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Pharmacological effects of compounds of plant-derived compounds in chronic diseases

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Abstract:

Plant-derived compounds demonstrate significant potential in the prevention and treatment of chronic diseases due to their rich bioactivity and diverse pharmacological effects. Common active constituents include flavonoids, polyphenols, alkaloids, and terpenoids, which exert therapeutic effects through mechanisms such as antioxidant, anti-inflammatory, antitumour, and immunomodulatory actions. Research indicates that plant-derived compounds not only improve insulin sensitivity and regulate blood glucose levels in diabetic patients but also offer effective interventions for cardiovascular diseases, cancers, and neurodegenerative disorders. Compared to conventional pharmaceuticals, their multi-targeted action, low toxicity, and minimal side effects offer new possibilities for personalised treatment. However, their efficacy requires validation through large-scale clinical trials. Future efforts should focus on enhancing mechanism research, improving bioavailability, and advancing the application of big data and artificial intelligence in drug development to achieve precision medicine and clinical translation. Further exploration of interdisciplinary collaboration will offer novel approaches to chronic disease prevention and control. Concurrently, the development and utilisation of plant-derived compounds will play a significant role within sustainable healthcare systems.

Keywords: Plant-derived compounds; Chronic disease therapy; Pharmacological mechanisms.

1. Introduction

Natural plant products have long constituted a vital source for drug discovery and development. As one of humanity‘s earliest utilised medicinal resources, plant-derived compounds boast a long history of research and application, demonstrating significant therapeutic potential and broad biological activity. In modern medicine, numerous commonly used clinical drugs are either directly sourced from plants or de-

rived and modified from them. For instance, morphine is employed to alleviate severe pain and improve patients' depressed mood states; aspirin not only inhibits platelet aggregation but also treats rheumatism and alleviates joint pain; artemisinin has been successfully employed against malaria, saving millions of lives; and vinca alkaloids (such as vincristine and its derivatives) have become vital anti-cancer therapeutics. These examples fully demonstrate the irreplaceable value of plant products within the modern medical system. Plant-derived compounds (PD compounds) typically exhibit diverse pharmacological actions, encompassing anti-inflammatory, anti-tumour, antioxidant, and anti-infective functions. This study focuses on clinically prevalent representative drugs and certain highly targeted natural compounds, exploring how they exert therapeutic effects by binding to specific molecular targets (such as enzymes, receptors, and signalling pathways). For instance, paclitaxel binds to tubulin and inhibits cell division, playing a pivotal role in cancer treatment [1]; whereas curcumin achieves antitumour and anti-inflammatory effects by inhibiting signalling pathways such as MAPK and PI3K/AKT [2].

Existing research indicates that plant-derived compounds have an exceptionally broad range of applications, with increasingly systematic screening and testing methodologies being developed. For instance, the authoritative platform MedChemExpress (MCE) not only provides compound libraries but also offers services such as high-throughput screening (HTS) and high-content screening (HCS) for evaluating the biological activity of drug candidates. With rapid advances in molecular biology and pharmacology, substantial evidence indicates that plant-derived bioactive compounds play an irreplaceable role in the prevention and treatment of chronic diseases.

In diabetes management, certain plant-derived compounds can improve metabolic abnormalities by enhancing insulin sensitivity, promoting glucose transport, and inhibiting gluconeogenesis, thereby effectively controlling blood glucose levels. Flavonoids and polyphenolic compounds, owing to their antioxidant properties, can reduce free radical damage to pancreatic beta cells, fundamentally delaying the progression of diabetes. In the prevention and treatment of cardiovascular diseases, plant compounds similarly demonstrate unique advantages. For instance, polyphenols and carotenoids can reduce atherosclerosis risk by inhibiting platelet aggregation, improving vascular endothelial function, and lowering blood lipid levels. Certain alkaloids achieve antihypertensive effects by blocking calcium channels, offering cardiovascular patients treatment options with fewer side effects.

