

Food uses of ferns in China: a review

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Abstract

Edible ferns are some of the most important wild vegetables in China. This paper reviews their food uses. The history of eating ferns in China may go back as far as 3000 years. An ethnobotanical inventory of edible ferns was created, with 52 species (including 4 varieties), which were traditionally used. The potential species number of edible ferns was estimated as 144 species (including 4 varieties). The cuisines, products and chemical components of ferns were also summarized. The most commonly eaten fern, *Pteridium aquilinum* var. *latiusculum*, was discussed in terms of its toxicity, massive productivity and development strategies. Suggestions and recommendations were proposed for the future development of edible ferns in China.

Keywords: edible ferns, food uses, China, ethnobotany, *Pteridium aquilinum* var. *latiusculum*, pterosin, detoxification

Introduction

Wild gathering, together with hunting, used to be the only food source for our ancestors. Although a total of 82 species commodities (or 103 species taxonomically) contribute 90% of national per capita supplies of food plants in the world [1], wild plant gathering is still a tradition that has endured in many local communities [2]. For example, the indigenous peoples of different countries, like Mexico [3], China [4–6], Ethiopia [7], India [8,9], Kenya [10], Palestine [11], and Thailand [12] collect various wild plants for supplementary diets or substitutes for staple food in famine years.

Food uses of wild plants are not only common in developing countries, but also in Japan, Europe and North America. For example many wild plants are still consumed in Spain, Portugal and Italy [13–15]. In some European countries, however, the tradition of wild food plant collection and consumption has been lost for generations. In Poland, for example, among over a hundred wild edible plant species recorded, only a few species are still commonly gathered, including two green vegetables, 15 folk species of fruits and seeds and four taxa used for seasoning, or as preservatives. The traditions of use of other species have either been forgotten or are very rarely used [16]. Both American Indians and white people have collected wild vegetables, fruits and mushrooms for consumption, in the United States and Canada [17–19]. In

Japan, wild vegetables used to be important food resources in the cold northern parts. Local communities have developed preservation methods including pickling, salting and drying of edible wild plants to be used throughout all the seasons [20]. The number of edible wild plants occurring in Japan is estimated to be over 1000 species [21], or even around 2000 species [22]. However, only around 25 or less species were utilized on a regional scale [23].

Edible ferns are some of the most common wild food plants collected by people around the world. The fern stems, rhizomes, leaves, young fronds and shoots, and sometimes the whole plants are used for food. As early as the 1940s, *Athyrium esculentum*, *Ceratopteris siliquosa*, *C. pteridoides*, *Dryopteris prolifera*, *Pteris nodulosa*, *P. esculenta*, and *Helminthostachys* sp. were reported as consumed by the indigenous Filipino [23]. In recent years, more and more research has reported the food uses of pteridophytes in different parts of the world. The fronds of *Ophioglossum polyphyllum* and those of *O. nudicaule* are cooked as a vegetable in Nepal. The fronds of *Helminthostachys zeylanica* are eaten as a salad in rural areas of Malaysia and the Philippines. Tender leaves of *Botrychium lanuginosum* are regarded as a delicious vegetable in Nepal [24].

Tree ferns have often been used as food and starch in Hawaii [24]. Both young fronds and underground stems of *Asplenium ensiforme* are used for food in the Himalayas. In Malaysia, the *Blechnum orientalis* rhizomes are eaten, and the fronds of *Ceratopteris thalictroides* and *Diplazium esculentum* are used as vegetables. The rhizome and young shoots of *Nephrolepis biserrata* are edible. *Ophioglossum reticulatum* is also eaten as a salad and as a vegetable [25]. In India, stems of *Angiopteris* sp. are eaten for starch. *Pteris ensiformis*, *Helminthostachys zeylanica*, *Phymatosorus longissimus* and *Microsorium alternifolium* fern fronds are also used for food. The Maori and Oceanic precedents collected the rhizomes of *Pteridium esculentum* and made food in spring and early

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summer when the sweet potato or taro was not available [24,26]. The starchy paste of the sporocarps of *Marsilea drummondii* is made into cakes and is eaten by the natives of Australia [26].

There are about 10000–12000 species of pteridophytes in the world. In North America, 420 ferns and fern allies have been recorded. Some Asian countries are rich in pteridophyte diversity. For instance, 639 species of ferns occur in Japan, about 1000 in the Philippines, 550 in Malaysia, more than 700 in Thailand, and about 600 in India [27–29].

China is one of the richest countries in pteridophyte species. About 2600 species, in 63 families and 230 genera have been reported in China, which occupies more than 20% of the global pteridophyte flora [27]. The Chinese people have traditionally used ferns for various purposes for many centuries. The indigenous uses include medicines (*Cibotium barometz*, *Davallia mariesii* and many others) [27,30,31], ornamentals (*Neottopteris nidus*, *Nephrolepis auriculata* and others) [27,32], and food as well.

