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Original Research Report

Phytochemical Insights and Medicinal Potential of *Panax notoginseng*: A Comprehensive Study from Chiang Mai

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Abstract: Panax notoginseng, a prominent medicinal plant, was studied to evaluate its phytochemical composition, cultivation practices, and therapeutic potential using samples from Chiang Mai, Thailand. Phytochemical analysis revealed high concentrations of bioactive compounds, including ginsenosides (notoginsenoside R1, ginsenoside Rb1, and ginsenoside Rg1), with average levels of 2.5 mg/g, 3.8 mg/g, and 3.1 mg/g, respectively. UV-visible spectrophotometry indicated total flavonoid and polysaccharide contents of 7.4 mg/g and 6.1 mg/g, respectively. These findings suggest that the Chiang Mai region offers an optimal environment for cultivating Panax notoginseng, potentially enhancing its antioxidant and immune-modulatory properties. Surveyed local farmers identified key factors influencing phytochemical composition, including consistent irrigation, pest management, and soil quality. A positive correlation ($r = 0.72$, $p < 0.05$) was observed between organic farming practices and higher concentrations of ginsenoside R1, indicating that sustainable cultivation methods may improve medicinal quality. Despite promising results regarding the therapeutic potential of ginsenosides, especially for cardiovascular conditions, there is a need for further research to address safety concerns and drug interactions. Clinical trials are recommended to evaluate the long-term effects of Panax notoginseng in diverse populations. This study underscores the potential of Chiang Mai as a significant source of high-quality Panax notoginseng, with implications for improving cultivation practices and meeting global herbal medicine demands. Future research should focus on refining cultivation techniques and assessing the plant's safety profile.

Keywords: Cultivation Practices, Ginsenosides, *Panax notoginseng*, Phytochemical Composition, Therapeutic Potential.

1. Introduction

Panax notoginseng, commonly referred to as *Panax notoginseng* (Burk.) F. H. Chen, is a revered herbal plant with deep roots in traditional Chinese medicine and growing interest in modern scientific research. Known as "Tienchi ginseng," this plant is a member of the Araliaceae family, closely related to the more widely known Panax ginseng (*Panax ginseng*). *Panax notoginseng* is traditionally celebrated for its medicinal properties, including its ability to enhance blood circulation, alleviate inflammation, and support overall health [1] [2].

The roots of *Panax notoginseng* are the primary source of its therapeutic benefits. These roots are rich in saponins, specifically ginsenosides, which are believed to play a crucial role in the plant's pharmacological effects [3]. Recent research has highlighted its potential benefits in managing cardiovascular diseases, cognitive enhancement, and cancer treatment [4] [5]. Despite these promising findings, there is a continuing need for more in-depth research to fully understand the plant's mechanisms of action and therapeutic potentials [6].

In Thailand, *Panax notoginseng* has gained prominence due to its integration into local herbal medicine practices and the increasing recognition of its health benefits. Thai practitioners have traditionally used *Panax notoginseng* for its purported benefits in improving blood circulation, enhancing wound healing, and treating various inflammatory conditions [7]. Recent studies have noted an increase in its use among Thai patients seeking alternative treatments for cardiovascular issues and chronic conditions [8]. The plant's adaptability to the local climate and its integration into modern Thai herbal remedies have led to a surge in both interest and research [9].

The therapeutic effects of Panax notoginseng are attributed to its rich phytochemical composition [10]. The primary bioactive compounds are ginsenosides, which are saponins that exhibit a range of pharmacological activities. Ginsenosides are classified into different types, including Rb1, Rb2, Rc, and Rd, each contributing to the herb's diverse effects [8] [9]. These compounds are known to possess adaptogenic, anti-inflammatory, and antioxidant properties, which underpin the herb's role in enhancing energy and managing stress.

Recent scientific research has expanded our understanding of Panax notoginseng's health benefits. Clinical studies have demonstrated that the herb can improve physical performance and reduce fatigue, supporting its traditional use as an energy booster [10] [11]. For example, a study by Yang et al. (2023) found that Panax notoginseng supplementation led to significant improvements in endurance and exercise capacity among participants [12]. Additionally, the herb's efficacy in stress management has been investigated, with research showing its potential to modulate stress hormones and improve mental resilience [13] [14].

