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The Phytochemistry and pharmacological viewpoint of Gynostemma pentaphyllum, an immortal herb with remarkable medicinal potential.

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Abstract

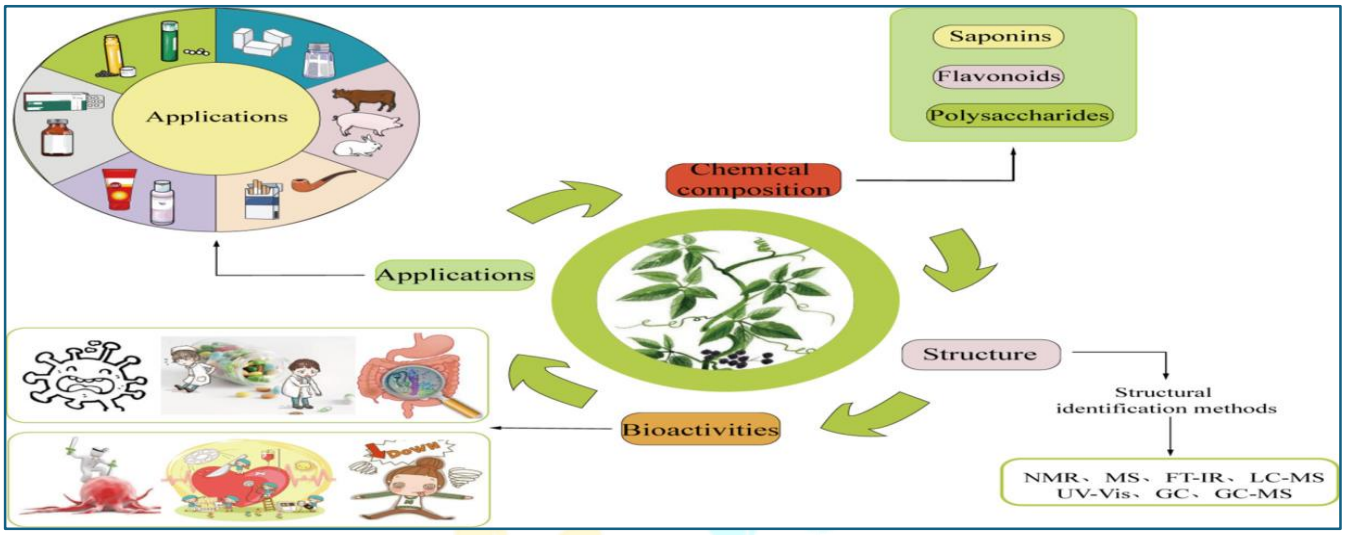
Gynostemma pentaphyllum, commonly known as an immortal herb, is a member of the Cucurbitaceae family and is indigenous to China. This herb is gaining recognition for its rich array of phytochemicals, which hold significant therapeutic potential. Notably, its key phytochemicals include saponins and sterols. Gynostemma pentaphyllum contains a diverse range of saponins, with researchers identifying 100 different types to date. Additionally, several sterols have been recognized in this plant, including ergostanol, sitosterol, and stigmasterol. These bioactive compounds are known for their remarkable therapeutic and pharmacological effects, which have been explored in various studies reviewed in this article. The first section provides a brief overview of the herb's taxonomic classification, botanical characteristics, and geographical distribution, while the second section offers an in-depth discussion of its phytochemistry, therapeutic applications, and pharmacological characteristics.

Keywords; Gynostemma pentaphyllum, saponins, gypenosides, ergostanol, antioxidant, Anti-inflammation, Anti-diabetic.

1. Introduction Gynostemma Blume is a small genus within the Cucurbitaceous family, consisting of 19 species primarily found in regions such as China, tropical Asia (including Vietnam, Thailand, and Malaysia), East Asia (Korea and Japan), the Himalayas (India and Bangladesh), and New Guinea (Chen et al., 2011). The most well-known species is Gynostemma pentaphyllum (Thunb.) Makino, commonly called "Jiao-Gu-Lan," which has a longstanding history as an edible plant in China, as noted in the herbals from the Ming Dynasty (1368–1644 AD) (Blumert and Liu, 1999). Today, various products made from G. pentaphyllum, such as tea, beverages, sports

drinks, tablets, instant powders, capsules, oral liquids, and pills, are marketed in the United States, Europe, China, and other Asian nations (Razmovski-Naumovski et al., 2005).

Research into the Photochemistry of G. pentaphyllum began with the isolation and identification of panaxadiol and 2α-hydroxypanaxadiol from a hydrolysed saponin-rich fraction of its aerial parts (Nagai et al., 1976). Panaxadiol, originally extracted from Korean ginseng (Panax ginseng), is identified as a distinctive sapogenin associated with ginseng (Fujita et al., 1962). This discovery made G. pentaphyllum a subject of significant phytochemical interest. Following the work of Takemoto and colleagues, who reported the structures of 21 saponins from this species (Takemoto et al., 1977, 1979, 1980), over 300 saponins and sapogenins have since been isolated and characterized from Gynostemma, alongside other compounds like flavonoids and polysaccharides? The gypenosides or saponin-rich fractions of G. pentaphyllum have been subjected to numerous pharmacological tests, showing diverse effects, including anti-diabetic, anti-obesity, anti-cancer, anti-inflammatory, cardio protective, hepatoprotective, and neuroprotective properties. Additionally, randomized controlled clinical trials have assessed the effects of standardized extracts of G. pentaphyllum on diabetes, obesity, and anxiety in humans.



Species within the Gynostemma genus are also recognized as promising sources of traditional medicine. Some of their medicinal uses have been validated by pharmacological research, such as anticancer effects (G. pentaphyllum) (Li et al., 2016), ant diabetic properties (G. pentaphyllum and G. longipes) (Lee et al., 2019; Pham et al., 2018), and neuroprotective effects (G. pentaphyllum and G. alum) (See et al., 2017). These various biological activities are mainly attributed to their key components: flavonoids, polysaccharides, and sapiens. Interestingly, despite not being botanically related to ginseng, Gynostemma species also contain ginsenosides and similar dammarane triterpenoid structures, referred to as gypenosides or longipenosides (Ha et al., 2019; Razmovski-Naumovski et al., 2005). Through extensive structure elucidation and biological evaluations, these dammarane triterpenoids have highlighted the potential of Gynostemma species in developing natural therapies for metabolic conditions, including diabetes mellitus, metabolic syndrome, aging, and neurodegenerative diseases.

This paper provides a thorough overview of the botany, ethno pharmacology, photochemistry, pharmacological activities, molecular mechanisms, safety, and clinical uses of Gynostemma species and their derivatives. It aims to offer valuable insights and a scientific foundation to enhance health products derived from these herbs.

