



## Review

## Research and application of leek roots in medicinal field

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## ABSTRACT

Some Chinese herbs have been used to prevent and treat diseases, and are also used as common food ingredients. These Chinese herbs are potential resource for research and development of new drugs. Leek roots is a typical medicine of food and medicine continuum. It has a long history of medicinal applications and edible food in China. In this paper, the origin, biological active components, pharmacological action and clinical application of leek roots were introduced. We hope that this review will contribute to the development of leek roots for pharmaceutical research and clinical applications, as well as related health products.

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## 1. Introduction

Roots and bulbs of leeks (*Allium tuberosum* Rottl. ex Spreng) (Fig. 1A and B, and Fig. 2) are traditional Chinese herbs and common vegetables in China with a long history. It can be used directly after cleaned and dried after harvested. They have good nutritional and medicinal values. In terms of food, leek leaves are the main edible part, and the bulbs above roots are often eaten after food processing. Yellowish leeks (Fig. 1C and D)- *A. tuberosum* that farmers of Gansu Province, China, cultivated in winter are edible in the above ground part and the part of roots (Li, 2015). Leek roots are warm in nature and pungent in flavor. The *Compendium of Materia Medica* by Shizhen Li (1518–1593) recorded that cooked leek roots can reconcile viscera, help appetizing, stop bleeding pus, treat abdominal pain. Juice of leek roots can detoxify and treat chest pain untouchable, rabies, poisons of snake, scorpion, pest (Li, 2005). At present, the incidence of cardiovascular and cerebrovascular diseases is increasing in China and other developing countries. The leek roots have the effects of promoting blood circulation and removing blood stasis, which can be used for the treatment of cardiovascular and cerebrovascular diseases. Therefore, through the review of leek roots, we can explore the therapeutic value and clinical application value of leek roots, and even develop new drugs.

Fifteen compounds were isolated and identified from leek roots, including sulfur compounds, phenolic compounds, lignan compounds, unsaturated fatty acids and saponins (Ma, 2012). They

showed various pharmacological activities such as antibacterial, antioxidant, vascular endothelial protection and expectorant action.

## 2. Botanical resources

The roots and bulbs of *A. tuberosum* and the related species have been used for the medical purpose since 960, and now *A. tuberosum* is the major species of leek roots (Lan et al, 2020). The species of leeks including *A. tuberosum*, *A. senescens*, *A. anisopodium* and *A. tenuissimum* were largely cultivated during the Song and Ming Dynasties (A.D. 960–1644) (Lan et al., 2020) (Fig. 3). Now the leek roots are mainly from *A. tuberosum*, according to *Chinese Materia Medica*. At present, leeks are cultivated in most areas of Gansu, Sichuan and Yunnan provinces in China (Song, 1999).

## 3. Chemical composition

Leek roots are the Chinese herb of food and medicine continuum, rich in nutrients and bioactive components.

### 3.1. Nutritional ingredients

Studies showed that in every 100 g fresh roots, water content was 81.8 g, sugar 2.43 g, crude protein 1.51 g, cellulose 0.73 g, ascorbic acid 3.3 mg, phosphorus 74 mg, calcium 26 mg, and iron 1.82 mg (Zhou, Liu, & Xue, 2017). And a small amount of volatile



Fig. 1. Roots and bulbs of leeks in March (A and B) and yellowish leeks (C and D) (Pictures were from <https://image.baidu.com/>).

