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Allelopathic Medicinal Plants 1. *Panax ginseng*

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CONTENTS

ABSTRACT

Panax ginseng（Chinese ginseng) is precious traditional Chinese medicine in China, which is commonly used to treat central nervous system diseases, cardiovascular diseases, endocrine system diseases, cancer and other diseases. Due to its excellent medicinal properties, it is widely used in East Asia (Korea, China and Japan) as herbal medicine and also known as the king of medicinal herbs. This paper reviews the origin and distribution of ginseng in China, different cultivation methods, economic significance of ginseng industry and allelopathy research on ginseng. This paper also describes the economic importance of ginseng in medical and other uses, and suggests future research areas of ginseng.

Key words: Economic importance, ginseng distribution, ginseng industry, ginseng market, P*anax ginseng.*

1. INTRODUCTION

Panax ginseng C. A. Meyer (genus *Panax*, family Araliaceae) is an important medicinal plant (41) called the “King of herbs” as it provides nourishment and strength, invigorates qi and calm down Shen and anti-ageing effects (35,57,68). China is the birthplace of medicinal ginseng, recorded 4000 years ago. Ginseng cultivation and processing has a history of about 1600 years (95). The ginseng (wild ginseng) is mainly distributed in East Asia (China, Russia, Korea, Japan) and other countries (1) and was first produced and used in ancient China in Taihang Mountains in Hebei and Shanxi. In the Ming Dynasty (1368-1644AD), the wild ginseng in the Taihang Mountains was extinct due to the destruction of forest ecology. However, in the Qing Dynasty (1636-1912AD), wild ginseng was extensively developed in the Changbai Mountains of Northeast. Over the past 300 years,

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due to the continuous cropping problem in ginseng production in Changbai Mountain ginseng have been reduced year by year (3). Wild ginseng is still found in small quantities in Russia, but has largely disappeared in Japan and North Korea (58). Ginseng is cultivated mainly in China, Korea and Japan, among them, Chinese ginseng accounts for 70 % of the world's total production. The genus Panax was first named by Russian botanist Carl Meyer (36), originated from the Greek word Pan, meaning "All" and "Axos", meaning "Medicine", indicating that ginseng is good medicine for all diseases (8). This paper reviews the origin and distribution of ginseng in China, briefly introduces different cultivation Methods, allelopathy research on ginseng and economic significance of ginseng industry (4).

2. ECONOMIC IMPORTANCE

Ginseng has high medicinal and edible value. In addition to traditional Chinese medicine, ginseng is also used for food and health care products in many countries (1), hence, its demand has been increasing. In China, ginseng is not only used as Chinese herbal medicine for clinical treatment, but has also developed many ginseng health products, which brought considerable economic benefits to China. The ginseng root, stem, leaf, flower and fruit are also used as medicinal health Products. Because of its unique medicinal and edible value, ginseng occupies a certain market share in markets of various countries, this has extremely important economic significance (76). According to the statistics, the international market of ginseng is 6000 ~ 6500 t, in which American ginseng and ginseng occupy half. In ginseng market, China accounts for 80 % - 90 %, while, South Korea, North Korea and Japan account for 10 % - 20 %. But in general, the high-end market of ginseng products is occupied by Japan, South Korea and Europe (41). Ginseng industry is one of the important export industries in China. Chinese ginseng has large output, but has low value and weak competitiveness in international market than South Korean ginseng (54).

Ginseng is widely used in pharmaceutical research and development and functional foods owing to its high invigorating vitality, enhancing immunity, outstanding effects in nervous system, endocrine system and blood regulation and long-term use prolongs life. Its various nutrients and physiologically active substances and their efficient utilization meets the needs of modern people's daily medical care. As per the Chinese Pharmacopoeia (2020), now Ginseng Zaizao Pills are also available. There are 758 Chinese Patent medicines such as Shengmai Yin, Zhenyuan Tablets, Zhenyuan Capsules, Shenyi Capsules, and Ginseng Liquor. Ginseng is rich in ginsenosides, niacin and other ingredients, which improves the antioxidant activity of skin cells, delay ageing, and replenish collagen fibers and elastic fibers of the skin. In addition, amino acids, polypeptides, and multivitamins are used for developing natural, non-toxic cosmetics and as feed additives etc. Ginseng whiskers, steamed ginseng water, red ginseng and other products have strong whitening and moisturizing effects, hence, used in cosmetics. Thus ginseng provides broad market prospects for the in-depth development of ginseng industry in pharmaceutical research and development and functional products.