2. The Pharmacokinetic (ADME) processes related to Gynostemma pentaphyllum:

1. Absorption:

Bioavailability: The herb contains saponins called gypenosides, believed to be responsible for its therapeutic effects. However, due to their large molecular structure and amphipathic qualities, the absorption of these saponins is often low in the intestinal tract.

Enhancement of Absorption: Some studies indicate that combining these compounds with other substances, like piperine or specific fatty acids, might enhance their absorption.

2. Distribution:

Plasma Concentration: After being taken orally, the active substances from Gynostemma pentaphyllum are found in plasma and can distribute throughout different tissues, with moderate concentrations observed in the liver, kidneys, and brain.

Protein Binding: The saponins appear to bind partially to plasma proteins, which may affect their distribution and efficacy.

3. Metabolism:

Phase me and II Metabolism: Compounds present in Gynostemma pentaphyllum are metabolized in the liver, going through processes like cytochrome P450-mediated oxidation and subsequent conjugation such as glucuronidation or sulfation. The specific metabolic pathways and enzymes responsible for gypenoside metabolism remain partially clarified.

Metabolites: Some metabolites of gypenosides may have pharmacological activity, though further research is ongoing to define their specific effects.

4. Excretion:

Elimination: The main excretion route for the herb's compounds seems to be urine, but some metabolites can also be eliminated via feces.

Half-life: The active compounds' half-life varies and can be influenced by dosage, individual metabolic rates, and co-administration of other substances.

Key Considerations:

Herb-Drug Interactions: Due to its impact on multiple biochemical pathways, Gynostemma pentaphyllum may interact with other medications, particularly those processed by liver enzymes (CYP450 family).

Safety and Efficacy: While generally regarded as safe, further clinical studies are necessary to deepen the understanding of its pharmacokinetics and potential interactions with other treatments, especially concerning long-term use.

3. Pharmacodynamics of Gynostemma pentaphyllum:

The pharmacodynamics of Gynostemma pentaphyllum involve several key active components that contribute to its therapeutic effects. Among these, gypenosides—triterpenoid sapiens—are the most significant, showcasing a range of biological activities:

Adapt genic Effects:

Gynostemma pentaphyllum possesses adaptogenic qualities, aiding the body in resisting stress and achieving balance. It enhances responses to both physical and mental stress, thus boosting overall vitality.

Antioxidant Effects:

The gypenosides in Gynostemma pentaphyllum exhibit robust antioxidant properties, which shield cells from oxidative harm and may lower the risk of chronic diseases and aging.

Immune Modulation:

Research indicates that Gynostemma can enhance immune response by promoting the production of immune cells and strengthening the bodies defines mechanisms.

Anti-inflammatory Effects:

This herb has shown anti-inflammatory characteristics, which could be advantageous for managing conditions linked to chronic inflammation.

Cardiovascular Effects:

Gynostemma pentaphyllum may assist in lowering blood pressure and enhancing heart function. Some studies imply it offers protective benefits against atherosclerosis by improving blood circulation and decreasing lipid build-up.

Potential: Anticancer

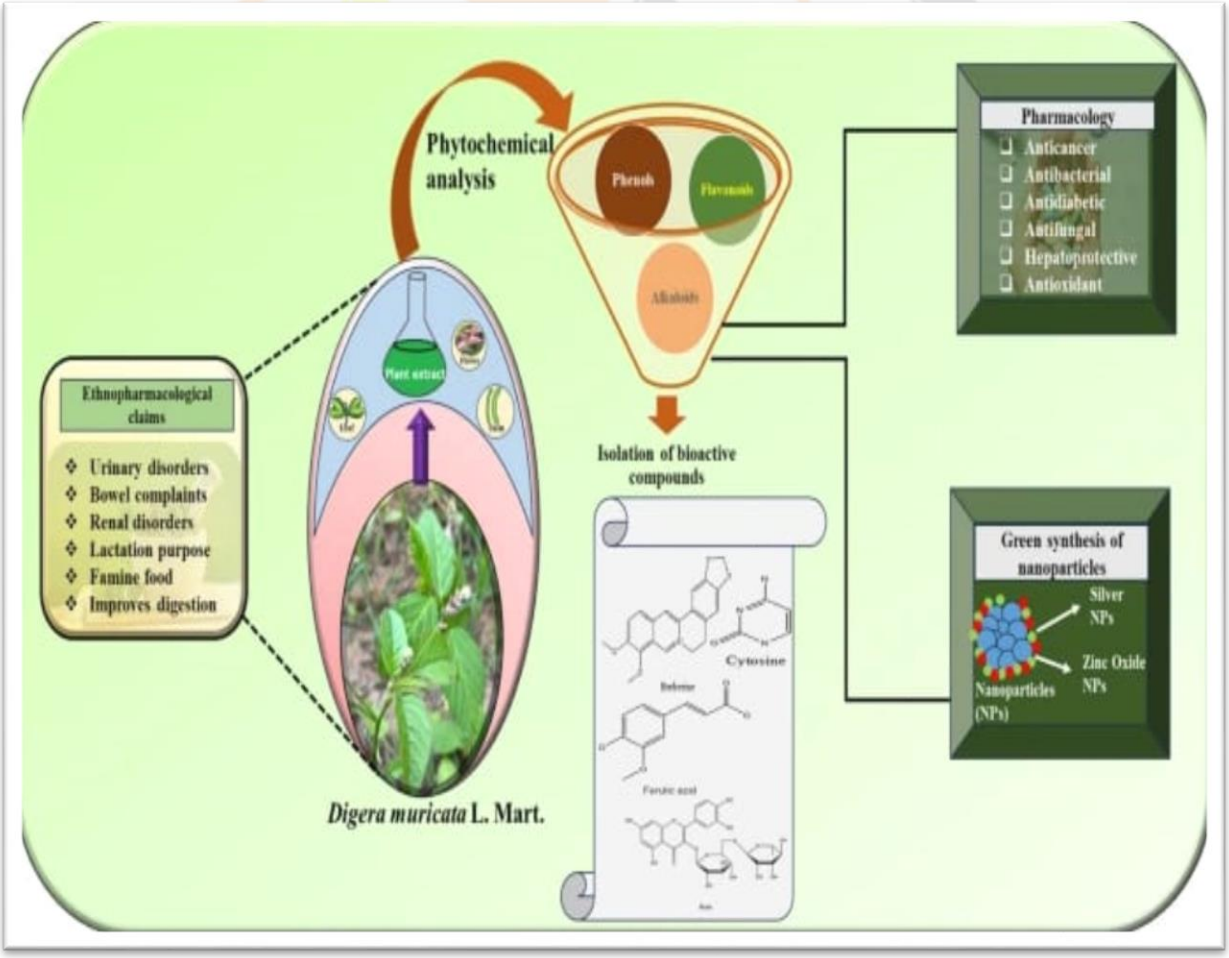
Initial research suggests that Gynostemma pentaphyllum may possess anticancer effects, with certain components capable of inhibiting cancer cell growth or triggering apoptosis (cell death) in malignant cells.