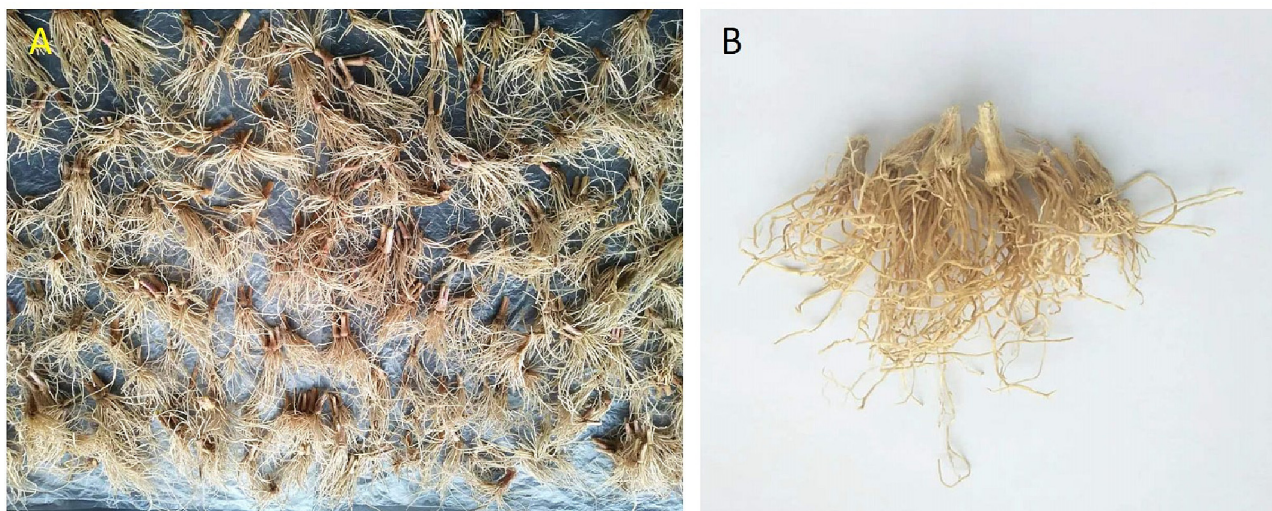


Fig. 2. Fresh (A) and dried (B) leek roots.



**Fig. 3.** Some related species of *A. tuberosum*. A, *A. senescens*; B, *A. anisopodium*; C, *A. tenuissimum* (Pictures were from <https://weibo.com/u/2566240181>).

oil leads to a unique flavor (Kim et al., 2016; Mnayer et al., 2014; Wang & Feng, 2002). Its abundant crude fibers can promote intestinal peristalsis and prevent constipation; vitamin, phosphorus, calcium, iron and other trace elements have positive effects on male sexual function (Zhang, Shi, Xu, & Shan, 1996).

### 3.2. Active compounds

Sulphur compounds are the main active substances in leek roots followed by phenolic compounds and lignin compounds. Ma (2012) isolated 15 compounds from the ethyl acetate portion of leek roots, largely including five acid compounds 1–5, two ester compounds 6 and 7, one lignin compound 8, two alcohol compounds 9 and 10, two ketone compounds 11 and 12, sterol compounds 13 and 14, and two sulfur compounds 15 and 16 (Fig. 4). Although there are few studies on the chemical constituents of leek roots, we speculated that the components were accumulated more in roots than in leaves, because the roots are older than the leaves.

#### 3.2.1. Sulphur compounds

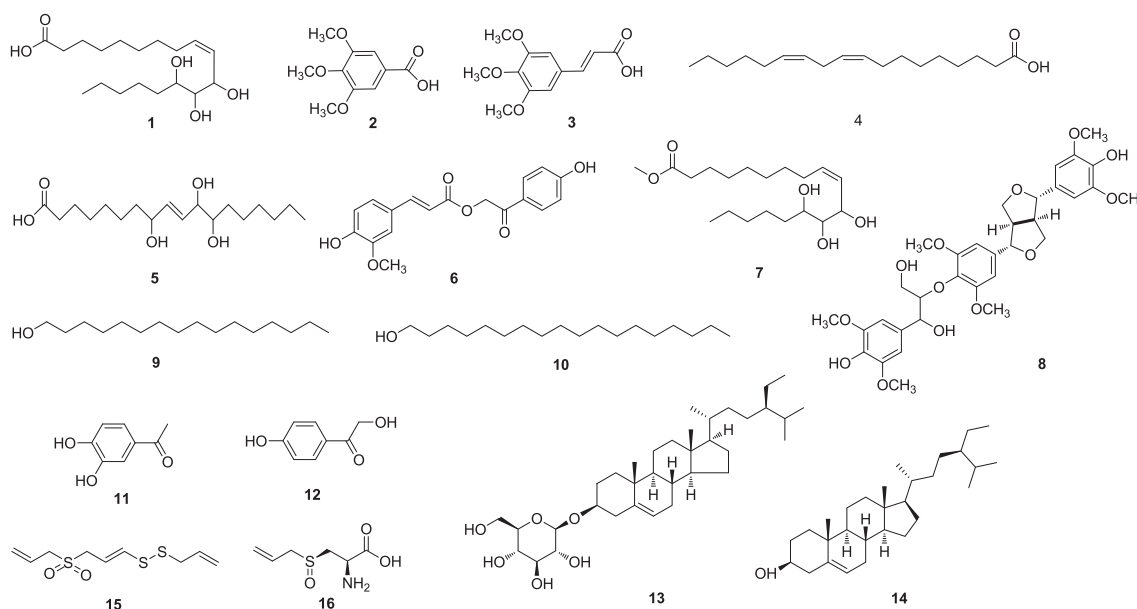
The volatile oil of leek roots contains a lot of sulfur compounds, and the main content of volatile oil is disulfide, trisulfide; less tetrasulfide content (Wang & Feng, 2002). Liu, Zhou, Liu, & Liu, 2015 found the principal constituents of leek roots volatile oil were allyl methyl trisulfide (35.19%), diallyl disulfide (28.31%) (15), diallyl trisulfide (20.91%), and dimethyl trisulfide (12.33%). All these proved that the content of sulfur compounds in leek roots was very rich (Table 1).