Cancer therapy represents another major focus in plant compound research. Natural products such as paclitaxel, which inhibits cell division by binding to microtubules, have become widely used anticancer drugs in clinical practice. Compounds like curcumin and resveratrol can jointly regulate apoptosis and proliferation through multiple signalling pathways (e.g., MAPK, PI3K/AKT, NF-κB), demonstrating multi-targeted antitumour effects. These effects have been validated not only in laboratory studies but also demonstrated positive outcomes in certain animal experiments and preclinical research. Regarding inflammatory diseases, plant-derived compounds garner significant attention due to their potent anti-inflammatory properties. Extensive research indicates that flavonoids, polyphenols, and other natural products can ameliorate chronic inflammatory states through mechanisms including inhibiting inflammatory mediator synthesis, blocking inflammatory signalling pathways, and reducing oxidative stress levels. Related to relationship between chronic inflammation and numerous diseases, like rheumatoid arthritis, inflammatory bowel disease and even neurodegenerative disorders which the anti-inflammatory effects of plant compounds hold broad application prospects in disease intervention.

It is noteworthy that, compared to conventional pharmaceuticals, plant-derived compounds offer advantages such as multi-targeted action, low toxicity, and fewer side effects. This not only enables them to demonstrate favourable outcomes in treating individual diseases but also provides novel approaches for combined interventions in complex chronic conditions. In clinical practice, drug resistance poses a significant challenge; plant-derived compounds, by regulating multiple signalling pathways and improving the intracellular environment, help reduce the incidence of resistance and enhance overall therapeutic efficacy.

For more, now plant-derived compounds still encounter challenging about from application. Firstly, their bioavailability is significant low, there are significant changes in absorption, distribution, and metabolism in the body. Secondly, the absence of unified quality standards and dosage specifications leads to efficacy discrepancies between different batches of formulations. Furthermore, a substantial volume of research remains confined to cellular or animal studies, with insufficient large-scale randomised controlled clinical trials, thereby limiting their widespread clinical adoption. Consequently, future research should prioritise enhancing drug stability and bioavailability, establishing standardised quality control systems, and advancing higher-level clinical translational studies to realise the full potential of plant-derived compounds in disease prevention and treatment.

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2. Chronic disease

The disease that contains affected over 16 weeks in patients are be called as chronic disease, the treatment which need plant-derived compounds can be classify to Diabetes, cardiovascular disease, cancer, inflammatory diseases, etc. These diseases are having wide range of patient populations and a high incidence worldwide, which make them become a major global health burden [3].

Plant compounds may also protect against chronic diseases by modulating metabolic pathways, enhancing immune function, and improving metabolic disorders. For example, some plant compounds can improve insulin sensitivity and help control blood sugar levels, which can prevent or manage diabetes. In the second hands, plant-based diets are believed to reduce the risk of chronic diseases such as cardiovascular disease, cancer, and obesity [4].

In addition, many plant compounds have antioxidant effects, scavenging free radicals and protecting cells from oxidative damage. For example, plant compounds such as flavonoids, phenols, and carotenoids play an important role in preventing cardiovascular disease, cancer, and neurodegenerative diseases [5].

3. Advantages and Future Prospects of Plant-derived Compounds in Chronic Disease Therapy

Plant-derived compounds have garnered significant attention in recent years due to several notable advantages over conventional therapies. Traditional chronic disease management approaches, particularly chemotherapy and radiotherapy in oncology, can indeed effectively suppress tumour proliferation in the short term. However, their benefits are often counterbalanced by severe drawbacks: high toxicity, pronounced side effects, strong resistance development, and limited therapeutic targets. Patients frequently endure distressing symptoms such as nausea, hair loss, or immunosuppression, whilst treatment efficacy diminishes progressively as resistance develops. These limitations underscore the urgent need to develop alternative or complementary therapeutic strategies that maintain therapeutic efficacy without imposing such a heavy physical and psychological burden.

In this context, plant-derived compounds demonstrate distinct therapeutic effects. These naturally occurring substances possess intrinsic anti-cancer activity and frequently exert their effects through multiple mechanisms. For instance, paclitaxel blocks tumour cell division by binding to tubulin, with minimal impact on normal tissues; while curcumin and resveratrol modulate multiple signalling pathways including PI3K/AKT, MAPK and NF-κB, demonstrating the multi-target flexibility of botanical interventions. This multifunctionality not only delays the emergence of drug resistance but also expands the scope of potential therapeutic targets beyond the reach of traditional single-pathway drugs. By inducing apoptosis, inhibiting angiogenesis, blocking metastasis, and modulating immune responses, plant compounds have emerged as potent candidate drugs in modern oncology research [6,7].

