

Ethnobotanical review of food uses of *Polygonatum* (Convallariaceae) in China

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Abstract

According to our literature survey, fifteen species in the genus *Polygonatum* (Convallariaceae) have been used as food in China. Five main categories of use (drinks, snacks, vegetables, staple food and seasoning) were found. The plants from this genus are used mainly as vegetables. Rhizomes are the main parts used. The categories of use and diverse preparation methods have some similarities with those in other countries. Among all the recorded species, *Polygonatum sibiricum* and *P. odoratum* are the most commonly consumed species in China. Local people from different places have their own unique preparation methods and customs. However, the use of *Polygonatum* still remains at the level of family consumption, and the resources have not been fully used yet. We proposed ideas for further exploitation and conservation of edible *Polygonatum* species, and suggested further research, e.g. on the nutritional properties of all recorded edible species. It is believed that there is still plentiful traditional knowledge about food uses of *Polygonatum* to be documented in China.

Keywords: *Polygonatum*, food uses, ethnobotany, China

Introduction

China is the third largest country in the world. Its diverse climate and geography, varied terrain and range of soil types harbor an enormous diversity of plants, with 31142 species (of higher plants). At least 1156 species and 274 varieties and/or cultivars of food plants have been used by the inhabitants of China, who belong to 56 ethnic groups, including the dominant Han Chinese nationality [1]. Over thousands of years, they have accumulated very rich and precious traditional knowledge of using plants. That is why Prof. Richard I. Ford, a renowned ethnobotanist at University of Michigan at Ann Arbor, once said “the root of ethnobotany is in China”. Since the 1980s, ethnobotanical studies have been carried out to document traditional knowledge of plant use in China, including wild food species [2–12]. It seems that using wild plants for food is more popular in southern China than in its northern part. Ethnic groups in some areas in southern China, like Yunnan Province, which harbors the richest diversity of plants in the country, consume more wild vegetables than cultivated ones. In some villages, which are far from the markets, wild vegetables are the local people’s main sources of vegetable dishes [7].

The plants in genus *Polygonatum* Mill. are perennial rhizomatous herbs belonging to the family Convallariaceae (also named Liliaceae). Up to June 2012, 63 species are accepted by the “World checklist of selected plant families” in the genus *Polygonatum* [13]. Plants in the genus are widely distributed in temperate regions of the northern hemisphere, mainly from the Himalayas to Japan, and especially in China and Japan, where approximately 40 different species of *Polygonatum* have been reported. They are also found in India, Korea, Afghanistan, Bhutan, Nepal, Pakistan and Russia. *Polygonatum* also grows in the temperate climate zones of northern and eastern America and Europe [14].

China is one of the richest countries in *Polygonatum* species, with 39 described species (61.9% of the whole genus), and some studies suggest that China might be the distribution and differentiation center of the genus *Polygonatum* [15,16]. Among them, 20 species (31.7%) are endemic. They are distributed throughout the country, and they can be found mainly in the northeast, Yunnan, Guizhou, Anhui, Guangxi, Hebei, Inner Mongolia, Henan, Shandong, Shanxi, Zhejiang, and Jiangxi provinces of China. Yunnan and Guizhou are the richest in *Polygonatum* species. The typical natural habitat of these plants is wet slope below 2000 m above sea level. Most of them grow in wet places and forests or bushes with thick and fertile soil [17].

Polygonatum species have a long history of traditional use, both as medicine and food, in China and other countries, like the northern and eastern United States, south-central Canada, India and Korea [18–20]. There are numerous ancient books describing medicinal and food uses of *Polygonatum* in China. It was recorded for the first time in the Mingyi Bielu (a pharmaceutical work, written at the end of Han Dynasty, AD 220), and ranked to the top grade of herbal medicine. Thereafter,

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all Chinese medicine scholars studied and documented it. “Got the essence of soil, be the first in tonics”, a description of *Polygonatum*, was recorded in the famous Chinese medicinal book “Bencao gangmu” (i.e. “Compendium of materia medica”, written by the famous medical expert Li Shizhen in Ming Dynasty, in 1590).

Polygonatum was recorded as a food item in the ancient medical works Shiliao Bencao and Jiuhuang Bencao as early as in the Tang Dynasty (AD 618–907). However, folk usage of *Polygonatum* in China should be much earlier than these ancient published works. Also in recent years, some ethnobotanical studies have documented the food uses of *Polygonatum* among the rural population (including various ethnic groups) [21–35].