Blood Sugar Regulation:

There is some indication that Gynostemma pentaphyllum could aid in regulating blood sugar levels, making it relevant for diabetes management or improving insulin sensitivity.

Mechanisms of Action of Gynostemma pentaphyllum

Gypenosides are thought to influence multiple pathways, including modulation of the hypothalamic-pituitary-adrenal (HPA) axis, enhancement of mitochondrial function, and increased expression of various antioxidant enzymes. Additionally, it may help regulate cortisol and other stress hormones, thus supporting homeostasis under stressful conditions.

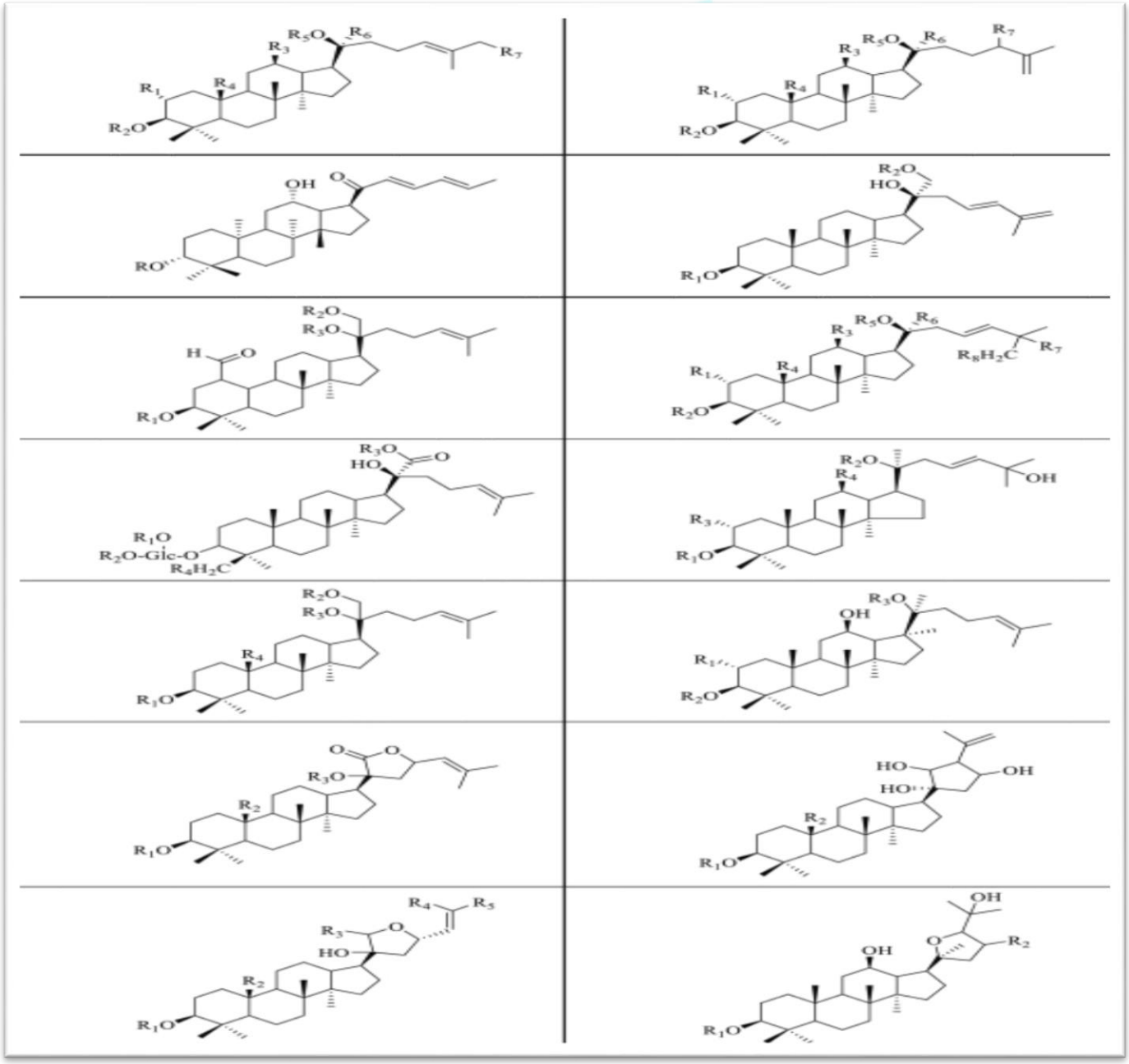


While the pharmacodynamics profile of Gynostemma pentaphyllum is promising, further clinical studies are necessary to fully elucidate its mechanisms and potential therapeutic uses.

Photochemistry and Bioactive Compounds.

3.1. Gynostemma pentaphyllum Saponin

The Gynostemma genus comprises several species including G. pentaphyllum, G. aggregate, G. cardiospermum, G. longipes, and G. yixingense, all of which are known to contain ginsenosides. Consequently, G. pentaphyllum has earned the label "South Ginseng" (Lou et al., 2021). It harbours multiple saponin components, including ginsenoside-like compounds such as Rb1, Rb3, F2, Rg3, Rc, and Rd, along with unique saponins like malonyl Rb1 and malonyl Rd. The advancement of separation technologies and analytical methods in recent years has significantly progressed the exploration of G. pentaphyllum saponins. Researchers are consistently identifying



new saponins, which not only broadens the range of G. pentaphyllum saponins but also enhances our understanding of their biological activities. Recent studies have unveiled novel saponin structures in G. pentaphyllum extracts that exhibit distinct chemical compositions and biological functions. The identification of ginsenoside Rb2 is particularly noteworthy, as it offers new insights into the pharmacological properties of G.

pentaphyllum (Liu et al., 2008). Evidence suggests that ginsenoside Rb2 possesses various biological activities, including anti-inflammatory, antioxidant, and anti-tumour effects, potentially explaining the therapeutic benefits of G. pentaphyllum in treating certain ailments. Moreover, ongoing research is yielding more new saponin components from G. pentaphyllum. One notable discovery is GP saponin XVII (seven leaf bile glycoside XVII), which has been isolated and characterized by scientists, suggesting promising biological activity and possible applications in drug development. As a valuable source of ginsenosides apart from Araliaceous plants, the concentration of G. pentaphyllum saponins is much higher than that found in ginseng, which underscores the significant academic, economic, and social implications of these discoveries.