#### 3.2.2. Phenol compounds

Xie et al. (2022) found two phenolic compounds in the volatile oil of leeks, of which the volatile oil of leeks is particularly abundant in leek roots.

#### 3.2.3. Lignin compounds

Buddlenol D (8) is a sesquiterpene, showing anti-tumor, anti-inflammatory and neuroprotective activities (Zhang, Li, Lin, &



**Fig. 4.** Some compounds extracted from leek roots, (Ma, 2012). Acid compounds: (E)-11,12,13-trihydroxy-9-octadecenoic acid (1), 3,4,5-trimethoxybenzoic acid (2), 3,4,5-trimethoxyphenyl acrylic acid (3), linoleic acid (4) and tianshic acid (5). Ester compounds: 4,8-dihydroxyacetophenone-8-O-ferulic acid ester (6) and (E)-11,12,13-trihydroxy-9-octadecenoic acid methyl ester (7). Lignin compound: buddlenol D (8). Alcohol compounds: hexadecanol (9) and octadecanol (10). Ketone compounds: 3,4-dihydroxyacetophenone (11) and 4,8-dihydroxyacetophenone (12). Sterol compounds: daucosterol (13) and  $\beta$ -sitosterol (14). Sulfur compound: (E)-1-allyl-2-(3-allylsulfonyl) prop-1-en-1-yl) disulfane (15) and alliin (16).

**Table 1**  
Chemical constituents of essential oil of *A. tuberosum* roots (Liu, Zhou, Liu, & Liu, 2015).

| Compounds                 | Content (%) |
|---------------------------|-------------|
| Allyl methyl sulfide      | 0.06        |
| Dimethyl disulfide        | 0.09        |
| Diallyl sulfide           | 0.13        |
| Allyl isothiocyanate      | 0.08        |
| Allyl methyl disulfide    | 0.17        |
| Methyl propyl disulfide   | 0.09        |
| Dimethyl trisulfide       | 12.33       |
| 1,3-Dithiane              | 0.09        |
| Diallyl disulfide         | 28.31       |
| Dipropyl disulfide        | 0.12        |
| Allyl methyl trisulfide   | 35.19       |
| Methyl propyl trisulfide  | 0.08        |
| Dimethyl tetrasulfide     | 0.15        |
| Diallyl trisulfide        | 20.91       |
| Diallyl thiosulfinate     | 0.08        |
| Dipropyl trisulfide       | 0.08        |
| Allyl methyl tetrasulfide | 0.06        |
| Diallyl tetrasulfide      | 0.16        |
| Total identified          | 98.18       |

Wang, 2007). Several lignan compounds were also isolated, however they were not identified due to purity. Ma (2012) speculated that many lignan compounds were accumulated in leek roots, however they were hard to be isolated and identified due to small molecules and very close in polarity.

#### 3.2.4. Unsaturated fatty acids

The fat-soluble volatile components of leek roots contain a large amount of unsaturated fatty acids (4), among which the contents of *n*-hexadecanoic acid (12.81%) and (*Z,Z*)-9,12-octadecadien-1-ol (11.72%) are high. Those unsaturated fatty acids have certain effects on reducing blood lipids, preventing atherosclerosis, relieving arrhythmia, and ensuring brain development in infants (Ma, 2012).