This paper aims to review the traditional knowledge of *Polygonatum* used as food in China. The objective is to gather and document information that will lead to a better understanding of the knowledge of traditional uses of *Polygonatum* in China.

Results

Fifteen species of *Polygonatum* are traditionally used as food in China through literature studies (Tab. 1). Five main categories of use (drink, snack, vegetable dish, staple food and seasoning) were found.

Vegetables dishes (‘cai’)

The largest category (14 species) is vegetable dishes (“cai”). In China “cai” is usually a plate of mainly one kind of vegetable eaten as a side-dish accompanying a meat dish and rice. Young leaves, stems and rhizomes are the main parts used, and are consumed raw or after frying, decocting, stewing, roasting or steaming. Different places have their own unique mode of preparation and consumptions.

One example is Simao, a tropical county in Yunnan, southwest China, with many minorities, e.g. Yi, Dai, and Lahu. The Dragon-boat festival is one of the important traditional holidays in China. In Simao, it is considered that this festival is the turning point of the wet and dry seasons in a year. Local herbal doctors believed that this time is when people are most vulnerable to disease, so people need to take some tonics to strength themselves and enhance immunity. They collected the rhizomes of *P. cirrhifolium* and *P. kingianum*, and braised them with chicken or pig’s feet for use as tonics by people of all ages. The local people also considered that these dishes would strengthen the body, tranquilize the mind and increase appetite [6].

In Changbai Mountains, northeast China, because of the long and cold winter, the local people got used to eating steamed or roasted hot food. They usually use steamed or roasted rhizomes of *P. sibiricum*, *P. odoratum*, *P. filipes*, *P. acuminatifolium*, *P. stenophyllum*, *P. humile*, *P. involucreatum* and *P. inflatum* as vegetables [23]. Also in northeast China, people like to eat some plants as salad, usually in the form of vegetables dressed with salty soybean paste. In northern China, fresh cultivated vegetables are not abundant in winter. During the summer or autumn, when plenty of green vegetables are harvested, the local people make some pickled vegetables (including wild vegetables), which can be stored for a long time. The sprouts of *Polygonatum odoratum* are salted for consumption in winter [31]. In some other places, the young leaves, stems, sprouts or rhizomes of *P. odoratum* are usually collected for use in fried dishes or salad, or for soup, after blanching [25].

Drinks

This group consists of three species used to prepare drinks, including wine or liquor and a substitute for tea. The rhizomes of *P. sibiricum* and *P. nakaianum* are soaked in rice wine for a month to make into herbal wine, which will make the drinkers’ hair darker and brighter [35]. The rhizomes of *P. odoratum* are usually soaked with liquor and sugar for six months. Before use, the drink is strained with gauze. Drinking it frequently is supposed to eliminate fatigue, moisten skin, and make one beautiful. The rhizomes are also used as a substitute for tea. Some previous studies recorded that rhizomes of *P. sibiricum* were boiled with water for use as tea. It is believed that daily use of this tea will strengthen the body and is especially good for recovering from weakness [15].

Snacks, staple foods, and seasonings

Ten species are consumed as snacks. In the Inner Mongolian Autonomous Region, China, the rhizomes of *P. sibiricum*, *P. odoratum*, *P. macropodium*, were consumed as fresh “fruits” (snacks) by herdsman. While the livestock were grazing on grassland, herdsman could collect and eat edible plants any time they felt hungry or thirsty. Grassland areas have always been short on fruits. Because of their good taste, herdsman usually took the rhizomes of *Polygonatum* as fresh “fruits” (snacks). They believed that people who eat the rhizomes of *Polygonatum* regularly will gain strength and live a long life [11]. In addition, the local Mongolians named *P. sibiricum* “imaan orhodai” and named *P. odoratum* “ebsen orhodai”. Here “orhodai” means ginseng (*Panax ginseng*). It implied that the Mongolians have highly appreciated the values of these plants [34].

According to the nutritional study reported [35], the *Polygonatum* rhizomes are rich in starch (25.6–68.46% of dry mass). The starch from *P. sibiricum*, *P. odoratum*, *P. filipes*, *P. acuminatifolium*, *P. stenophyllum*, *P. humile*, *P. involucreatum* and *P. inflatum* has traditionally been used in China for a long time.

The local people in northeast of China steam or roast the *Polygonatum* rhizomes and eat them as a snack. The rhizomes are also fried with sugar and honey to make a kind of “candy” [22].