Jilin province is the planting base of Chinese medicinal materials in North China. Fusong County of Jilin Province is the hometown of Chinese ginseng, and the ginseng planting industry is one of the major industries in Jilin Province. The output of ginseng in Jilin province is > 98 % of the total output of Chinese medicinal materials in Jilin province (42). In 2020, the ginseng production in Jilin Province reached 39,500 tons (60 % of national production). There are > 300 processing enterprises (Yisheng Pharmaceutical, Kangmei Xinkaihe, Liuhe Zixin Pharmaceutical, Dunhua Aodong Pharmaceutical, Hunchun Huarui Ginseng) producing 1000 kinds of products including the health care products, cosmetics and biological products.

3. ORIGIN

Ginseng (genus Panax, family Acanthaceae) is a perennial herbaceous plant. It is a relict plant of the third age in the temperate northern hemisphere and has a history of 60 million years. The word “Shen” (Figure 1) is engraved on the fourth page of the seventh volume twenty-five of “*殷墟书契前编*”, a representative work of oracle bone inscriptions, which proves that China was the first country in the world to use ginseng and record it in written form, it is more than3500 years (7). This word is very vivid, not only the ginseng’s aboveground part, including its stem growing many (In ancient China, the “Three” usually represented the majority) stone fruit-like berries, but also the ginseng underground part, including ginseng roots, taproots, lateral roots. Ginseng has a fusiform or cylindrical fleshy root. Because it looks like a human, it has a head, hands, and feet, so it is called “人参” in Chinese (Figure 2). The Ming Dynasty (1368-1644AD)"*YiZong BiDu*" also recorded that "The human-shaped ginseng works best in herbal medicine". Because of its unique shape, excellent medicinal value and long history, ginseng has also derived many stories and

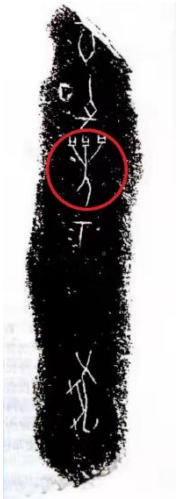


Figure 1. The word “Shen” in *Yinxu Shuqi Qianbian*

Figure 2. The complete plant of ginseng

legends related to ginseng. The mysterious description of ginseng and its growing environment was first recorded in "*Chunqiu Yundoushu*"(202 BC-220 AD). In the Southern and Northern Dynasty (420-589AD), ginseng has been linked with healing, forming a simple plot of legend. According to *Liang Shu* (vol. 51), a filial man named Ruan Xiaoxu came to Zhongshan to collect ginseng because his mother was ill. On the way, a deer guided him to get the ginseng. His mother got well after eating the ginseng. "Tai Ping Yu Lan" (vol. 991) also contains: During Emperor Wen of the Sui Dynasty (541-604AD), a family in Shangdang heard people calling from their backyards every night. They searched in the courtyard but found no one. But they found a branch of ginseng. After digging, they got a human-shaped ginseng. After digging away, they never heard the call again. In the Tang Dynasty (618-907AD), ginseng had developed into the terms "grass demon" and "goblin". Some people even described ginseng as being able to heal "unintelligent" and longevity "brown-clothed old men". These legends not only show the miraculous curative effect and important value of ginseng, but also reflect the psychological state and beautiful vision of the working people at that time, which are of profound significance (Table 1).

Table 1. Development chronology of ginseng in ancient China

Dynasty	Year	ancient books	ancient records
The Xia or Shang dynasties	2070-1046 BC	*Yinxu Shuqi Qianbian*	It's engraved with the word "Shen."
Han dynasty	202 BC-220 AD	*Chunqiu Yundoushu*	Ginseng and its growing environment were described
Northern and Southern dynasties	420-589AD	*Liang Shu*	There are some legends that ginseng can cure diseases
Tang Dynasty	618-907AD		ginseng had developed into the terms "grass demon" and "goblin".