Sapiens are amphiphilic compounds comprising a polar sugar chain and a non-polar sapogenin. The sugar chain typically consists of 2 to 5 sugar units predominantly linked to hydroxyl groups at the C-3 and C-20 positions, mainly composed of one or more monosaccharide's (Singh et al., 2017). Common sugars found in these chains include glucose, galactose, arabinose, xylose, ramose, and glucuronic acid (Du et al., 2014; Lásztity et al., 1998). Based on the number of sugar chains, saponins can be categorized into monosaccharide, disaccharide, trisaccharide, and tetra saccharide chain saponins. The foundational chemical structure of G. pentaphyllum saponins is dammarane-type tetracyclic triterpene saponins, with key representatives being 20(S)-protopanaxadiol and 2α-OH-20(S)-protopanaxadiol. The chirality at position C-20 in G. pentaphyllum saponins exhibits R and S configurations, the latter being more prevalent. Recently, numerous new gypenosides have been discovered, prompting the need for systematic classification and summarization of G. pentaphyllum saponins. Researchers have grouped them based on structural similarities, categorizing them according to the characteristics of sapogenins, the positioning of double bonds in side chains, and the nature of the side chain loops. The side chain structure may contain one or two double bonds, and when present, these double bonds are classified by their positions—C23-C24, C24-C25, and C25-C26. Most side chains feature C24-C25 double bonds, while some exhibit conjugated double bond formations. Additionally, the side chain can undergo cyclization to create lactones, five-membered rings, and epoxy structures. Notably, C21 and C23 can cyclically form lactone structures, while different epoxy configurations arise at C20 with C24 and C25. The five-membered ring structures primarily result from the cyclization between C21 and C24. Since 2021, nearly 300 chemical structures of G. pentaphyllum saponins have been documented (Fan et al., 2017; Su et al., 2021). This review consolidates 20 general structural formulas for G. pentaphyllum saponins.

3.2. Polysaccharides from Gynostemma pentaphyllum

In recent years, a variety of polysaccharides with different structures have been extracted from Gynostemma pentaphyllum (GP). Their essential chemical structures have been analyzed using techniques such as FT-IR, UV, GC, NMR, HPGPC, and HPLC-MS. Furthermore, their conformational behaviours and surface features have been examined using Scanning Electron Microscopy (SEM) and Atomic Force Microscopy (AFM). Table 2 highlights the key structural properties of GPP, including molecular weight, monosaccharide composition, and fundamental chemical structure. The average molecular weight of GPP plays a crucial role in determining its chemical properties and is closely linked to its biological activities. Currently, HPLC and HPGPC are commonly used methods for measuring the average molecular weight of polysaccharides; in this case, HPLC can be utilized to assess GPP's average molecular weight. It is important to note that experimental conditions significantly influence the average molecular weight of GPP, which can range from 6.7 to 3297 kDa depending on these conditions, as shown in the research.

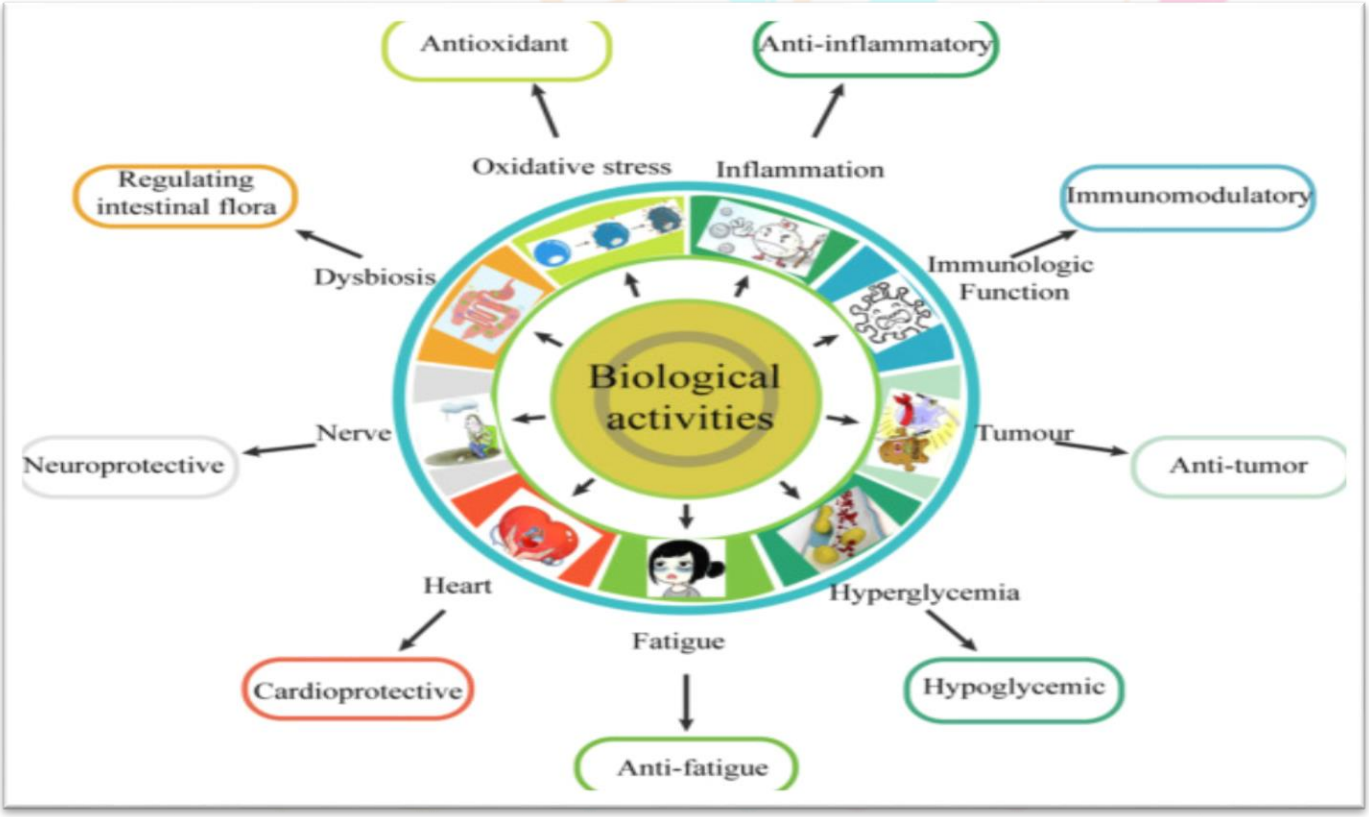
3.3. Other components

Gynostemma reportedly contains 23 inorganic elements, including iron, zinc, copper, manganese, chromium, molybdenum, selenium, nickel, alum, silicon, boron, calcium, phosphorus, potassium, sodium, magnesium, and so on. In addition, the flavonoid content in GP is 2 %–5 %, mainly including Shangluoin, quercetin, rutin, malonic acid Shangluo glycoside, isorhamnetin, and so on. Furthermore, GP is rich in amino acids, vitamins, terpenes, phospholipids, organic acids, alkaloids, proteins, and other nutrients.