When used as staple food, the local people usually sun-dry the rhizomes of *P. sibiricum*, *P. odoratum*, and *P. nakaianum*, grind them into powder with a stone roller, then sift them to mix into flour to make cakes.

The local people also prepare the rhizomes of *Polygonatum* as seasonings to make some sweet dishes. The pulped rhizomes of *P. sibiricum* are boiled for 4 hours, then filtered, and 2% barley flour is added, to obtain a sugar solution. The sugar solution will be placed into a pot and boiled for 4 hours over a gentle heat. When the sugar solution is boiled into filamentous bright yellow droplets, the *Polygonatum* seasoning named sugar diluents (“tangxi”) was processed [36].

Polygonatum uses in other countries

In some other countries, some species in *Polygonatum* are believed to have medicinal properties [18], and have been used as a source of food too. For example, in India, *Polygonatum cirrhifolium* and *P. verticillatum* are considered to be wild tasty leafy vegetables [19]. *Polygonatum biflorum* is distributed in the eastern United States and south-central Canada. Its starchy, edible rhizomes were formerly used by early Americans as a potato-like food or the starch was extracted and used to make bread, or mixed in with other foods such as soups. Young shoots can be added to salads, consumed raw or can be boiled

Tab. 1 Species of *Polygonatum* traditionally used as food in China.

Latin name	Used parts	Categories of use	Preparation methods	References
<i>P. acuminatifolium</i> Kom.	Rhizome	Snack	Cooked (steamed or roasted) as snack	[23]
	Sprout	Vegetable	Raw (salad, pickled, dressed with sauce) or cooked (fried or added to soups after blanching)	[31]
<i>P. cirrhifolium</i> (Wall.) Royle	Young stem	Vegetable	Cooked	[7]
	Tuber, rhizome	Vegetable	Raw (salad) or cooked as vegetable	[6,24,29,32]
<i>P. cyrtoneura</i> Hua	Rhizome, sprout	Vegetable	Cooked	[25,26,32]
<i>P. filipes</i> Merr.	Rhizome	Vegetable, snack	Cooked as vegetable	[25]
	Sprout	Vegetable	Cooked (steamed or roasted) as snack	[25]
<i>P. humile</i> Fisch. ex Maxim.	Rhizome	Vegetable, snack	Cooked as vegetable	[25]
	Rhizome	Vegetable, snack	Raw (salad, pickled, dressed with sauce) or cooked (fried, steamed, roasted or added to soups) as vegetable	[23,28]
<i>P. inflatum</i> Kom.	Sprout	Vegetable	Cooked (steamed or roasted) as snack	[23]
	Rhizome	Vegetable	Raw (salad, pickled, dressed with sauce) or cooked (fried or added to soups after blanching)	[31]
<i>P. involucreatum</i> (Franch. et Sav.) Maxim.	Rhizome	Vegetable, snack	Cooked (steamed or roasted) as snack	[23,30]
	Sprout	Vegetable	Cooked (steamed or roasted) as snack	[23,30]
<i>P. kingianum</i> Coll. et Hemsl.	Rhizome	Vegetable	Raw (salad, pickled, dressed with sauce) or cooked (fried or added to soups after blanching)	[28,31]
	Tuber, rhizome	Vegetable	Raw or cooked (fried or stewed)	[6,7]
<i>P. macropodium</i> Turcz.	Rhizome	Vegetable, snack	Cooked as vegetable	[12,23,28,34]
	Rhizome	Vegetable, snack	Raw as snack (fruit)	[12,23,28,34]
<i>Polygonatum megaphyllum</i> P. Y. Li	Sprout	Vegetable	Raw (salad, pickled, dressed with sauce) or cooked (fried or added to soups after blanching)	[28,31,32]
	Rhizome	Snack	Roasted on embers as famine food	[57]
<i>P. nakaianum</i> Ishidoga	Rhizome	Drink, staple food	Raw as drink (wine)	[35]
	Rhizome	Drink, staple food	Cooked as staple food (make into powder and mixed with flour)	[35]
	Rhizome	Drink, staple food	Raw as drink (wine)	[35]
<i>P. odoratum</i> (Mill.) Druce	Young stem and leave	Vegetable	Cooked (fried dish or added to soups after blanching)	[21,27–29]
	sprout	Vegetable	Raw (salad, pickled, dressed with sauce) or cooked (fried or added to soups after blanching)	[28,31]
	Rhizome	Vegetable, drink, snack, stale food	Raw or cooked (steamed or roasted) as snack	[11,23,27,28,31,33–35,57]
<i>P. sibiricum</i> Delar. ex Red.	Rhizome	Vegetable, drink, snack, stale food	Raw (wine) or cooked (boiled) as drink (substitute for tea)	[11,23,27,28,31,33–35,57]
	Rhizome	Vegetable, drink, snack, stale food	Cooked (steamed) as vegetable	[11,23,27,28,31,33–35,57]
	Rhizome	Vegetable, drink, snack, stale food	Make into powder and mixed with flour as staple food	[11,23,27,28,31,33–35,57]
<i>P. sibiricum</i> Delar. ex Red.	Sprout	Vegetable	Roasted on embers as famine food in some areas	[27,28,30]
	Rhizome	Vegetable, snack, drink, staple food, seasoning	Cooked (fried dish or added to soups after blanching)	[27,28,30]
	Rhizome	Vegetable, snack, drink, staple food, seasoning	Raw (fruit) or cooked (steamed or roasted) as snack	[11,21–23,27,28,31–35]
<i>P. stenophyllum</i> Maxim.	Rhizome	Snack	Raw (pickled) or cooked (steamed, roasted, fried) as vegetable	[27,28,31–35]
	Rhizome	Snack	Raw as drink (wine/liquor)	[27,28,31–35]
	Rhizome	Snack	Boiled as substitute for tea	[27,28,31–35]
<i>P. verticillatum</i> (L.) All.	Rhizome, sprout	Vegetable	Make into powder and mixed with flour as staple food.	[24,28,29,32]
	Rhizome, sprout	Vegetable	Cooked to make seasonings	[24,28,29,32]
<i>P. stenophyllum</i> Maxim.	Rhizome	Snack	Cooked (steamed or roasted) as snack	[23]
<i>P. verticillatum</i> (L.) All.	Rhizome, sprout	Vegetable	Cooked	[24,28,29,32]