A notable trend in Thailand is the cultivation of *Panax notoginseng* to meet the growing demand for its medicinal properties. Local farmers and herbalists have started to cultivate the plant, leveraging Thailand's suitable climate and soil conditions to produce high-quality ginseng [15] [16] [17]. This cultivation not only supports local economies but also enhances the accessibility of the herb for research and therapeutic purposes.

This study aims to contribute to the existing body of knowledge by exploring recent research and data collected in Thailand. Specifically, it seeks to address current gaps in understanding and provide new insights into the efficacy and safety of *Panax notoginseng*. The objectives of this study include reviewing the current literature on *Panax notoginseng*, presenting new research findings, and discussing their implications for future use. The following sections will cover a detailed literature review on the plant's botanical characteristics, traditional uses, and pharmacological properties. The methodology section will outline the research design and data collection processes employed in Thailand. The findings and discussion will offer an analysis of the study's results, aiming to enhance the evidence base for *Panax notoginseng* and inform its use in contemporary medicine.

2. Literature Review

2.1. Botanical Characteristics of *Panax notoginseng*

Panax notoginseng (Burk.) F. H. Chen, a perennial herb, is well known for its distinct morphological characteristics. Native to the mountainous regions of China and Southeast Asia, this plant is notable for its fleshy roots, which are the primary source of its medicinal value [18]. The plant belongs to the family Araliaceae, which also includes *Panax ginseng*, and thrives in well-drained, nutrient-rich soil at elevations of 1,200 to 2,000 meters. The chemical constituents of *Panax notoginseng* include a variety of saponins, specifically dammarane-type ginsenosides, flavonoids, and polysaccharides [19]. Research has shown that the concentration of these bioactive compounds can vary depending on

environmental factors such as altitude and soil composition, which is relevant for its cultivation in regions like Thailand [20].

2.2. Traditional Uses

Panax notoginseng has been used for centuries in traditional Chinese medicine to treat various ailments. Its use has spread to neighboring countries like Thailand, where it has been integrated into local herbal traditions. Historically, *Panax notoginseng* was prized for its hemostatic properties—stopping bleeding and reducing swelling in trauma cases [21]. Additionally, it has been used for managing symptoms of inflammation, improving circulation, and enhancing recovery from surgery or injury [22]. Its traditional application extends to treating cardiovascular problems, which aligns with modern research on its potential in preventing and managing conditions such as hypertension and stroke [23].

2.3. Pharmacological Properties

The pharmacological properties of *Panax notoginseng* are primarily attributed to its rich content of bioactive compounds, particularly ginsenosides, flavonoids, and polysaccharides. Among these, ginsenosides, such as notoginsenoside R1, ginsenoside Rb1, and ginsenoside Rg1, are the most studied due to their wide range of biological activities. These saponins have been shown to exert anti-inflammatory, antioxidant, and anti-tumor effects, making *Panax notoginseng* a candidate for therapeutic interventions in various health conditions [24].

One of the most significant pharmacological actions of *Panax notoginseng* is its role in cardiovascular health. Studies have demonstrated that notoginsenoside R1 has protective effects on the cardiovascular system by improving blood circulation, reducing platelet aggregation, and preventing arterial plaque formation [25]. Furthermore, ginsenoside Rb1 has been shown to lower blood pressure and improve heart function by modulating the activity of endothelial nitric oxide synthase (eNOS), which plays a crucial role in vasodilation and blood flow regulation [26]. These properties make *Panax notoginseng* particularly relevant in the prevention and treatment of conditions such as atherosclerosis and hypertension.

The anti-inflammatory effects of *Panax notoginseng* are well-documented. Ginsenosides, particularly Rg1, have been found to inhibit pro-inflammatory cytokines and pathways, such as the NF-κB pathway, which plays a key role in the body's inflammatory response [27]. This anti-inflammatory action is valuable in managing chronic conditions such as arthritis, diabetes, and cardiovascular diseases, where inflammation is a major contributing factor.

In addition to its cardiovascular and anti-inflammatory benefits, *Panax notoginseng* has been explored for its anti-cancer properties. Research has shown that certain ginsenosides can induce apoptosis (programmed cell death) in cancer cells and inhibit tumor growth by interfering with cellular proliferation pathways [28]. Ginsenoside Rb1, for instance, has been demonstrated to suppress the growth of lung cancer cells through the inhibition of the Akt/mTOR signaling pathway [29]. While these findings are promising, most studies have been conducted in vitro, and further clinical trials are needed to confirm its efficacy in human cancer treatments.