According to reports, in order to improve the extraction rate and biological activity of the active ingredients in GP, we can use physicochemical and biological methods (Wang, Zheng, Hu, et al., 2024). On the one hand, combining modern extraction techniques such as ultrasonic extraction and microwave extraction can effectively destroy the cell wall of GP, promote the release and dissolution of active ingredients, and thus improve the extraction rate (Wang et al., 2023). On the other hand, the use of biological methods such as enzymatic extraction or microbial fermentation can specifically break down the cell wall components, transform or enhance the active ingredients in GP, and further enhance its biological activity (Wang, Zheng, Zhou, et al., 2024). The combined application of these methods not only helps to improve the extraction efficiency and purity of the active components of GP, but also provides strong support for the development of more efficient and bioactive GP products.

4. Pharmacological Properties

The saponins that have been studied in China are primarily responsible for the therapeutic effects of G. pentaphyllum, earning the plant the nickname "immortality herb" due to its versatility.



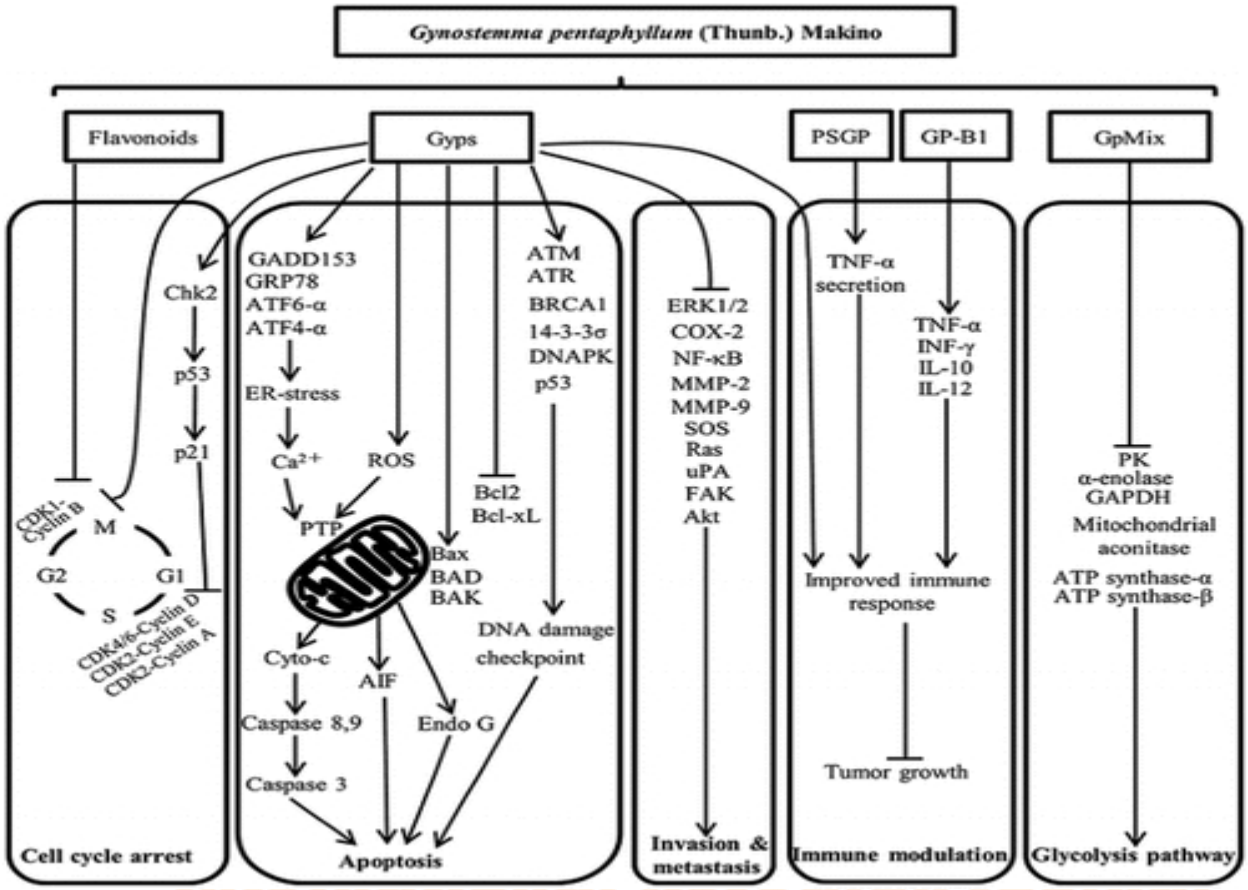
Anti-Cancer Effect

In 1993, a study involving 59 patients with confirmed malignant tumours tested the effects of G. pentaphyllum. Results showed that those treated with a G. pentaphyllum formula experienced cancer recurrence and spread rates of 11.9% and 8.5%, respectively, in contrast to 72.4% and 55.2% in the control group. Furthermore, the study by Wang et al. indicated an 8.1% increase in T lymphocyte activation and acid-naphthyl acetate esterase (ANAE+) activity post-treatment. A subsequent five-year observational study demonstrated significant reductions in cancer recurrence and spread rates among patients treated with the G. pentaphyllum formula, as well as improved mortality rates and immune function. G. pentaphyllum also appears to enhance the immune response in cancer patients following chemotherapy, as shown by improvements in T lymphocyte activation and decreases in IgG and IgM levels in breast cancer patients. Additionally, it was found to bolster immune function in lung cancer

patients after treatment, and recent research suggests that G. pentaphyllum can work alongside chemotherapy drugs.

Mechanisms of Action

Proposed mechanisms by which G. pentaphyllum exerts its anti-cancer effects include cell cycle arrest, induction of apoptosis, inhibition of colonization and metastasis, restriction of glycolysis, and immune regulation.



Cell Cycle Arrest

Gypenosides (Gyps) from G. pentaphyllum have been shown to cause cell cycle arrest in SAS human oral cancer cells, WEHI-3 leukaemia cells, A549 human lung adenocarcinoma cells, and HL-60 human myeloid leukaemia cells, specifically in the G0/G1 phase. They induce this arrest by modifying the expression of cell cycle regulators such as cyclin-dependent kinases (CDK2, CDK4, CDK6) and activating checkpoint kinase 2 (Chk2), resulting in up regulation of p53 and its targets p21 and p16, which lead to decreased levels of cyclin D and E, ultimately causing cell cycle arrest.