and served like asparagus [20]. Some species, in particular *P. sibiricum*, are used as a herbal tea called dungulle in Korea [13].

Medicinal effect

According to “China Pharmacopoeia” (2010), *Rhizoma polygonati*, prepared from the dried rhizomes of *Polygonatum sibiricum*, *P. kingianum* and *P. cyrtoneura*, and processed *P.*

odoratum products are the most commonly used medicines in Traditional Chinese Medicine (TCM). TCM considered that the former contains the properties of reinforcing “qi”, nourishing “yin” and moistening the lungs, strengthening kidney and spleen, while the processed *P. odoratum* products have the properties of moistening heart and lungs, nourishing the stomach and enhancing bone marrow [37].

Different pharmacologically active groups of compounds have been isolated phytochemically, such as polysaccharides, saponins, phytohormones, glycosides, flavonoids and alkaloids. Pharmacological research has demonstrated that *Polygonatum* species produce effects, showing antihyperglycemic potential, anticancer, analgesic, antipyretic diuretic, antimalarial, antioxidant, antimicrobial, phytotoxic etc. [14]. Polysaccharides are the major bioactive compounds in these plants [38–41]. Phytochemical and pharmacological research on several species including *P. odoratum*, *P. verticillatum*, *P. cyrtoneuma*, *P. kingianum* have been reported. The research results have shown biological activities and possessed potentially medical applications [42–50]. In fact, based on our literature studies, we see that all the species recorded as used for food, also have medicinal effects. The local people in China believe that to take *Polygonatum* food enhances immunity and longevity, which are in full accord with the results of modern scientific research.

Discussion and conclusions

China is the richest country in *Polygonatum* resources, with 39 species (61.9%). The local inhabitants of China have developed a rich traditional knowledge about the food use of this genus. Based on our literature survey, we have found 15 species used for food, out of which *P. macropodium*, *P. cytonema*, *P. filipes* are endemic to China. There are 5 main categories of use in China, including wild vegetables, drinks, snacks, staple food and seasonings. All the species in the genus have been used for vegetable dishes, 10 species for snacks, 3 species for making drinks, 3 species as staple food and 1 species for seasonings. Some species can be classified into more than one category. For example, the rhizomes of *P. sibiricum* have traditionally been used as elements of vegetable dishes, drinks, snacks, and as a staple food.