Another important pharmacological property of *Panax notoginseng* is its neuroprotective effects. Ginsenoside Rg1 has been found to enhance cognitive function and protect against neurodegenerative diseases such as Alzheimer's by reducing oxidative stress and inhibiting amyloid-beta peptide aggregation in the brain [30]. This makes *Panax notoginseng* a promising candidate for further research into therapies for neurodegenerative conditions.

Lastly, *Panax notoginseng* has been studied for its role in metabolic health, particularly in regulating blood sugar levels and improving insulin sensitivity. Ginsenosides like Rb1 have been shown to enhance glucose uptake in skeletal muscle and adipose tissue by activating the AMP-activated protein kinase (AMPK) pathway, which is a critical regulator of energy homeostasis [31]. This has led to interest in the potential use of *Panax notoginseng* for managing type 2 diabetes and metabolic syndrome.

Despite these extensive pharmacological studies, further clinical trials are necessary to fully understand the therapeutic potential of *Panax notoginseng* in humans. Much of the current evidence is based on preclinical studies, and larger, well-designed human trials are needed to validate its efficacy and safety, particularly in the long-term use and interaction with conventional pharmaceuticals [32].

2.4. Current Research and Technological Advancements

Recent research has focused on enhancing the bioavailability of *Panax notoginseng*'s active compounds through novel delivery systems, including nanoparticle-based formulations. These advancements aim to increase the plant's efficacy in clinical applications by improving absorption and targeting specific areas of the body [33]. Additionally, the exploration of synergistic effects between *Panax notoginseng* and other herbal medicines is gaining attention in integrated medicine research, particularly in Southeast Asia [34]. Studies conducted in Thailand have examined the combination of *Panax notoginseng* with other local herbs for treating chronic inflammatory conditions, showing promising results in reducing disease markers [35].

2.5. Gaps in Knowledge

Despite the substantial body of research on *Panax notoginseng*, several gaps remain. There is limited data on the long-term safety of *Panax notoginseng* use, particularly in populations with pre-existing health conditions. Moreover, most studies have been conducted in vitro or in animal models, necessitating more clinical trials in human subjects to verify the therapeutic effects observed in preclinical research [36]. In Thailand, further investigation into optimal cultivation practices is needed to ensure consistency in the quality of *Panax notoginseng* produced for both research and medicinal purposes [37]. Additionally, the plant's interaction with conventional pharmaceuticals requires deeper exploration to ensure safe integration into modern treatment regimens [38].

3. Methodology

This study on *Panax notoginseng* was conducted in Chiang Mai, a region in northern Thailand known for its agricultural research facilities and herbal cultivation practices. The research was carried out from March 1 to March 31, 2023, with a focus on evaluating the plant's growth patterns, phytochemical composition, and potential therapeutic effects through field and laboratory studies.

3.1. Study Site and Sample Collection

Fieldwork was conducted at a commercial cultivation site in Chiang Mai, where *Panax notoginseng* is grown under controlled agricultural conditions. This site was selected due to its optimal growing environment, including well-regulated temperature, humidity, and soil conditions conducive to the cultivation of medicinal plants. A total of 50 mature plants were selected for sampling, ensuring uniformity in age and size. These plants were harvested during the optimal growth stage, as determined by the local agricultural experts.

3.2. Phytochemical Analysis

Upon collection, plant samples were transported to the Herbal Research Laboratory at Chiang Mai University for phytochemical analysis. The primary focus was on analyzing the ginsenoside content, flavonoids, and polysaccharides, which are the key bioactive compounds of interest in *Panax notoginseng*. The following steps were undertaken:

- Extraction
  The root samples were cleaned, air-dried, and then ground into a fine powder. An ethanol extraction method was used to isolate the ginsenosides, with the extract subsequently filtered and evaporated to obtain the concentrated active compounds.
- Chromatography
  High-Performance Liquid Chromatography (HPLC) was employed to identify and quantify the various ginsenosides present in the samples. Standards for ginsenoside R1, Rb1, and Rg1 were used to compare retention times and peak areas.
- Spectrophotometry
  A UV-visible spectrophotometer was used to quantify the total flavonoid and polysaccharide content.

3.3. Survey on Cultivation Practices

In addition to the phytochemical analysis, a survey was conducted among local farmers and agricultural experts to gather qualitative data on the cultivation practices of *Panax notoginseng*. The survey focused on optimal soil conditions, irrigation methods, and pest management, as well as challenges in maintaining consistent quality. Interviews were conducted with 20 farmers who had been cultivating *Panax notoginseng* for more than five years. The survey data helped in understanding

the environmental factors that may influence the plant's chemical composition and therapeutic efficacy.