Induction of Apoptosis

G. pentaphyllum promotes cancer cell death through various signalling pathways. It enhances the formation of Bax/Bak channels on the outer mitochondrial membrane by inhibiting anti-apoptotic proteins like Bcl-2 and Bcl-xL while increasing pro-apoptotic proteins Bax, Bad, and Bak. This cascade activates initiator caspases-8 and -9, leading to the activation of effector caspase-3 and the subsequent release of cytochrome c and other pro-apoptotic proteins into the cytoplasm, thereby triggering apoptosis. Research also indicates that different components of G.

pentaphyllum, such as flavonoids and water extracts, can induce apoptosis in tumor cells by modulating the Bcl-2 protein family.

Inhibition of Colonization and Metastasis

Gyps has been shown to block the invasiveness and motility of SCC4 human tongue cancer cells by repressing nuclear factor kappa B (NF-κB) and matrix metalloproteinase-9 (MMP-9). It also inhibited migration in SAS cells and reduced the proliferation of SW-480 human colon cancer cells in vitro, correlating with observed clinical outcomes where patients treated with G. pentaphyllum experienced lower metastasis rates compared to controls.

Restriction of Glycolysis

Cancer cells often exhibit dysregulated energy metabolism, referred to as "aerobic glycolysis." In this regard, targeting glucose metabolism represents a promising avenue for cancer treatment. The GpMix, a combination of triterpenoid saponins from G. pentaphyllum, was shown to significantly reduce cancer cell proliferation.

Immune Regulation

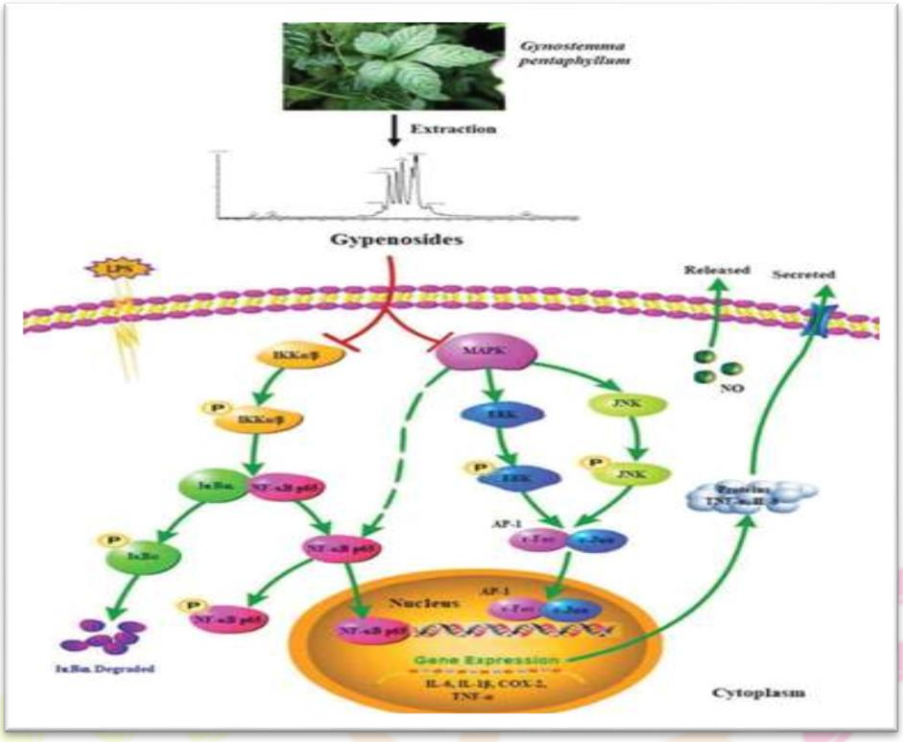
The anti-cancer effects of G. pentaphyllum are partially attributed to its immune-regulatory properties. For example, a water-soluble polysaccharide from G. pentaphyllum herb tea was found to enhance macrophage immune response and TNF production against SW-1116 human colorectal adenocarcinoma cells and HT-29 in a dose-dependent manner. Additionally, another polysaccharide from G. pentaphyllum, GP-B1, not only inhibited cancer cell growth but also enhanced cellular immune responses by increasing serum levels of TNFα, IFN-γ, IL-10, and IL-12 in melanoma-B16-bearing animals.

Ant diabetic Effects

Spooning components from G. pentaphyllum reduced plasma glucose levels in STZ-induced diabetic rats over a two-week period. G. pentaphyllum phanoside was found to stimulate insulin secretion from isolated rat pancreatic islets and improve glucose tolerance while enhancing plasma insulin levels in hyperglycaemic rats. Gypenosides also increased insulin receptor sensitivity and mitigated glucose-induced hyperglycaemia in Zucker diabetic fatty rats.

Inhibition of α-Glycosidase

G. pentaphyllum has shown a dose-dependent inhibitory effect on α-glucosidase, an enzyme crucial for carbohydrate digestion in the small intestine. The effectiveness of G. pentaphyllum in inhibiting α-glucosidase was more pronounced in vitro compared to other known inhibitors.



Influence of Gypenosides on Pro-Inflammatory Mediator mRNA Expression

Inhibiting mRNA expression of key pro-inflammatory mediators like IL-6, IL-1, COX-2, and TNF-α may help alleviate inflammation. Gypenosides have been found to suppress the transcription of COX-2, IL-6, and IL-1 mRNA, with higher doses correlating to stronger suppressive effects on cytokine mRNA expression.

The impact of gypenosides on the release of pro-inflammatory mediators in LPS-stimulated RAW264.7 macrophage cells was examined by assessing the protein levels of IL-6 and TNF-α in the culture media. Following LPS stimulation, significant increases in IL-6 and TNF-α levels were noted ($p < .01$). However, the addition of gypenosides led to a reduction in the release of both mediators. Notable inhibition of IL-6 was seen at concentrations of 150 µg/ml ($p < .05$) and 200 µg/ml ($p < .01$), while TNF-α was significantly suppressed between 100–200 µg/ml ($p < .01$). Alterations in the protein levels of these cytokines were linked to changes in their mRNA expression. Gypenosides were found to inhibit both IL-6 and TNF-α release and nitric oxide generation in LPS-stimulated RAW264.7 macrophages.

In the context of NF-κB induction, gypenosides were observed to block LPS-stimulated activation of this crucial transcription factor, which regulates inflammatory mediators. Under normal conditions, NF-κB exists in the cytoplasm as an inactive complex with IκBα. LPS activation prompts IκBα phosphorylation and degradation by the IKK complex, allowing NF-κB to enter the nucleus and initiate transcription of pro-inflammatory cytokines. Previous studies have indicated that soy saponins can mitigate inflammation by reducing NF-κB activation, suggesting that gypenosides similarly modulate this pathway in RAW264.7 macrophages to exert their anti-inflammatory effects.