#### 3.2.5. Saponins

*Chinese Materia Medica* (Song, 1999) records that the bulb parts of leek roots contain saponins which are mostly colorless or milk-white amorphous powder, and only a few are crystals. Most of them have bitter and spicy tastes, and have strong irritation to human mucosa and especially to nasal mucosa. Most of them have hygroscopicity and most triterpenoid saponins are acidic. Saponins are composed of sapogenin and sugar chains. According to the different aglycones, saponins can be divided into triterpenoid saponins or steroid saponins. The aglycone of triterpenoid saponins is triterpenoid compound, and the aglycone of steroid saponins is helical sterane compound. Saponins are a class of natural products with high pharmacological activities, such as enhancing immunity, reducing cholesterol, lowering blood glucose, hemolysis, antioxidant, antiviral, anticancer, anti-inflammatory, anti-allergic, prevention and treatment of cardiovascular diseases, treatment of leukemia, etc. Drugs with saponins as their main components are now widely used (Cai, 2017).

### 4. Clinical application in TCM

Outdoor-planted leeks can be harvested in spring, summer and autumn in the northern China and throughout the year in the southern China, while the greenhouse can be harvested throughout the year. Stems and leaves above bulbs have to be cut off when leeks were digged. The roots and bulb parts of leeks are kept with cleaned and dried, and then freshly used.

Leek roots dosage is as follows: the daily dosage is 3–9 g, and the daily dosage of fresh leek roots is 15–60 g. For internal use, it can be decocted in soup or mashed with fresh products to take juice. And when external use is required, the appropriate amount, grams that can cover the affected area with 1 mm thickness, should be smashed before applied to the affected area, or powdered into paste when treating hot ironing.

Leek roots are acrid in flavor, and warm in nature with function of warming liver and tonifying kidney, warming the Middle Energizer, promoting flow of *qi* and dispersing blood stasis. They can be used in combination with other herbs to treat a variety of diseases, including fever, headache, abdominal distention, upset, bronchitis, cough, cholecystitis, acute chest pain, constipation; trauma, joint pain, soft tissue injury, hemorrhoids anal fistula; toothache, nasal bleeding, alopecia, and skin diseases; leucorrhea anomaly; ascariasis, mosquito bites, rabies.

Leek roots can be used to treat fungal diseases. Sulfides and saponins have strong inhibitory effects on *Mucor mucedo* (Liu, Zhao, Su, Wang, & Zhang, 2006), *Colletotrichum gloeosporioides*, *Rhizoctonia solani* and *Penicillium citrinum*. Thirty-six patients with acute ankle sprain including five patients with severe ankle sprain were treated by using fresh leek roots (Gong, 1996). The fresh leek roots were used at a dose depending on the size of the sprain site. The mashed leek roots are mixed well with an appropriate amount of flour, and made into a thick paste with yellow rice wine, and then are affixed upon the sprained part. The results showed that 36 patients were cured within 5 d. Huang et al. (2006) found that leek roots solution could reduce the damage of gastric mucosa induced by reserpine, increase SOD activity, and reduce MDA content, which had obvious protective effect on gastric mucosa damage in rats. Its mechanism may be related to its anti-lipid peroxidation damage. Yang (2014) found that self-made Dilong Jiugen Ointment, the cast that earthworms produce feeding on leek roots was superior to Acyclovir Ointment in treating herpes zoster.

### 5. Diet application

The bulb part of leek roots can be used as food materials with the stems and leaves of leeks. After cooking, it becomes a variety of delicious foods on the Chinese table, such as leek dumplings, steamed bun with leeks, leek cake, leek box, leek fried eggs, and leek fried meat (Fig. 5). The salted leeks made from chopped and salted leeks are the essential condiment for the Jiangshui Noodles of Gansu Province in summer. After pickled, leek roots are often used as local delicacies that can be eaten directly and made into some local characteristics dishes, such as dried leeks chicken and leek roots fried meat in Guizhou Province, China. And in Sichuan Province, there are pickled leek roots with meat, pickled leek roots double cooked pork, etc (Zhou et al., 2017). Although leek roots are not eaten as wide as leek leaves, it is unique and delicious. Moreover, these leeks-based dishes can promote intestinal peristalsis to prevent and treat constipation. Their aphrodisiac action can prevent male function decline.