Equally significant are their immunomodulatory properties. Plant compounds enhance the body‘s capacity to recognise and eliminate tumour cells, contributing to improved overall health and offering potential for long-term prevention of recurrence and metastasis. This immune-supporting action suggests they may be as crucial in sustaining remission as they are in initiating tumour suppression. From a broader perspective, this mechanism not only provides therapeutic approaches but also underpins preventive strategies—strategies capable of transforming cancer treatment from acute intervention into enduring control.

In addition to pharmacological advantages, plant-derived preparations are usually renewable from renewable sources, widely obtained, relatively low cost, and have high safety under reasonable use, so they have important application value in the long-term management of chronic diseases and medical practice in resource- limited areas.

However, enthusiasm must be tempered by recognizing the ongoing challenges. The chemical complexity of plant extracts, coupled with variations in cultivation and harvesting practices, can lead to inconsistent quality and treatment outcomes. Bioavailability remains another obstacle, as rapid metabolism in the human body often reduces clinical potency. In addition, despite the encouraging results from in vitro and animal studies, there is still little evidence from large-scale, rigorously designed human clinical trials. Without this data, it is difficult to establish the reliability, dosing standards, and long-term safety required for regulatory approval and clinical adoption.

Taken together, the promise of plant-derived compounds lies in their multi-targeted mechanisms, lower toxicity, and accessibility, which distinguish them from conventional therapies and align them with the long-term goals of sustainable cancer management. Yet this promise can only be realised if future research addresses unresolved issues: standardisation of active ingredients, improvements in delivery systems, enhanced bioavailability, and clear regulatory frameworks to ensure consistency and safety. Only by overcoming these obstacles can plant-derived compounds move from experimental potential to established clinical

practice [8, 9].

4. Main types of the Plant-derived compounds

According to PD compounds, there are a wide range of applications in the medical, agricultural, food, and cosmetic fields. If they have high market and pharmaceutical R&D value. The classification of plant-derived (PD) compounds can vary depending on the perspective taken, but when organized according to chemical structure and biological function, four broad categories can be classified. Among these, flavonoids represent one of the most extensively studied classes. Ubiquitous in fruits, vegetables, and medicinal plants, flavonoids are recognised for their strong antioxidant, anti-inflammatory, and anti-tumour activities. They act through a wide array of mechanisms, including regulation of signalling pathways, suppression of oxidative stress, and protection against chronic conditions such as cardiovascular disease and cancer. Quercetin and resveratrol, for example, have been shown to enhance insulin sensitivity, reduce inflammation, and protect cellular structures from oxidative damage [10].

Polyphenols form another important class of bioactive compounds. Celebrated for their antioxidant and anti-inflammatory potential, they are abundant in foods such as tea leaves, grapes, and berries. Epidemiological studies consistently associate polyphenol intake with reduced risk of chronic illnesses, particularly cardiovascular disorders and type 2 diabetes. Beyond mitigating oxidative and inflammatory stress, polyphenols modulate immune responses and improve metabolic resilience, suggesting a central role in both prevention and management of chronic disease.

Terpenoids add further diversity to the spectrum of PD compounds. This structurally varied group is widely present in plant essential oils and demonstrates biological versatility, with documented anti-inflammatory, antibacterial, antifungal, and anticancer properties. Their applications extend across traditional remedies and modern medicine, as well as the food, cosmetic, and pharmaceutical industries. Research has highlighted that certain terpenoids can simultaneously inhibit tumour growth, reduce infection, and regulate inflammatory cascades, illustrating their multi-functional potential [11, 12]. In summary, the therapeutic prospects of plant bioactive compounds cannot be reduced to a single mechanism or isolated results. They often work through multiple pathways, and when combined with conventional treatments, their benefits may be magnified. Evidence increasingly suggests that these compounds can alleviate inflammation, improve metabolic health, and reduce the risk of chronic diseases such as diabetes and cardiovascular disorders, offering a complementary and sometimes synergistic role alongside established pharmacological therapies.

4.1 .The mechanics compounds effects

The fundamental reason these plant-derived compounds demonstrate unique advantages in the prevention and treatment of various chronic diseases and tumours lies in the diversity and complexity of their mechanisms of action. Broadly speaking, they exert pharmacological effects by modulating multiple signaling pathways, inhibiting inflammatory mediators, and modulating gene expression levels. For example, flavonoids potently inhibit the activation of the nuclear factor κB (NF-κB) signaling pathway, which is considered a key regulator of the inflammatory response and is involved in the transcription of almost all major pro-inflammatory cytokines. By inhibiting NF-κB activity, flavonoids significantly reduce the expression levels of inflammatory factors such as tumor necrosis factor-α (TNF-α) and interleukin-6 (IL-6), thereby alleviating chronic inflammatory states. Additionally, flavonoids have powerful free radical scavenging capabilities, which can reduce oxidative stress levels and protect vascular endothelial cell function. This can improve the vasodilatory response and promote cardiovascular health and stability.