The antioxidant properties of various bioactive components, particularly polysaccharides, are well-documented. Research indicates that polysaccharides from G. pentaphyllum demonstrate significant antioxidant potential both in vitro and in vivo. Recent studies have identified antioxidant activities in fractions GPA1, GPA2, and GPA3, with GPA3 showing superior abilities in scavenging DPPH and hydroxyl radicals, as well as in ferrous ion chelation and reducing power. The polysaccharides GMA, GMB, and GMC from G. pentaphyllum were also

purified and found to possess antioxidant capabilities; notably, GMC exhibited strong scavenging effects on superoxide radicals and inhibited self-oxidation.

Considering immunomodulatory activity, polysaccharides with organic origins are believed to play a notable role in immune response modulation. Investigations have shown that G. pentaphyllum polysaccharides enhance various types of immunity. In studies conducted on rats, GPMPP was found to significantly increase splenic and thymic indices, activate macrophages and NK cells, and influence splenocyte activity in a dose-dependent manner. Additionally, GPMPP improved the counts of CD4+ T lymphocytes and altered serum and spleen levels of various oxidative stress biomarkers, thus pointing toward its potential immunomodulatory benefits.

As for hepatoprotective effects, non-alcoholic fatty liver disease (NAFLD) is often associated with oxidative stress and fatty liver degeneration. The liver's antioxidant defense system, including enzymes, works to combat damage from lipid peroxidation. Previous rat studies indicated the preventive capabilities of G. pentaphyllum against NAFLD, while recent research suggested that mice models more accurately resemble the human condition. An in-silico analysis identified potential active components from G. pentaphyllum and their interactions with NAFLD-related genes and proteins, highlighting gypenoside XL as a key element with numerous connections to NAFLD targets. The findings suggest that various compounds—including gypenoside XL—are critical in managing NAFLD through their interactions with significant biological pathways like those involving PPARα, BRD4, and SOX9. Data were sourced from various databases, including STITCH and PharmGKB.

NALFD is a component of a compound-target network, where yellow triangles represent active compounds from G. pentaphyllum and blue rectangles depict potential NAFLD target genes, with the gray line illustrating the relationship between the compounds and their targets. Source: Shang et al.[Citation107] (b). This section also highlights six potential anti-NAFLD compounds derived from G. pentaphyllum along with their chemical compositions.

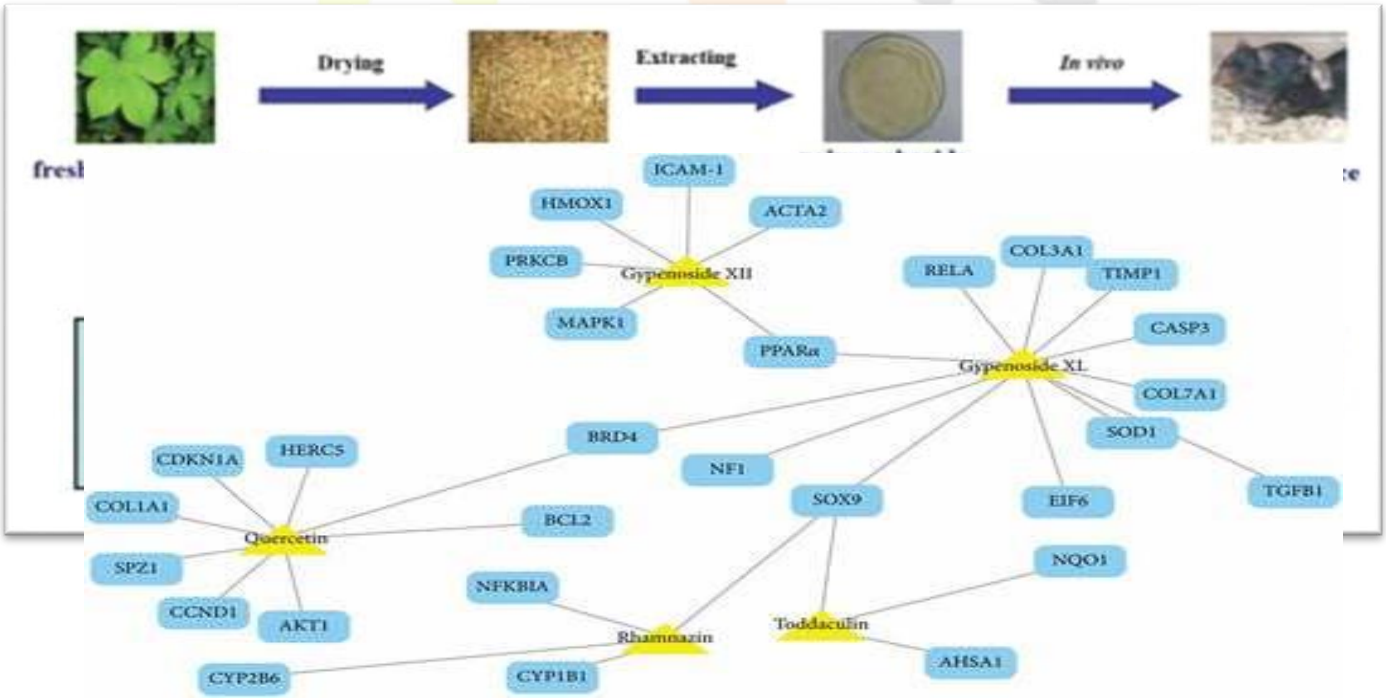


Figure 8. (a). NALFD is integrated into a compound-target network, with yellow triangles denoting active G. pentaphyllum compounds and blue rectangles indicating likely NAFLD target genes; the gray line indicates the compound-target relationship. Source: Shang et al.

(b). the six potential anti-NAFLD compounds from G. pentaphyllum and their corresponding chemical compositions.

Neuroprotective Activity:

Research identified active compounds from G. pentaphyllum that protect SH-SY5Y cells from oxidative damage induced by hydrogen peroxide. Using various chromatographic techniques, four novel dammarane-type saponins were isolated and identified as gypenoside S1 (1), gypenoside S3 (2), gypenoside S2 (3), and gypenoside S4 (4), based on HRESIMS and NMR analysis. The MTT assay evaluated their cytotoxic effects on three human cancer cell lines: A549 (lung), HepG2 (liver), and SH-SY5Y (nerve), showing moderate cytotoxicity with IC50 values exceeding 100 μM.

Additionally, these compounds exhibited dose-dependent protective effects against hydrogen peroxide-induced cell death in SH-SY5Y cells, increasing survival from 66% to over 69% at 20 μM, compared to vitamin C's effect of 67%. Compounds 3 and 4 restored over 79% cell viability at 100 μM, indicating the antioxidative properties of G. pentaphyllum and suggesting its saponins are active constituents with neuroprotective and non-toxic effects.