Preparation methods are also diverse. Some of the species are eaten as salad, directly or after simple processing. Some of them can only be eaten after being well-cooked or processed. The cooking methods include frying, decocting, stewing, roasting and steaming.

There are some interrelations between the used parts and categories of use. Young leaves, stems and rhizomes are mainly used in vegetable dishes. Rhizomes are used to make drinks, snacks and seasonings. Therefore the rhizomes are the most commonly used parts. Some ancient publications recorded that the roots, leaves, flowers and fruits of *P. sibiricum* were edible. Nowadays, however, there are no records about the use of flowers or fruits of this species as food [51]. Meanwhile, some literature sources report that the fruits of *Polygonatum biflorum* (not distributed in China), contain anthraquinone, which is poisonous, but with a low toxicity, mostly causing vomiting and diarrhea [52]. Thus the fruits of this species are not edible. Based on this information we should be aware of the toxicity of *Polygonatum* fruits. It is possible that the toxicity of a *Polygonatum* species varies depending on the place where it grows or which species, subspecies or variety is taken into account. Therefore further research on the chemistry of *Polygonatum* fruits is necessary to determine whether the fruits of Chinese *Polygonatum* species are edible or poisonous. Some nutritional studies on *P. sibiricum* seeds have been done recently, and showed that the contents of methionine, lysine and isoleucine are higher than those of wheat or corn, and suggested that the seeds of *P. sibiricum* could be eaten [53].

Local Chinese people from all over the country have used *Polygonatum* as food sources. The different places have their

own distinctive features. They believe that it would enhance immunity and longevity to take *Polygonatum* as food, which is in full accord with the results of modern scientific research. However, the usages of *Polygonatum* are still at the family level of consumption. Although China is rich in wild *Polygonatum* resources, they have not been fully used and exploited yet. To explore and develop new resources, the traditional preparation methods of *Polygonatum* can provide information. Considering that the plants from this genus have both nutritional and medicinal value, they can be classified into the health food category and are worth developing into more widely used functional foods by combining modern food processing technology and traditional preparation methods. The following points should be taken into account:

(i) The wild species of *Polygonatum* are usually pollution free, so they are attractive to food processing industries.

(ii) As the plants have medicinal functions, the rhizomes of *Polygonatum* can be developed into functional foods such as “*Polygonatum* paste”, “*Polygonatum* porridge”, “*Polygonatum* powder” [54]. These products have already appeared on the market, but are not very commonly used.

(iii) The rhizomes are the main parts used for the development of food products. The rhizomes are soft and contain starch, other carbohydrates, carotene, vitamins and low coarse cellulose. They are suitable for making various drinks, such as wine, tea substitutes or different flavored drinks. They can be processed into snacks, such as dried, canned, or puffed foods. The fruits of *P. sibiricum* can be exploited as a vitamin B1 source [15]. In addition, other parts, such as seeds, are worth using, but further investigation into the nutritional properties of all useful parts is necessary.

(iv) The most popular consumed species of *Polygonatum* in China were *P. sibiricum* and *P. odoratum* (Tab. 1). However, there are still some other species, which are little known and processed. For example, *P. cyrtoneuma*, which is rarely used for food by local people, has high nutritional quality, unique medicinal functions and plentiful wild resources [55]. *P. filipes*, which has a wide distribution in 8 provinces in China, i.e. Anhui, Fujian, Guangdong, Guangxi, Hunan, Jiangsu, Jiangxi and Zhejiang, was only used by the local people in Qiandaohu, Zhejiang Province. The *Polygonatum* plants in Anhui Province present another example. Anhui Province, located in eastern China, is one of the major production areas of *Polygonatum* in China, with 11 species of *Polygonatum* and the production of 20–100 tons every year [54]. However, the local people paid more attention to the medicinal value than the edible value so that a few species were collected and used for food. Further study and exploitation could be carried out regarding these species for product development.

(v) Most of the *Polygonatum* species are not protected. The local people mainly consume wild *Polygonatum* species for food, and the rhizomes are the main parts used. In addition, most of the *Polygonatum* plants used as medicines sold on the markets are also from wild specimens. All the above-mentioned factors have greatly damaged the local plant resources. There are some species, such as *P. macropodium*, *P. kingianum*, *P. verticillatum*, *P. cirrhifolium*, which have been frequently used both for food and medicine in some places. However, because of the increasing demand, their resources have shrunk. Given this situation, it is necessary to select the species which have the largest use potential for cultivation, or to conserve resources in situ to reduce threats to the rare species and their habitats.