Records of the medicinal value of ginseng first appeared in the *Shennong Bencao Jing* in the Eastern Han dynasty (25-220AD), which is one of the oldest classics in the history of herbal medicine in the world (66). Li Shizhen synthesized the available data, and made a systematic and comprehensive description of the medicinal value of ginseng in *Bencao Gangmu*. In the record of traditional Chinese medicine, ginseng can be used for the defense and treatment of various diseases, with tonic and strong, blood coagulation and anti-aging effects, etc (9,34). The medicinal value of ginseng in modern medicine has been gradually confirmed (74). Due to its therapeutic effects (14), which are attributable to anticancer (38,55,65), antidiabetic (13,18), antistress (19,62), antioxidant (11,26), and immunomodulatory (32) activities. In recent years, ginseng and American ginseng in the United States and other Western countries have become popular dietary supplements (33). Ginseng is widely recognized for its intrinsic medicinal value and magical legend in oriental traditional culture, which is regarded as the essence of heaven and earth and the crystallization of nature. Therefore, ginseng is not only an important traditional Chinese medicine, but also a cultural symbol in the traditional Chinese medicine system.

4. DISTRIBUTION

Ginseng is a perennial herb (Araliaceae family), distributed in China, North Korea, South Korea, Japan, eastern Russia and other places (Table 2). Among them, China and South Korea are the two major countries with the largest ginseng cultivation area in the world. In Chinese history, there were two major producing areas:

(i). Shangdang County (present-day Shanxi, Hebei, Shandong and other provinces) i.e. Central Plain region,

(ii). Liaodong (present-day Jilin, Liaoning, Heilongjiang) i.e. Northeast region.

Table 2. Time of origin of Panax ginseng in major growing countries

Country	Time of origin	Name of medicinal material	Main producing area
China	Around 400 AD	Common ginseng, Biantiao ginseng, Shizhu ginseng	Jilin, Liaoning, Heilongjiang, Shanxi, etc.
Korea	1567-1608 AD	Korean ginseng	Buyeo County, Chungnam-do, Gyeongbuk-do
Japan	18th century	Oriental ginseng	Nagano, Fukushima, Shimane
North Korea	16th century	Korean ginseng	Jeollanam-do, Kaesong, Ryanggang-do
Russia	Early 20th century	Russian ginseng	Ussuri River Region in the Far East

Nowadays, China accounts for about 70 % of the ginseng cultivation in world. However, ginseng planting areas are mainly concentrated in the Changbai Mountains in the northeast region (121°~134° east longitude and 38°~47° north latitude, middle temperate zone). Jilin province is the main producing area (67), its Yanbian, Baishan and Tonghua are the main producing areas. The main ginseng varieties are : big horse teeth (Yanbian, Fusong County and Tonghua) and two horse teeth and Biantiao (Ji'an), while Goryeo ginseng (South Korea).

Among these production areas, the planting area, yield per unit area and total yield of ginseng in Changbai Mountain area rank first in the world. Jilin province is the major ginseng production base in China accounting for 80 % of the total output of ginseng in China (44). In 2014, the fresh ginseng production in Ji'an City was 4000 t increased to 4800 t in 2018, however, the planting area of under-forest ginseng remained stable at 10,000 ha (Table 3). Ginseng is now widely cultivated in Heilongjiang, Jilin and Liaoning and introduced in Hebei and Shanxi. In addition, ginseng is also distributed in the Far East Russia, North Korea, South Korea and Japan. Wild ginseng is now endangered due to long term over-harvesting gown mainly in Eastern Asia, including Northeast China, the Korean Peninsula, and the Far Eastern Federal District (45).

Radix Ginseng, also known as wild ginseng, is defined in the Pharmacopoeia of the People's Republic of China as the whole growth process of ginseng in a natural environment, without artificial control and management, not seriously harmed by natural growth. Wild

Table 3. Ginseng acreage in different growing systems in Ji'an, Jilin province, China (2015-2018)

Year	Fresh ginseng yield/t	Ginseng area (hm^2)		
		Under forest	Woodland	Non-woodland
2015	4000	10000	746	1000
2016	4000	10000	733	1000
2017	4000	10000	667	1067
2018	4800	10000	467	1067

ginseng grows in a special environment, most of which grow in the mountain area under the broad-leaved mixed forest, where the light is weak, the humidity is moderate, the soil humus content is high, the structure is loose, and the acidity is weak (72). Wild ginseng was once widely distributed in eastern and northern Asia. However, in the 1980s, due to the reduction of forest area and over exploitation, wild ginseng germplasm resources faced the dilemma of withering and extinction. Due to slow individual development and low self-reproduction ability, wild ginseng has become a very rare plant, and was listed as a national rare and endangered plant in 1992(53). At present, only a few wild ginsengs are distributed in Northeast China, Korean Peninsula and far east of Russia (98,99). Wild ginseng is a rare Chinese medicinal material with high medicinal value, and it has been paid more and more attention because of its unique traditional Chinese culture (7). Ginseng under forest is a semi-wild ginseng that is harvested after about 10 years by artificially sowing ginseng seeds into the natural environment and allowing it to grow naturally. Its quality is comparable to pure wild ginseng of the same age. Traditional ginseng planting is cutting forests and reclaiming new land to plant ginseng, causing serious soil erosion and causing serious damage to the balance of the ecosystem. With China's gradual restrictions on the available forest land for logging and planting ginseng, farmland planting will become the main model for the development of the ginseng planting industry, and it is also an inevitable trend for the development of my country's ginseng industry.

