Quercetin was studied for its in vivo antioxidant activity in contrast with the carcinogen and testosterone, by estimating the histology and oxidative stress markers, eg. Reduced glutathione, hydrogen peroxide and lipid peroxidation in rats. In contrast to quercetin-treated rats, carcinogen-and-testosterone-treated rats had greater levels of LPO and H2O2 and lower levels of GSH. [75]

Breast Cancer - Quercetin has anti-carcinogenic properties. Upregulation of Connexin 43, whose expression is inversely associated with tumour aggressiveness, was reported to control cell proliferation in MDA-MB-231 human breast cancer cells in a sample. Quercetin also inhibited the growth of MCF-7 breast cancer cells and downregulated the expression of surviving, which is highly expressed in most cancers. [76] Breast cancer is most common cancers in women. Quercetin, a dietary supplement, may be used as a complementary or alternative medicine in the treatment of breast cancer. [77]

Prostate Cancer – Apoptosis is created by quercetin in a human prostate cell line (LNCaP). Prostate cancer has been related to urokinase-type plasminogen activators.[78] Quercetin reduces the production of MMP-2, MMP-9, EGF,-catenin, and NF-KB, which prevents prostate cancer cell proliferation, migration, and invasion.[79] In a prostate cancer inducing rat model, quercetin substantially reversed the decrease in superoxide dismutase (SOD), catalase (CAT), and GPx activates, as well as the rise in Akt phosphorylation.[80]

Colorectal Cancer - Quercetin shows multiple chemopreventive effects on colorectal cancer such as cell cycle arrest, antioxidant replication, regulation of signalling pathways, increase in apoptosis, modulation of estrogenic receptors, inhibition and metastasis and angiogenesis. [81] In colorectal carcinogenesis, activation of β-catenin/Tcf signalling plays a major role. As quercetin shows the property to inhibit cell proliferation by supressing the β-catenin/Tcf signalling and surviving expression in SW480 colon cancer cells.[81] Quercetin is also demonstrated to suppress the cell proliferation in HT-29 colon cancer cells, as it activates AMPK and lowers the expression of COX-2. [82]

Quercetin inhibits the cell viability of colon 26 (CT26) and colon 38 (MC38) cells and induces apoptosis by mitogen-activated protein kinases pathway in colon 26 cells. This indicates that quercetin can be a powerful therapeutic agent for the treatment of metastatic colorectal cancer. [83,84] The in vitro study of quercetin was done and was found to be capable of improving the efficacy of irinotecan metabolite, the in vivo study was done in combination with irinotecan and it was concluded that when quercetin is combined with low dose of antitumor drug shows greater inhibitory effect on progression of gastric cancer cells. [85]

Lung Cancer - Quercetin induces apoptosis in A549 lung cancer cells by activating capase-3, cleavage of PARP, activation of ERK and phosphorylation. [86] Mice treated with benzo(a)pyrene are used as an in vivo model to study the chemopreventive activity of quercetin for lung cancer. Pre-treatment with quercetin protected against induced cytotoxicity by increasing the activity of antioxidants. [87]

Skin Cancer - Quercetin reduces chromosomal aberration in skin carcinogenesis induced in mouse. Similarly, quercetin treatment inhibited the DMBA-TPA-induced tumour formation in the BK5.IGF-1 transgenic mouse model for skin carcinogenesis and it suppresseds activation of IGF-1 signalling (Jung et al., 2013). [88]

Ali et al., have evaluated the chemopreventive activity of quercetin for skin cancer in swiss albino mouse model. It was reported that quercetin reduced the size of tumour and also lowered the serum glutamate oxidase transaminase, alkaline phosphate, bilirubin and thus possess chemopreventive effect on 7,12-dimethyl benz (a) anthracene and croton oil induced skin cancer in mice by increasing the antioxidant activities. [89]

Esophageal Cancer - Esophageal cancer is considered to be one of the commonest cause of cancer-related death worldwide. Despite advancements in esophageal cancer care, existing procedures are still unsuccessful. Quercetin can be an effective supplement in the detection, prevention, and maintenance of esophageal cancer due to its natural origin and low cost relative to synthetic cancer drugs.

While quercetin has anti-esophageal cancer properties, the function of quercetin's proapoptotic properties in the therapy of esophageal cancer is unknown. [90]

One of the analogues of quercetin, quercetin-3-methyl ether (Q3ME), can inhibit the stimulation of AKT and ERKs. Furthermore, activating protein-1 (AP-1) can be suppressed in esophageal preneoplastic lesions as a consequence of Q3ME therapy, which may suppress cell growth and inflammation levels in vivo. [91]

The effects of quercetin, 5-FU, and a mixture of these two components on the EC9706 and Eca109 cell lines were studied by Chuang-xin et al. treatment with quercetin, 5-FU,

and a combination of quercetin and 5-FU caused apoptosis of the cancer cells. However, because of quercetin's inhibitory effect on the NF-B activation pathway, the apoptotic effects on cancer cells were greater in the combination treatment than in the two other treatments. [92]

DIFFERENT FORMULATIONS OF QUERCETIN FOR THE TREATMENT OF DISEASES

As quercetin exhibit several pharmacological activities, developing its appropriate formulation will lead to ease in drug delivery to the desired site. Some of the quercetin formulations developed in last few years are reported in **table 1**.

Table 1: Formulations developed for the treatment of specific diseases

Formulation	Disease	Year / Reference
Quercetin Nanoliposomes	Rheumatoid arthritis	(2016) [93]
Quercetin Freeze-dried polymeric micelles	Glioma chemotherapy	(2016) [94]
quercetin nanocomposite (CPQN)	Oxidative stress related diseases	(2017) [95]
Quercetin Zein nanoparticles	Alziehmeir disease	(2017) [96]
Quercetin -loaded liposomes	Oxidative stress related disease	(2017) [97]
Quercetin Lipid nanocapsules	Skin inflammatory disorder and Psoriasis	(2018) [98]
Nanoparticles	Colorectal cancer	(2019) [99]
Quercetin loaded liquid crystalline nanoparticles (LCN) and surface modified liquid crystalline nanoparticles (sm-LCN)	Asthma	(2019) [100]
Quercetin Nanoparticles	Rheumatoid arthritis	(2019) [101]
Quercetin loaded TiO_2 nanotubes	Arthritis	(2020) [102]
Quercetin nanoparticles	Wound healing	(2020) [103]
Quercetin Polymeric niosomes	Inflammation	(2021) [104]
Quercetin nanoemulsion	Diabetic-induced Cardiotoxicity	(2021) [105]

CONCLUSION

Quercetin is a polyphenolic flavonoid evaluated by different researchers for its ability to prevent and treat several diseases. It possesses a lot of beneficiary effects on human health and thus can be considered as a multidisciplinary compound. It is obtained from several plant sources. Quercetin shows therapeutic activities such as anti-oxidant, anti-inflammatory, anti-allergic, anti-viral, cardio-protective and anti-cancer activity etc. The mechanism behind their activities is explained in this article. Researchers have also developed several formulations of quercetin like liquid crystalline nanoparticles, niosomes, micelles, liposomes and nanocomposites etc. in recent years for treating several diseases. Thus quercetin can be regarded as a multi-faceted compound for curing several diseases.

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