In the past, the Chinese used wild plants for food in famine times when main crops and cultivated vegetables were not available. Nowadays, however, with the intensive development of agricultural and marketing techniques, it is easy to find various cultivated fruits and vegetables and other food in markets throughout the year. Therefore, the younger generation has little awareness of using wild food plants, and the traditional knowledge of using plants for food survives only in the memory of the elders. As a result, it is eroding due to changing social values and a lack of participation of the younger generation in collection and processing of wild plants [56]. However, we believe that there is still plentiful traditional knowledge of food usage of *Polygonatum* to be documented in China, which can provide important scientific clues to developing new food resources.

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References

- Hu SY. Food plants of China. Hong Kong: Chinese University Press; 2005.
- Pei SJ. Preliminary ethnobotanical study of Xishuangbanna. In: Proceedings of tropical plants researches. Kunming: Yunnan People's Press; 1982. p. 16–32.
- Dao ZL, Long CL, Liu YT. On traditional uses of plants by the Nu people community of the Gaoligong Mountains, Yunnan Province. Sheng Wu Duo Yang Xing. 2003;11(3):231–239.
- Li QJ, Liu HM, Xu YK, Chen J, Xu ZF. Changes in species number and causes that used as wild vegetable by Dai people in Xishuangbanna, China. Acta Bot Yunnan. 2007;29(4):467–478.
- Khasbagan, Soyolt, Man L, Enhebayar, Gerelt, Hu W. Traditional usage of wild plants for food by the Ejina Mongolians and its exploitation and ethnoecological significance. Journal of Inner Mongolia Normal University (Natural Science Edition). 2005;34(4):471–488.
- Liu YT, Long CL, Dao ZL. Ethnobotanical survey on medicinal roots eaten by the local people in Simao, Yunnan Province, during the Dragon-boat Festival. Journal of Plant Resources and Environment. 2003;12(2):33–38.
- Wang JR, Long CL. Ethnobotanical study of traditional edible plants of Jinuo nationality. Acta Bot Yunnan. 1995;17(2):161–168.
- Long CL, Li H, Zhou YL, Dao ZL, Abe T. Ethnobotanical studies in Gaoligong Mountains: II. the Dulong ethnic group. Acta Bot Yunnan. 1999;11 suppl:137–144.
- Long CL, Li H, Dao ZL, Zhou YL. Ethnobotanical studies in Gaoligong Mountains: I. the Dulong ethnic group. Acta Bot Yunnan. 1999;11 suppl:131–136.
- Jin S, Tie J, Liu RX. Ethnobotanical study on folk wild edible plants in southeast region of Shanxi province. Journal of Jindongnan Normal College. 2004;21(2):13–15.
- Khasbagen, Huai HY, Pei SJ. Wild plants in the diet of arhorchin mongol herdsmen in inner mongolia. Econ Bot. 2000;54(4):528–536. <http://dx.doi.org/10.1007/BF02866550>
- Wujisguleng W, Khasbagen K. An integrated assessment of wild vegetable resources in Inner Mongolian Autonomous Region, China. J Ethnobiol Ethnomed. 2010;6(1):34. <http://dx.doi.org/10.1186/1746-4269-6-34>
- World checklist of selected plant families [Internet]. Kew Royal Botanic Gardens. 2012 [cited 2012 Jul 7]; Available from: http://apps.kew.org/wcps/prepareChecklist.do;jsessionid=EE82AA0DBD9A249F1939FB9DE7E211B4?checklist=selected_families%40%40298241020120745409
- Haroon K, Muhammad S, Naveed M. Pharmacological and phytochemical updates of genus *Polygonatum*. Phytopharmacology. 2012;3(2):286–308.