### 6. Pharmacological activities

#### 6.1. Antibacterial effects

The volatile oil and extracts from leek roots have obvious antibacterial activity. The volatile oil of leek roots has significant inhibitory effects on some pathogens that are transmitted by food, such as *Escherichia coli*, *Salmonella enterica*, *Shigella dysenteriae*, *Staphylococcus aureus*, *Pseudomonas aeruginosa*, *Streptococcus suis*, and can also inhibit some fungi such as *Aspergillus flavus* Link, *Aspergillus niger*, *Penicillium citrinum* Thom and *Rhizopus nigricans* Ehren-



**Fig. 5.** Some foods made of leek roots. A, leek dumplings; B, steamed bun with leeks; C, leek cake; D, leek box; E, leek fried eggs; F, leek fried meat (Pictures were from <https://image.baidu.com/>).

berg. Wang et al. (2010) found that leek roots have significant antibacterial activity on *E. coli*, *S. enterica*, *S. dysenteriae*, *S. aureus*, *P. aeruginosa* and *S. suis* compared with eight Chinese herbal medicines such as *Taraxaci Herba* (Pugongying in Chinese), *Lonicerae Japonicae Flos* (Jinyinhua in Chinese), *Artemisiae Argyi Folium* (Aiye in Chinese), herbs of *Allium tuberosum*, leaves of *Solanum melongena*, *Momordicae Charantiae Fructus* (Kugua in Chinese), *Lasiophaera Calvatia* (Mabo in Chinese) and flowers of *Jasminum sambac* *in vitro*. And the diameter of inhibition zone of the full fresh herbs was greater than 16.6 mm, and the diameter of inhibition zone of leek roots was greater than 9.1 mm, showing that the leek roots have potential broad-spectrum antibacterial activity. And the effective components in leek roots have synergistic effect. Rattanachaikunsopon & Phumkhachorn (2008) observed that diallyl sulfides (diallyl monosulfide, diallyl disulfide, diallyl trisulfide, and diallyl tetrasulfide) of the volatile oil were abundant in leek roots and responsible for antibacterial activity (Liu, Zhou, Liu, & Liu, 2015; Wang & Feng, 2002).

*Chinese Materia Medica* (Song, 1999) recorded that leek roots contain alliin that can be converted into allicin under the action of garlic enzyme and shows strong antibacterial effect. The antibacterial range is wide, and it has inhibitory effect on a variety of gram-positive and negative bacteria, and it is also effective for fungi, rickettsia and Amoebae. Modern medical studies have confirmed that alliin is a natural plant bacteriocidin, which can inhibit and kill many pathogens that endanger human beings. Abbehausen et al. (2013) found that a water soluble Pd(II) complex with l-alliin has inhibitory effect on *E. coli*, *P. aeruginosa* and *S. aureus*, and also has anti-tumor effect. Liu et al. proved that alliin had inhibitory effect on many kinds of yeasts and fungus by plate counting method, and found that alliin had strong inhibitory effect on aflatoxin from the relationship between alliin and aflatoxin production test (Liu & Liu, 2002). The principle may be that oxygen atoms in alliin combined with cysteine in the bacteria, so that it cannot be converted into cystine, which affected the important metabolic activities in the bacteria. The study on the antibacterial activity of alliin and its alkali-treated products showed that the untreated

alliin sample had certain inhibitory effect on *Penicillium*. All these indicate that alliin can be used for food preservation to extend the shelf life, and alliin is non-toxic to human body and can be metabolized normally, which meets the requirements of green consumption. Compared with the non-polar monomers such as garlic oil, ajoene and allicin with good antibacterial and anticancer activities, alliin shows obvious differences from them. Therefore, the pharmacological activities of alliin are worth studying independently (Chen, 2016).

## 6.2. Antioxidant capacity

Oxidative stress contribute to occurrence of many degenerative diseases and aging-related diseases. In order to find the most effective antioxidants, a large number of studies have been conducted (Aruoma, 2003; Halliwell, 1995; Soobrattee, Neergheen, Luximon-Ramma, Aruoma, & Bahorun, 2005). Dudonné, Vitrac, Coutière, Woillez, & Ménilon, 2009 stated that a significant relationship between antioxidant capacity and total phenolic content indicate that phenolic compounds are valuable contributors to the antioxidant properties of these plants. Leek roots contain phenolic compounds which are potential molecules to develop new drugs.