5. CULTIVATION

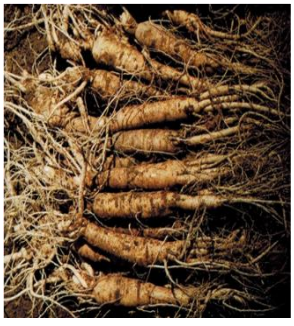
Ginseng under forest	Mountain ginseng	Garden ginseng
		

Figure 3. Types of ginseng plants roots obtained from different planting methods

Over the years the ginseng cultivating has been improved (96). The cultivated ginseng planting methods can be divided into (i). Ginseng under forest, (ii). Mountain ginseng and (iii). Garden ginseng (Figure 3).

(i). Ginseng under forest: This method refers to the natural growth of wild ginseng seedlings transplanted under the forest, and its growth environment is similar to that of wild ginseng. The seeds are germinated in artificial environment, and then its 1-3 years old seedlings are transplanted in the environment of forest.

(ii). Mountain ginseng: In this method, ginseng grows naturally in deep mountains and dense forests and grows up to 30-Years. The seeds of mountain ginseng are mainly spread naturally by wind, water, birds and animals, and the germination is very low. Moreover, its growth is very slow, hence, grows up to 30- Years. During its growth, it not only suffers from natural disasters such as freezing, heavy rain and diseases, but also trampled by animals and attacked by insects. Thus, the survival rate is very low and the surviving ginseng plant has strong vitality. Under ideal growing conditions, mountain ginseng may grow for longer period.

(iii). Garden ginseng: Compared with the forest ginseng and mountain ginseng, the garden ginseng is sown and grown in controlled in the artificial environment. This method refers to ginseng that is artificially planted and cultivated in the ginseng garden, and its growth period is 4-6 years. Although the quality of Garden ginseng is not as good as the forest ginseng and the mountain ginseng. It is the main source of Panax ginseng in market because of its advantages of easy planting, fast growth and high yield (12,58,59,60,82).

5.1. GINSENG PLANTING METHODS

In garden grown method, the crop is planted by 3-methods: Common ginseng, Biantiao ginseng and Shizhu ginseng (Figure 4).

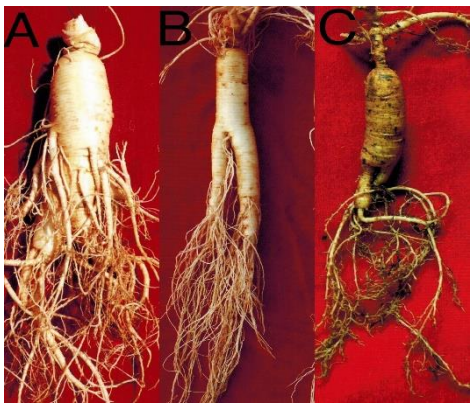


Figure 4. Types of garden ginseng. A: Common ginseng; B: Biantiao ginseng; C: Shizhu ginseng

5.1.1. Common ginseng: It is mainly produced in Fusong County, Jingyu County and Changbai Korean Autonomous County of Jilin province. Its seedlings are raised in Nursery for 2 or 3 years, then transplanted and harvested after 6 years. It is cultivated in very high organic matter humus soil. It has short main root, short branch roots and many fibrous roots. It has fast growth, high yield and strong cold resistance.

5.1.2. Biantiao ginseng: Biantiao ginseng is mainly produced in the Ji'an ginseng planting area of Jilin province. It is transplanted twice and the seedlings are raised for 2 or 3 years. When transplanting, long-shaped ginseng seedlings (two horse teeth and long-neck ginseng varieties), without fibrous roots on the main root are selected. These transplanted seedlings are harvested after 6 to 8 years. It is cultivated in the mountainous area (slope > 20 °), sandy loam soil with less organic matter, poor fertility and low soil water content. It is characterized by long rhizome, long taproot, long branched root and few fibrous roots. Its commodity price is about 2 times than common ginseng.