In addition to the NF-κB pathway, plant bioactive compounds influence cell proliferation, differentiation, and apocidosis by modulating signaling pathways, including MAPK, PI3K/AKT, and JAK/STAT. For example, quercetin and resveratrol have been shown to inhibit the sustained release of inflammatory mediators by inhibiting excessive MAPK pathway activation. At the same time, by activating the PI3K/AKT pathway, they can improve cell survival and reduce oxidative damage-induced apoptosis. Crucially, the regulatory role of these compounds at the gene expression level is equally important. Studies have shown that certain polyphenols can regulate the methylation status of tumor-related genes through epigenetic mechanisms, thereby affecting the growth and invasion ability of cancer cells. This mode of action not only deepens the molecular level understanding of plant compounds but also provides a theoretical basis for their application in personalized cancer treatment.

4.2 .The PD compounds are having important role on multiple chronic disease.

Plant-derived compounds (PD compounds) are playing an increasingly prominent role in the prevention and management of chronic diseases. Their mechanism of action is multifaceted, functioning simultaneously at the molecular,

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cellular, and systemic levels. They modulate signaling pathways, inhibit inflammatory mediators, and modulate gene expression, thereby exerting a wide range of protective and therapeutic effects through disparate but interrelated biological processes.

One of the most consistent characteristics of these compounds is their antioxidant capacity. By scavenging too many free radicals, they limit oxidative stress, a process widely recognized as the core pathogenic mechanism of cardiovascular disease, diabetes, neurodegenerative diseases, and many cancers. Reducing lipid peroxidation and protecting DNA integrity can not only delay the onset of pathology, but also slow down disease progression [13]. These findings resonate with decades of experimental work that suggests that markers of oxidative stress are strongly associated with the severity of chronic disease, and they suggest that dietary or pharmacological interventions using PD compounds can alter long-term risk trajectories.

The anti-inflammatory effects of PD compounds form another important dimension of their therapeutic potential. Chronic inflammation underpins conditions such as rheumatoid arthritis, inflammatory bowel disease, and metabolic syndrome. Bioactive groups such as flavonoids, polyphenols, and terpenoids have been shown to dampen inflammatory responses by suppressing the synthesis and release of cytokines including TNF-α, IL-1β, and IL-6. In experimental vascular models, flavonoids can attenuate NF-κB pathway activation, leading to improved endothelial function and reduced vascular inflammation [13]. Such findings bridge laboratory studies with clinical relevance, hinting at applications that range from autoimmune disorders to cardiovascular health.

Beyond antioxidative and anti-inflammatory properties, many plant compounds demonstrate compelling antitumour activities. Their mechanisms include triggering programmed cell death, halting cell cycle progression, preventing angiogenesis, and blocking the invasive behaviour of malignant cells. There are well-studied examples like Resveratrol and curcumin, Fuctional as modulating PI3K/AKT and MAPK signalling cascades to suppress tumour growth [14]. All of these these effects the breadth of underscores and why PD compounds are increasingly discussed as adjuncts to conventional chemotherapy or radiotherapy, and possiblely enhancing efficacy while mitigating toxicity.

Immunomodulatory properties are predicting similar importants. From fine-tuning the immune system, to PD compounds all improve the body‘s ability to defence infection and control abnormal cell proliferation. Extracts from certain plants can stimulate macrophage promote phagocytosis, T cell proliferation, and increase the cytotoxic activity of natural killer cells. Although effects make them promising candidates for treating infectious diseases immunodeficiency syndrome, even cancer, whih return balance in long-term outcomes is crucial more than blunt inhibition.

In summary, the provement focusing on distinctive therapeutic profile. Plant-derived compounds contribute to chronic disease prevention and treatment through complementary mechanisms—antioxidant, anti-inflammatory, antitumour, and immunomodulatory. Their ability to delay progression while supporting traditional therapies underscores their dual role as prophylactic agents and therapeutic adjuncts. This multifaceted potential not only broadens the horizons of pharmacological strategies but also underscores their relevance to global public health, especially in the context of long-term disease control and affordability being as important.