- Li JH, Zhou SB. Utilization of *Polygonatum* resources and its assessment of economic value. Anhui Agricultural Science Bulletin. 2006;12(5):64–65.
- Yang CR, Zhang Y, Wang D, Zhang YJ. Molecular evolution of steroidal saponins in the genus *Polygonatum* (Convallariaceae) and their chemotaxonomical significance. Acta Bot Yunnan. 2007;29(5):591–600.
- Polygonatum* [Internet]. eFloras.org. 2012 [cited 2012 Aug 25]; Available from: http://www.efloras.org/florataxon.aspx?flora_id=2&taxon_id=126394
- Youn YN, Lim E, Lee N, Kim YS, Koo MS, Choi SY. Screening of Korean medicinal plants for possible osteoclastogenesis effects in vitro. Genes Nutr. 2007;2(4):375–380. <http://dx.doi.org/10.1007/s12263-007-0062-1>
- Misra S, Maikhuri RK, Kala CP, Rao KS, Saxena KG. Wild leafy vegetables: a study of their subsistence dietetic support to the inhabitants of Nanda Devi Biosphere Reserve, India. J Ethnobiol Ethnomed. 2008;4(1):15. <http://dx.doi.org/10.1186/1746-4269-4-15>
- Polygonatum biflorum* [Internet]. Missouri Botanical Garden. 2012 [cited 2012 Aug 25]; Available from: <http://www.missouribotanicalgarden.org/gardens-gardening/your-garden/plant-finder/plant-details/kc/e750/Polygonatum-biflorum.aspx>
- Huang JS, Peng YL, Li M, Wang Y. Exploitation and utilization of wild vegetables in the north of Hunan. Chinese Wild Plants Resources. 2002;21(6):39–40.
- Su SL, Ma B, Huang K. Research on the ethnobotany of *Panax notoginseng*. Anhui Agricultural Science Bulletin. 2012;18(1):56–58.
- Zhou Y. The *Polygonatum* plant resources in Changbai Mountains and their exploitation. Chinese Wild Plants Resources. 2002;21(2):34–35.
- Wang ZK, Wang ZH, Xing Z, Li RQ, Liu H, Deqingcuomu. Preliminary investigation and studies on wild vegetable resources in Nyingtri, Tibet. China Vegetables. 2010;2:75–78.
- Feng BC, Yu MS, Xu GF, Yan SF, Chen AM, Liu WH, et al. Exploiting and utilizing edible wild plants in Thousand-Isle Lake. Central South Forest Inventory and Planning. 2010;29(1):41–44.
- Xu LZ. Exploitation and utilization of the wild vegetable resource in northeastern Guangdong province. Anhui Agricultural Science Bulletin. 2006;3(12):2690–2694.
- Zhu Q, Guo S, Wang J, Tian Y. Investigation on the wild edible plant resources in Ningxia. Journal of Ningxia University (Natural Science Edition). 2004;28(4):367–371.
- Khasbagen, Soyolt, editors. Wild vegetable resources in Inner Mongolia and their ethnobotanical study. Beijing: Science Press; 2008.
- Han YX, Zhao CH, Jing ZP, Li GF, Gong FL, Chen SY, et al. Hill wild vegetables investigation in Huzhubeishan forest region. Qinghai Prataculture. 2001;10(2):46–49.
- Fan SJ, Zhao ZT. Wild vegetable blog in Shandong. Jinan: Shandong Science and Technology Press; 1996.
- Dong R, Li GC, Fan SL. Wild vegetables in Changbai Mountains. Beijing: Science Press; 1997.
- Zhao JG, Wei XB, Guo WC. Chinese potherb. Changchun: Jilin Science and Technology Press; 2004.
- Dong SY, Wei CR, Yang CJ. Recipes of Chinese wild vegetables. Beijing: China Tourism Press; 1993.
- Khasbagan, Pei SJ. Wild plants used for the folk dietotherapy in Arhorchin Mongolians. Zhong Yao Cai. 2001;24(2):83–85.
- Bureau of Production & Consumption of Chinese Ministry of Commerce, Institute of Botany of Chinese Academy of Sciences. Flora of Chinese economic plants. Beijing: Science Press; 2012. (Flora of Chinese economic plants; vol 1).