5.1.3. Shizhu ginseng: It is mainly produced in mountains of Huanren County, Liaoning province. It is sown by direct seeding or seedling transplanting. Its natural conditions are unique, the soil is sandy, and plantation area is near river, with high air humidity. Although its growth rate is slow, hence longer crop duration and yield is low, but is tolerant to stresses.

5.2. GARDEN GINSENG

Garden ginseng can also be divided into following 4-categories as under (Figure 5):

Figure 5. Farm varieties of ginseng (A is big horse teeth; B is two horse teeth; C is round bladder round reed; D is Long neck)

5.2.1. Big horse teeth: Its taproot and rhizome are short and thick, with large stem scars, many fibrous roots and high root yield（Figure 6). It is the main variety of ginseng, cultivated in Jilin Province.

Figure 6. The plants of big horse teeth variety

5.2.2. Two horse teeth: Its taproot and rhizomes are long and thin, with small stem scars and low yield.

5.2.3. Round bladder round reed: It has long rhizomes, round bladders, beautiful roots, short plants and low yield.

5.2.4. Long neck: It has thinner rhizomes, longer whiskers, slow growth and low yield.

6. ALLELOPATHY RESEARCH

Allelopathy refers to the beneficial or unfavorable effects of metabolic secretions of plants or microorganisms on other plants or microorganisms in the environment (97). The allelopathic effects of ginseng are mainly autotoxic (71), which inhibits its own seed germination, callus growth, root tissue vigour, seedling growth, root enzyme activity and reduces yield and quality of ginseng (37,71,87). The allelopathic autotoxicity is one of the main reasons for the Continuous Cropping Problem of ginseng.

6.1. Continuous cropping problem: The continuous cropping problem has long hindered the development of ginseng industry. This problem is the result of the combined effects of ginseng-soil-microbes and other factors. Therefore, the study of allelopathic effects of ginseng is of great significance to solve the continuous cropping obstacles of plants. In higher plants, the allelopathy affects following 6-aspects (70):

(i). Affects the antioxidant enzyme system and cell membrane permeability (87,88).
(ii). Affects the absorption of water and nutrients (21,80).
(iii). Affects the hormones in plants (45).
(iv). Affects Cell division, elongation and submicroscopic structure (89).
(v). Affects photosynthesis and respiration (20,27,83,90).
(vi). Affects gene expression and protein synthesis (69,93).

After the crop harvest, the soil cannot be replanted with ginseng crop for several years or even decades (30) otherwise, it will be infested with many diseases and will have low yields (81). After planting ginseng crops, the following changes occurred in the physicochemical properties of the soil, namely (i). Deficiencies of micro and macro elements, (ii). Nutrient imbalance, (iii). Changes in soil physical properties, etc. (79). When continuous cropping problem occur in ginseng, crop yield and quality are reduced. In recent years, although the duration of continuous cropping problem has been shortened, but this problem has not been solved (91,92). The following are the major causes of Continuous Cropping Problems:

6.1.1. Changes in soil physico-chemical properties

Long-term continuous planting of ginseng destroys the basic structure of soil aggregates, resulting in deterioration of soil physico-chemical properties viz., soil compaction, reduced permeability etc (43). In the long term, the ginseng soil absorption capacity will decrease, the ability to store nutrient elements and organic matter will decrease, and these will adversely affect the growth and development of plants. With the increase in continuous replanting years of ginseng, the soil nutrients (organic matter, total nitrogen, carbon to nitrogen ratio, available silicon, etc.) decreases (24).

6.1.2. Soil acidification

The suitable soil pH range is 5.5-6.5 for ginseng growth. The soil acidification is one of the main reasons for continuous cropping problem in ginseng. Acidic soil increases the occurrence of ginseng root diseases and many other soil-borne diseases (15). The ginseng crop decreases the soil pH due to the concentration of $NH4^{+}$ and decrease in soil organic matter (28). Soil acidification decreases the activity of various beneficial soil enzymes (dehydrogenase, protease, and β-glucosidase) (43). When the forest land is used for ginseng cultivation, the soil organic carbon, total nitrogen, available potassium and other nutrients and soil pH are significantly reduced. This was because the ginseng crop absorbs the soil nutrients for its growth and development and hence, the nutrient elements became imbalanced, besides ginseng also results in the soil acidification (47).