## 6.3. Protect vascular endothelial function

The pathological basis of most cardiovascular diseases is atherosclerosis, and vascular endothelial dysfunction is one of the main causes. Endothelial glycocalyx adheres to the surface of vascular endothelium, and its damage and shedding are closely related to the pathogenesis of cardiovascular diseases (Cancel, Ebong, Mensah, Hirschberg, & Tarbell, 2016; Kolářová, Ambrúžová, Sviháľková Šindlerová, Klinke, & Kubala, 2014). Vascular endothelial is directly exposed to the blood and perceives its changes to mediate vasomotion, homeostasis, angiogenesis and vascular growth. Studies showed that endothelial protection and function were determined by the expression of endothelial glyco-

calyx, which can be used as both buffer and force transmitter (Cheng, Kumar, Sridhar, Webster, & Ebong, 2016). Yuan (2020) found that 0.025% volatile oil from leek roots can promote the proliferation of human umbilical vein endothelial cells in the concentration range of 10–80 μL/mL, and can reduce the damage and shedding of endothelial cell glycocalyx stimulated by lipopolysaccharide, maintain the function of damaged endothelial cells, promote the repair of glycocalyx, activate eNOS and increase the production of NO. Zhou (2021) found that leek roots extract can effectively protect the arterial vessel endothelial glycocalyx of atherosclerosis mice, reduce its damage and shedding, and can up-regulate the expression of Caveolin-1 in arterial vessel endothelium, maintain endothelial homeostasis, activate eNOS, increase NO release, inhibit platelet aggregation, relax smooth muscle cells, prevent leukocyte adhesion.

#### 6.4. Expectorant action

Leek roots have expectorant action. Saponins in bulbs of leek roots can stimulate gastric mucosa and reflexly increase secretion of respiratory mucosa, showing expectorant effect.

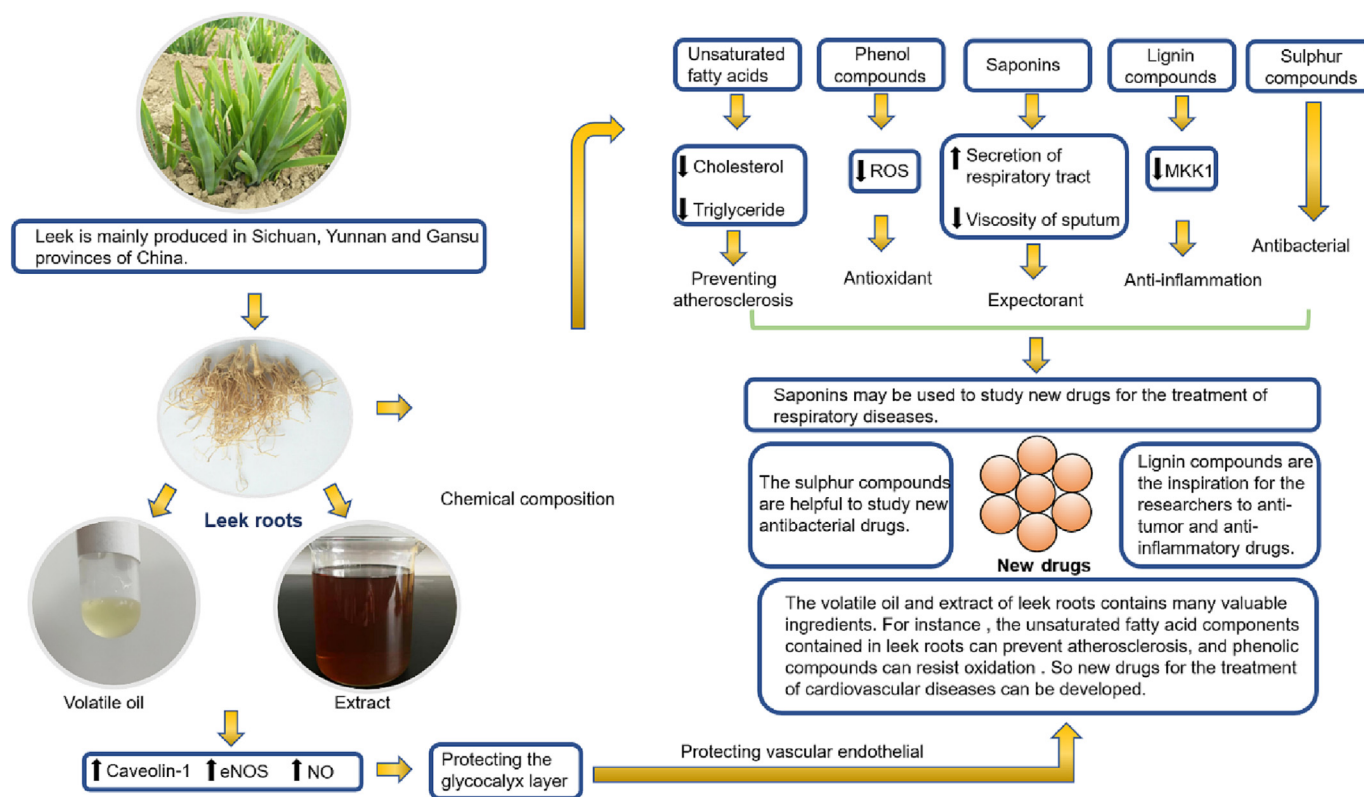
The principle of expectorant is mostly to increase the secretion of respiratory tract, dilute the sputum, reduce the viscosity of sputum by reducing the viscous component in sputum, or increase the cilia movement of respiratory mucosal epithelial cells, so that the sputum is easy to cough up. Saponins in leek roots can stimulate gastric mucosa by oral administration and increase bronchial mucosa secretion reflexively, so that sputum can be diluted and excluded (Song, 1999) (Fig. 6).