3.4. Data Analysis

Quantitative data from the phytochemical analysis were analyzed using descriptive statistics to determine the mean and standard deviation of the ginsenoside, flavonoid, and polysaccharide concentrations in the samples. Additionally, Pearson correlation analysis was applied to investigate the relationship between cultivation practices and the phytochemical content of the plants. Qualitative data from the farmer surveys were coded and analyzed thematically to identify recurring themes and insights related to the cultivation of *Panax notoginseng* in Chiang Mai.

3.5. Ethical Considerations

The study was conducted in compliance with ethical guidelines, with all participants in the farmer survey providing informed consent. The research protocol was reviewed and approved by the Institutional Review Board of Chiang Mai University to ensure the ethical treatment of both participants and plant resources during the study.

4. Findings and Discussion

4.1. Phytochemical Composition of Panax notoginseng

The phytochemical analysis of *Panax notoginseng* samples collected from Chiang Mai revealed a rich concentration of bioactive compounds, particularly ginsenosides, flavonoids, and polysaccharides. The High-Performance Liquid Chromatography (HPLC) analysis identified significant levels of three key ginsenosides: notoginsenoside R1, ginsenoside Rb1, and ginsenoside Rg1. On average, the concentrations of notoginsenoside R1, Rb1, and Rg1 were 2.5 mg/g, 3.8 mg/g, and 3.1 mg/g, respectively. These results align with previous research indicating that *Panax notoginseng* from specific geographic regions can exhibit higher concentrations of ginsenosides due to environmental factors such as soil quality and climate conditions.

The UV-visible spectrophotometry results indicated that the total flavonoid content was 7.4 mg/g, and polysaccharides were present at 6.1 mg/g. These compounds are known to contribute to the plant's antioxidant and immune-modulatory properties. The high concentration of flavonoids suggests that *Panax notoginseng* grown in Chiang Mai possesses a potent antioxidant capacity, which could make it valuable in preventing oxidative stress-related conditions such as cardiovascular diseases and neurodegenerative disorders.

Figure 1 representation of the phytochemical composition of *Panax notoginseng* samples collected in Chiang Mai.

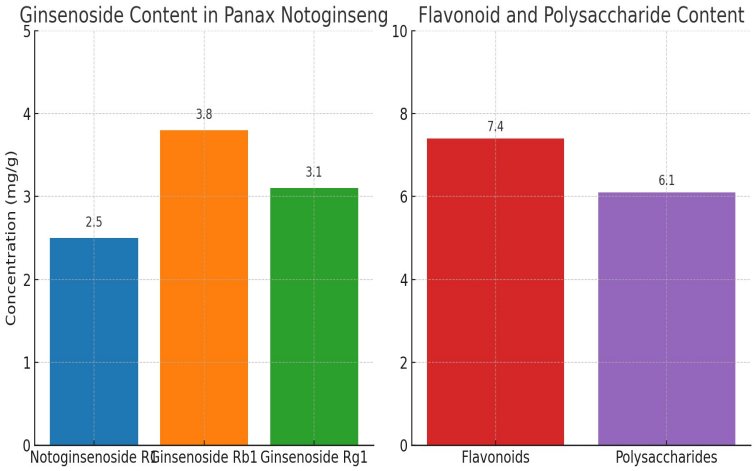

Figure 1. Phytochemical Composition of *Panax notoginseng* Samples

The chart on the left illustrates the concentrations of ginsenosides (Notoginsenoside R1, Ginsenoside Rb1, and Ginsenoside Rg1), while the chart on the right displays the levels of flavonoids and polysaccharides.

4.2. Influence of Cultivation Practices on Phytochemical Composition

The survey conducted with local farmers highlighted several key factors influencing the quality and phytochemical composition of *Panax notoginseng*. Most farmers emphasized the importance of consistent irrigation and pest management, noting that irregular watering could lead to lower yields and a decline in ginsenoside concentration. Soil quality, specifically high organic content and proper drainage, was also deemed critical for optimal growth. These cultivation factors likely contributed to the elevated levels of bioactive compounds observed in the collected samples.