6.1.3. Soil nutrients deficiency

Ginseng crop absorb nutrients from the soil, resulting in their deficiency. However, the unabsorbed elements will continue to accumulate, making the soil nutrients unbalanced in continuously cropped soil (43). In continuous cropped ginseng soil, Fe, Mn, Zn, Cu, K and Bo were decreased. Mainly boron decreased significantly, followed by Zn, Mn, Fe and Cu. The Continuous cropping of ginseng results in the depletion of soil nutrients, leading to the deficiency of nutrients and which adversely affects the normal growth of ginseng, which may be one of the reasons for Continuous Cropping Problem (29).

6.2. Allelopathy

Allelopathy means that a living plant releases some chemical substances into the environment through the volatilization of the above-ground parts and the secretion of roots to affect the growth and development of surrounding plants (40). The main routes of release of allelochemicals are: (i) Leachates from stem, branches, leaves, (ii) volatilization from leaves, (iii). Roots secretions and (iv). Release from decay of plant residues. Among them, ginseng allelochemicals are mainly roots secretions. For example, the rice stalk produces toxic substances during the decomposition process, which inhibits the growth of rice (10). *Casuarina equisetifolia* secretes allelopathic flavonoids, which are not only auto-toxic, but also inhibitory to other plants (17). In continuous cropping of medicinal plants, the auto-toxic substances continue to accumulate in rhizosphere, and this changed the soil micro-ecological environment, which adversely affects the normal metabolism of plants and eventually leads to Continuous Cropping Obstacles (43). Among them, phenolic acids are the most active allelopathic substances. Studies have shown that the allelochemicals secreted by ginseng are mainly autotoxic phenolic acids, which not only inhibits the seed germination and seedling growth, but also promotes the growth of hyphae and spore germination of the pathogen of ginseng rust rot (50).

Phenolic acids in root exudates also play important roles in plant autotoxicity and Continuous Cropping Problem (72,73). Li *et al*. (48) isolated and identified phenolic acids such as benzoic acid from the rhizosphere soil of ginseng. Long *et al.* detected 7-common phenolic acid compounds (Benzoic acid, benzoic acid, cinnamic acid, ferulic acid, salicylic acid, vanillic acid, P-Hydroxybenzoic acid and vanillin). These compounds confirmed that these phenolic acid compounds have allelopathic and autotoxic effects on the growth of ginseng. In ginseng allelopathy, when the concentration is low, it promotes the growth of ginseng, and when the concentration is high, it inhibits the growth of ginseng (50).

6.2.1. Increased soil borne diseases

In continuous cropped soil, the microorganisms are influenced: number of bacteria decrease, while, fungi increase (46). Zhang *et al*. (84) found that the occurrence of ginseng red skin disease and ginseng rust rot were related to the abnormal microbial flora in the root zone soil and root surface soil of ginseng. With the increase in ginseng planting years, soil-borne diseases increases and the total number of actinomycetes also increases. This may be because the continuous cropping f ginseng make the soil a good breeding and parasitic place for pathogenic microorganisms. The number of pathogenic microorganisms in the soil increases and they gather on the roots of ginseng, which causes the Continuous Cropping Obstacles to intensify, when ginseng is repeatedly grown. Continuous cropping of ginseng is not conducive to the survival of beneficial bacteria. The decrease in the number of beneficial bacteria greatly reduces the defence ability of ginseng against soil-borne diseases, thus making ginseng vulnerable to pathogens infections (48,87).

7. FUTURE RESEARCH AREAS

(i). Strengthen the development and clinical application of ginseng, to increase research and development of traditional Chinese medicine
(ii). innovation and upgrading of pharmaceutical aspects to enhance the application value of ginseng,
(iii). Exploration and development of non-medicinal parts of ginseng such as stems, leaves, buds and fruits, and explore their uses as new resources food, to utilize the whole ginseng plant,
(iv). Sustainable and healthy development of ginseng and to establish a standardized system for the development of ginseng industry,
(v). Enhance the added value of ginseng industry and promote the modern development of ginseng industrialization.

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CONFLICT OF INTEREST

The authors declare no conflict of interest. All authors agree to publish it.

DECLARATION

We declare that all authors of this Ms. have made substantial contributions. We did not exclude any author who substantially contributed to this Ms. We have followed our ethical norms established by our respective institutions.

ETHICAL APPROVAL

The authors declare that the study was carried out following scientific ethics and conduct. However, this study did not involve any use of animals, hence no ethical approval has been obtained from the concerned committee.

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