#### 7. Safety evaluation

Leek roots have been proved highly safe food over thousands of years, and excessive consumption may cause digestive problems (Rattanachaiakunsopon & Phumkhachorn, 2008; Yin & Tsao, 1999). We speculate that when overtaken leek roots, accumulated saponins in them might irritate the human stomach and bowel mucosa, and lead to digestive problem. Zhouhou Beiji Fang (Ge, 2016), an ancient Chinese medicine prescription monograph by Hong Ge (A. D. 283–363) that mainly records the treatment prescriptions, acupuncture and external treatment of various diseases in acute attack, records that the dosage leek roots could reach 1155 g in treating chest pain, showing that leek roots had high safety. However, there are few studies on the safety of leek roots, and no clear conclusion on the safe dosage of leek roots. The empirical dosage is obviously not standardized. We hope to find out the safe dosage of leek roots as soon as possible and provide reference for better utilization of it.

#### 8. Conclusion

Over thousands of years of development of traditional Chinese medicine, leek roots showed a unique medicinal and edible values. Phytochemical studies showed that leek roots contain sulfur compounds, phenolic compounds and lignin compounds, and have a variety of pharmacological potential, including antibacterial, antioxidant, vascular endothelial protection. Unfortunately, studies on chemical constituents and pharmacological effects of leek mainly focus on its leaves and seeds, instead of the roots. In the future, there are two key directions in leek roots research and



**Fig. 6.** Main active components of leek roots and new drug development prospects. The volatile oil and extract isolated from leek roots can up-regulate Caveolin-1, activate eNOS and increase NO production, which has a protective effect on vascular endothelium. Unsaturated fatty acids can lower cholesterol and triglyceride, which have the ability to prevent atherosclerosis. Phenol compounds can remove ROS and play an antioxidant role. Saponins increase respiratory secretions and reduce sputum viscosity. Lignin compounds down-regulated MKK1 to play an anti-inflammatory role. Sulphur compounds have antibacterial effects. The pharmacological effects of these compounds are of positive significance to the development of new drugs.

development. First, we believe that leek roots must have good new drug development value. For example, new antibacterial drugs might be developed from the antibacterial activity of its volatile oil to effectively solve the current antibiotic resistance problem. And it can be used to achieve new drugs development for cardiovascular diseases such as coronary heart disease with its antioxidant and protective effects on vascular endothelium. Second, in terms of dietary treatment, leek roots not only have a wealth of edible methods, but also can be used to develop health food for more suitable people. For instance, with its effects of preventing constipation and male function decline, to research some grand health products. In traditional Chinese medicine clinic, leek roots should be recommended for treatments of alopecia, constipation, angina pectoris, etc.

### Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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