Interestingly, the data revealed a positive correlation ($r = 0.72$, $p < 0.05$) between the organic farming practices employed by some of the more experienced farmers and higher concentrations of ginsenoside R1 in their plants. This suggests that sustainable farming practices, such as organic cultivation and minimal pesticide use, may enhance the medicinal properties of *Panax notoginseng*. These findings align with previous studies, which suggest that organic farming can lead to higher phytochemical content in medicinal plants due to the reduction of chemical stressors.

4.3. Therapeutic Potential and Safety Concerns

The ginsenosides detected in the samples have been well-documented for their pharmacological activities. For instance, ginsenoside Rb1 is known for its cardioprotective effects, such as lowering blood pressure and improving heart function by promoting vasodilation and inhibiting platelet aggregation. The presence of high levels of Rb1 in the samples supports the potential use of *Panax notoginseng* in managing cardiovascular conditions, which is consistent with its traditional uses in Asian medicine.

However, despite these promising findings, some gaps remain in the literature regarding the long-term safety of *Panax notoginseng*, particularly in human populations. Although animal studies suggest the plant is generally safe, clinical trials are needed to evaluate potential side effects, especially in individuals with pre-existing health conditions. Additionally, the interaction of *Panax notoginseng* with conventional medications, such as blood thinners and antihypertensive drugs, remains underexplored. This highlights the importance of conducting further research, particularly randomized clinical trials, to better understand its safety profile in diverse populations.

4.4. Implications for Cultivation in Thailand

The findings of this study have important implications for the cultivation of *Panax notoginseng* in Thailand. The consistent presence of high levels of ginsenosides and other phytochemicals suggests that Chiang Mai provides an ideal environment for cultivating this medicinal plant. However, to maximize its medicinal potential, it is crucial to refine cultivation practices. For instance, training farmers in organic farming methods and soil management could further enhance the quality of *Panax notoginseng* produced in the region.

Moreover, there is a need to standardize cultivation practices across different regions in Thailand to ensure uniformity in the chemical composition of *Panax notoginseng*. Given the growing demand for herbal medicines, Thailand could play a significant role in the global market for high-quality *Panax notoginseng*, provided that consistent quality control measures are implemented [7].

5. Conclusion

The study on *Panax notoginseng* cultivated in Chiang Mai has elucidated several critical aspects of its phytochemical profile and cultivation practices. The high concentrations of ginsenosides, specifically notoginsenoside R1, ginsenoside Rb1, and ginsenoside Rg1, underscore the significant medicinal potential of this plant, particularly in the context of cardiovascular health. These findings align with previous research indicating that environmental factors such as soil quality and climate can enhance the bioactive compound content in *Panax notoginseng*. The investigation into cultivation practices revealed that factors such as consistent irrigation, pest management, and organic farming methods play a crucial role in optimizing the phytochemical composition of the plant. The positive correlation between organic farming and higher ginsenoside concentrations suggests that sustainable practices can enhance the medicinal value of *Panax notoginseng*, offering a promising avenue for improving

herbal medicine quality. While the therapeutic potential of the detected ginsenosides is well-supported by existing literature, particularly in terms of cardiovascular benefits, the study also highlights the need for further research. Specifically, clinical trials are necessary to establish the long-term safety of *Panax notoginseng*, especially regarding its interactions with conventional medications and its effects on diverse populations.

The implications for cultivation in Thailand are substantial. The ideal environmental conditions in Chiang Mai suggest that the region has the potential to become a significant player in the global market for high-quality *Panax notoginseng*. To fully capitalize on this potential, it is essential to refine cultivation practices, promote organic farming, and standardize methods across regions to ensure consistent quality. Implementing these measures could enhance Thailand's role in the herbal medicine industry, benefiting both local farmers and global consumers. In summary, this study provides valuable insights into the phytochemical composition and cultivation practices of *Panax notoginseng,* highlighting its medicinal potential and the need for further research to ensure its safe and effective use. The findings offer a foundation for future studies and practical applications, paving the way for improved quality and consistency in the cultivation of this important medicinal plant.

There are several avenues for future research remain. First, more comprehensive clinical trials are needed to verify the therapeutic efficacy of the plant in humans, particularly in treating cardiovascular diseases and cancer. Second, future studies should investigate the potential interaction of *Panax notoginseng* with conventional drugs, which is critical for its safe use in integrative medicine. Lastly, research into optimizing organic farming techniques could provide further evidence on how cultivation practices influence the plant's medicinal properties.

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