36. Wang ZX. China resources plants utilization manual. Beijing: Chinese Science and Technology Press; 1989.
37. China Pharmacopoeia Committee. China Pharmacopoeia. Beijing: Chinese Medicine and Technology Press; 2010. (China Pharmacopoeia; vol 1).
38. Liu L. Purification, structure identification, biological activity and structure-activity relationship research of polygona polysaccharides. Shanghai: Shanghai Institute of Materia Medica; 2005.
39. Zhang TT, Xia XK, Chen CP, Wu AP, He M, Nie LW. Biological activities of polysaccharides from *Polygonatum sibiricum* Redoute. Chinese Journal of Experimental Traditional Medical Formulae. 2006;12(7):42–45.
40. Hu CY, Xu DP, Wu YM, Ou SY. Triterpenoid saponins from the rhizome of *Polygonatum sibiricum*. J Asian Nat Prod Res. 2010;12(9):801–808. <http://dx.doi.org/10.1080/10286020.2010.505562>
41. Deng Y, He K, Ye X, Chen X, Huang J, Li X, et al. Saponin rich fractions from *Polygonatum odoratum* (Mill.) Druce with more potential hypoglycemic effects. J Ethnopharmacol. 2012;141(1):228–233. <http://dx.doi.org/10.1016/j.jep.2012.02.023>
42. Janeczko Z, Jansson P, Sendra J. A new stereoidal saponin from *Polygonatum officinale*. Planta Med. 2007;53(1):52–54. <http://dx.doi.org/10.1055/s-2006-962618>
43. Yu HS, Ma BP, Kang LP, Zhang T, Jiang FJ, Zhang J, et al. Saponins from the processed rhizomes of *Polygonatum kingianum*. Chem Pharm Bull. 2009;57(9):1011–1014.
44. Hirai N, Miura T, Moriyasu M, Ichimaru M, Nishiyama Y, Ogura K, et al. Cardiotonic activity of the rhizome of *Polygonatum sibiricum* in rats. Biol Pharm Bull. 1997;20(12):1271–1273.
45. Lin HW, Han GY, Liao SX. Studies on the active constituents of the Chinese traditional medicine *Polygonatum odoratum* (Mill.) Druce. Yao Xue Xue Bao. 1994;29(3):215–222.
46. Khan H, Saeed M, Gilani AU, Khan MA, Dar A, Khan I. The antinociceptive activity of *Polygonatum verticillatum* rhizomes in pain models. J Ethnopharmacol. 2010;127(2):521–527. <http://dx.doi.org/10.1016/j.jep.2009.10.003>
47. Li XC, Yang CR, Makoto I, Hiromichi M, Ryoji K, Kazuo Y. Steroid saponins from *Polygonatum kingianum*. Phytochemistry. 1992;31(10):3559–3563. [http://dx.doi.org/10.1016/0031-9422\(92\)83727-G](http://dx.doi.org/10.1016/0031-9422(92)83727-G)
48. Liu B, Cheng Y, Bian HJ, Bao JK. Molecular mechanisms of *Polygonatum cyrtonema* lectin-induced apoptosis and autophagy in cancer cells. Autophagy. 2009;5(2):253–255.
49. Liu F, Liu Y, Meng Y, Yang M, He K. Structure of polysaccharide from *Polygonatum cyrtonema* Hua and the antihyperlipidemic activity of its hydrolyzed fragments. Antiviral Res. 2004;63(3):183–189. <http://dx.doi.org/10.1016/j.antiviral.2004.04.006>
50. Ye HC, Zhang XP, Gao GB, Jiang JH. Chemical constituents and biological activity of volatile oil from the tubers of *Polygonatum filipes*. Guihaia. 2009;29(3):417–419.
51. Materia medica for dietotherapy [Internet]. 2012 [cited 2012 Aug 25]; Available from: <http://baike.baidu.com/view/1080230.htm>
52. *Polygonatum* spp. [Internet]. Poisonous plants. 2012 [cited 2012 Aug 25]; Available from: <http://www.ces.ncsu.edu/depts/hort/consumer/poison/Polygsp.htm>
53. Li YG, Ji JY, Zhang YJ. Measurement and analysis of the nutrients of *Polygonatum sibiricum* seeds. Xibei Zhiwu Xuebao. 2009;29(8):1692–1696.
54. Li JH, Zhou SB. Advances in *Polygonatum* from Anhui Province. Chinese Wild Plant Resources. 2005;24(5):17–19.
55. Sun Z. An investigation of three species of *Polygonatum* and quality assessment of *Polygonatum cirrhifolium* (Wall.) Royle. Beijing: Beijing University of Chinese Medicine; 2009.
56. Balemie K, Kebebew F. Ethnobotanical study of wild edible plants in Derashe and Kucha Districts, South Ethiopia. J Ethnobiol Ethnomed. 2006;2:53. <http://dx.doi.org/10.1186/1746-4269-2-53>
57. Kang Y, Łuczaj Ł, Zhang S, Kang J. Wild food plants and wild edible fungi of Heihe valley (Qinling Mountains, Shaanxi, central China): herbophilia and indifference to fruits and mushrooms. Acta Soc Bot Pol. 2012;81(4):405–413. <http://dx.doi.org/10.5586/asbp.2012.044>