5. Plant-derived compounds naturally Phytoactive ingredients

Plant active ingredients are common to the pharmacological mechanisms of chronic diseases. It could improve glycosemia management and spend many ways to treat diabetes, like plant active ingredients have diverse pharmacological effects in antidiabetic mechanisms of action, giving more solutions and further development in the treatment of diabetes.

5.1 .Phytoactive ingredients functions to diabetes.

The potential of phytoactive ingredients in the treatment of diabetes is enormous, but their low bioavailability and optimal dosage still need to be studied, and improved delivery techniques and personalized nutrition strategies can help overcome these obstacles. Plant-derived compounds are potential alternatives due to their potent anti-inflammatory effects and low adverse effects, but their clinical applications still need to be further studied and optimized

The phytoactive ingredients mechanism of antidiabetic action includes enhancing insulin sensitivity (such as quercetin, resveratrol), inhibiting α-glucosidase, delaying the rise in blood sugar, antioxidant, anti-inflammatory, and protecting pancreatic islet cells. These mechanisms are supported and expanded in multiple pieces of evidence.

Resveratrol, as a natural plant antitoxin, is widely found in a variety of plants, and its pharmacological mechanisms of action on diabetes mellitus and its complications include activating SIRT1 and AMPK to improve insulin sensitivity, improving insulin resistance, as well as activating the Akt pathway, increasing GLUT2 expression, in-

hibiting PDK, affecting glucose metabolism, and lowering blood sugar levels.

In addition, resveratrol can also participate in the mitochondrial pathway, promote SOD1 production, reduce ROS expression, reduce mitochondrial apoptosis, and alleviate oxidative stress damage to pancreatic islet β cells by activating SIRT1 and PGC-1α proteins.

5.2 .The ingredients activities of Plant-derived components

In the sort including Flavonoids, polyphenols, alkaloids, terpenes, most of the plant compound source are having multi-target and low toxicity, these compounds are widely present in plants and are widely studied and applied due to their diverse biological activities.

The advantages of these compounds are broad and beneficial, multiple targeted common as using to many biological targets that can affect multiple physiological processes simultaneously, thereby improving therapeutic efficacy [8]. Low toxicity that can led patients take medicine in long period when compared to regular compounds. Natural compounds have shown good safety in long-term use and are suitable for the prevention and treatment of chronic diseases [9].

6. Discussion

In the research and prevention of chronic diseases, plant-derived compounds have gained significant attention due to their complexity and wide range of applications. Extensive research has shown that bioactive compounds of plant origin, with their diverse pharmacological properties and immense therapeutic potential, are becoming essential resources in modern medicine. These compounds – including flavonoids, polyphenols, alkaloids and terpenoids – are widely distributed in a variety of plant species. They exhibit multifaceted biological activities such as anti-inflammatory, antioxidant, antitumor, and immunomodulatory, playing a crucial role in maintaining human health and preventing diseases. In recent years, advances in molecular biology and modern pharmacology have produced a growing body of evidence confirming the unique advantages of plant-derived bioactive compounds in improving metabolic function and delaying disease progression. In addition, they provide novel methods and methods for personalized intervention and precision medicine, showing irreplaceable application prospects in the treatment of chronic diseases in the future.

7. Conclusion

Plant bioactive compounds are regarded as an extremely rich potential therapeutic resource and have important application prospects in the prevention and treatment of chronic diseases. Extensive research confirms that these compounds function through various molecular mechanisms, such as modulating signaling pathways, exhibiting anti-inflammatory and antioxidant properties, and modulating immune responses. This not only aids in slowing disease progression but also improves patients‘ overall health status. As research continues to advance, the future holds promise for developing more novel and highly effective therapeutic drugs in this field to address diverse health challenges. Concurrently, future research should place greater emphasis on elucidating action mechanisms and fully leverage emerging technologies such as big data and artificial intelligence to conduct systematic and precise evaluations of plant bioactive compounds‘ functions. Through multidisciplinary integration, this approach can drive innovation in drug development models and accelerate the clinical translation of research outcomes, thereby playing a more pivotal role in the prevention, control, and long-term management of chronic diseases. This not only contributes to elevating the overall standards of modern medicine but also provides practical new pathways for public health initiatives.

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