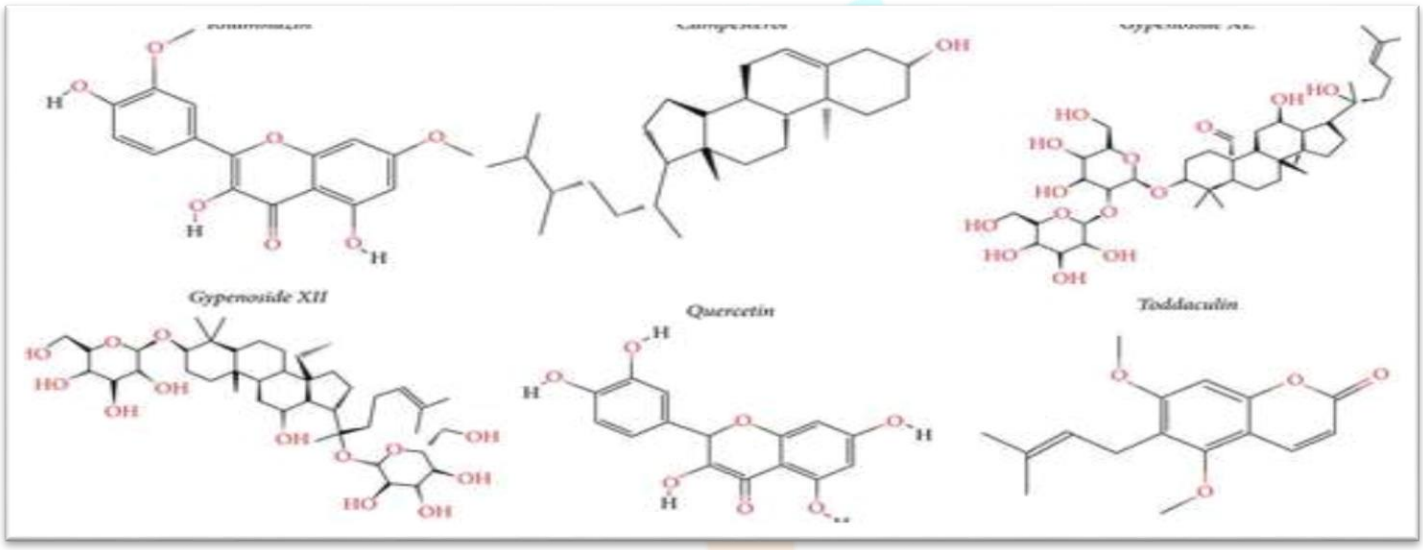
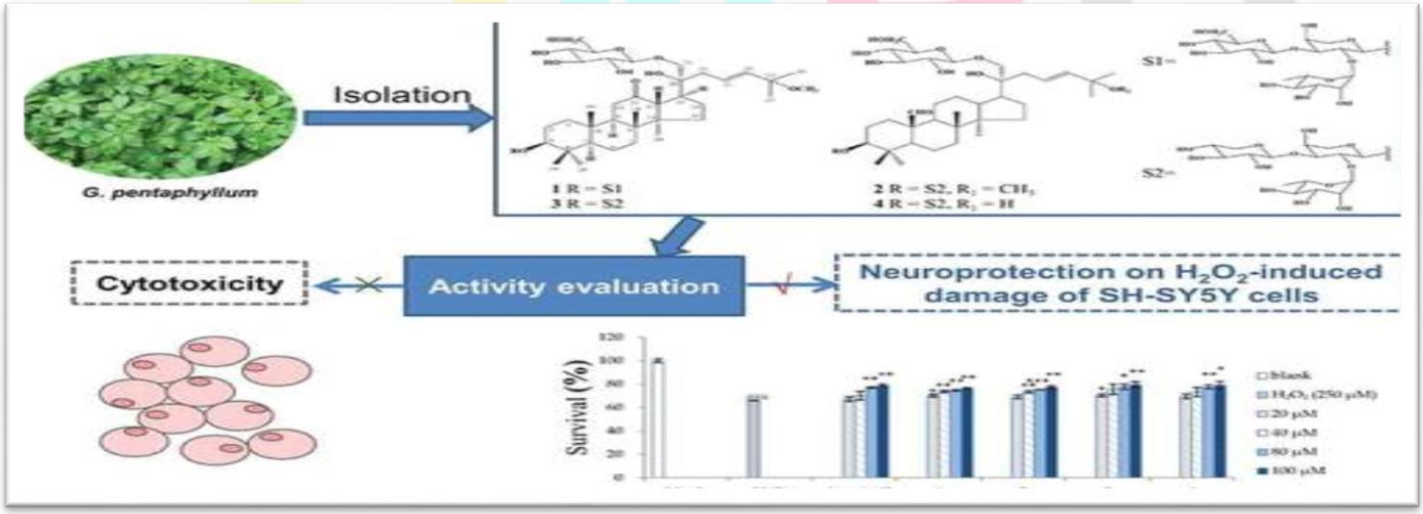


Figure. A graphical representation of the neuroprotective effects of Gynostemma pentaphyllum.



Anti-inflammatory Actions:

Chronic inflammation has been linked to diabetes and metabolic syndrome. To investigate G. pentaphyllum's potential anti-inflammatory effects in hypoglycemia, the levels of four crucial cytokines (IL-4, IL-6, IL-10, and TNF-α) were measured. After administering 0.5 mL of an 800 g/mL polysaccharide solution of G. pentaphyllum daily for four weeks, these cytokine levels nearly returned to normal. This suggests that G. pentaphyllum may provide anti-inflammatory benefits for diabetic mice. Similar effects were observed in studies exploring anti-inflammatory treatments related to diabetes. Liu et al. found that polysaccharides from Pleurotus citrinopileatus can alleviate hepatotoxicity by enhancing IL-10 levels while decreasing TNF-α and IL-6 levels. Future investigations will delve into G. pentaphyllum's anti-inflammatory mechanisms to boost its ant diabetic effects.

5. Conclusion:

Gynostemma pentaphyllum showcases significant therapeutic potential, attracting considerable interest from researchers in herbal medicine, leading to updated insights into its biology, chemistry, and toxicology. Scientific studies involving both animals and humans have revealed that G. pentaphyllum extracts can effectively manage lipid profiles. Furthermore, the herb exhibits pharmacological benefits for the cardiovascular and immune systems. However, the precise mechanisms behind its actions remain unclear and will require isolating the gypenosides for molecular study. Understanding the gypenosides' aglycone and sugar sequences will clarify their potential role in regulating various metabolic pathways. A comprehensive investigation of its pharmacological effects alongside its safety profile will help determine the herb's clinical applications against hyperlipidaemias, cancer, diabetes, and other lifestyle-related diseases.

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