The food uses of ferns in China have been recorded in many ancient books. Some fern species such as *Pteridium aquilinum* var. *latiusculum*, *Callipteris esculenta*, *Matteuccia struthiopteris*, *Osmunda japonica* and *Lygodium japonicum* are very common in the country [27]. Local people, especially those from ethnic minorities in rural areas, have kept the tradition of collecting and eating ferns for many generations.

So far, however, we cannot find any ethnobotanical investigative reports on edible ferns in China. And there is no calculation of the number of fern species, which have traditionally been eaten by local people. This review will try to give an outline of edible ferns for traditional food uses in the ethnic communities of China. The species number of pteridophytes with edibility will be estimated. The future development of edible ferns will also be proposed in the present paper.

Results

Records of edible ferns in ancient Chinese literature

Edible ferns were recorded for the first time in “Shi-Jing” (“Book of Odes”), about 3000 years ago. Two species of ferns, *Pteridium aquilinum* var. *latiusculum* (or “juecai” in Chinese) and *Osmunda japonica* (or “weicai” in Chinese), appeared in the ode [33]. These ferns are still often collected and eaten in rural areas.

The edible parts (fronds), collection time and morphology of ferns were described in the ancient books issued in the Three Kingdoms Period (called “San-Guo”, about 1800 years ago). The significance of edible ferns in livelihood had also been recorded in the literature of that period [33,34].

The time when eating ferns was most popular, was during the Tang Dynasty (AD 618–907). Many poets described, praised or admired edible ferns in their poems. The fronds of *Pteridium aquilinum* var. *latiusculum* and *Osmunda japonica* were the parts most commonly consumed by people in that period [33,35].

The first written record of extracting starch for food from fern rhizomes was during the Song Dynasty (AD 960–1276) [36]. In the Yuan Dynasty (AD 1271–1368), the fern starch from *Pteridium aquilinum* var. *latiusculum* became very important and sometimes it became the main substitute for staple food in the famine years [33].

How many species of ferns have traditionally been used for food in China?

Edible ferns or fern products can be seen in local markets or supermarkets in China. However, nobody can tell how many species of ferns have traditionally been used for food in China. In Guizhou Province only, 64 edible fern species were reported in recent years, covering both traditional and potential edible species [36,37].

Based on literature studies [27,36–40], and our field investigations over the past 20 years, we estimated that there are 52 species (including 4 varieties) of edible ferns traditionally consumed as food by various ethnic groups throughout the country (Tab. 1). Generally, ethnic minorities in the southwest region (especially Yunnan, Guangxi, Guizhou and Sichuan provinces) eat more fern species. Some species like *Neottopteris nidus* taste very bitter, but the local people in southern Yunnan still eat the young leaves as a precious vegetable.

The most common species used as food in traditional communities are *Pteridium aquilinum* var. *latiusculum* (“juecai”), *Callipteris esculenta*, *Osmunda japonica* (“weicai”), *Pteridium revolutum* and *Ceratopteris thalictroides*. Among them, *Pteridium aquilinum* var. *latiusculum* is widely distributed in China. It grows massively and produces a lot of fronds in spring, while the rhizomes, with rich starch, can be harvested in the fall. This species has become the most popular edible fern, consumed by a billion people in China every year. For example, in the Zhuzhou County of Hunan Province only, the dry fronds of *Pteridium aquilinum* var. *latiusculum* (“juecai”) reached 1200 tons in 2011, with a value of 70 million RMB (ca. 1 million in US dollars) [41]. An estimated over 1000 companies in China produce dry “juecai” and its products. Their annual production values reach 300 million US dollars.

Potential edible ferns in China

The stems, rhizomes, fronds, young leaves and shoots, or the whole plants of many fern species can be used for food. The starch in the stems or rhizomes can be harvested, processed and cooked for food, or used to make liquor. The fronds, young leaves and shoots can be eaten as vegetables.

Because of the inaccessibility of habitats, low biomass, lack of consumers, or for cultural, religious and legal reasons, many edible fern species have never, or hardly ever, been collected for food, or have not been recorded in any literature sources. For example, *Metapolypodium memeiense* (Christ) Ching, an epiphytic fern species in southwestern China, has been used as a taste-enhancer for cooking with vegetables by the Jinuo ethnic group in southern Yunnan. Tree ferns are CITES-listed species [42], and also listed in the “Red data book of China” [43]. These species were not included in Tab. 1. Only *Alsophila spinulosa* in the tree fern group is an exception because of its larger population. Sometimes the local people collected the starch from stems which fell down in the forests.

We estimated the potential species number of edible ferns, based on literature analysis [25,26,36–39], field surveys, edibility investigation, and phylogenetic or taxonomic information. The total number reaches at least 144 species, including 4 varieties (Tab. 1, Tab. 2).

Among these 144 potential species (varieties) of edible ferns, the biggest groups are *Allantodia* (Athryiaceae, 30 spp.), *Pteris* (Pteridaceae, 20 spp.), *Angiopteris* (Angiopteridaceae, 18 spp.), *Coniogramme* (Hemionitiaceae, 15 spp.), *Alsophila* (Cyatheaceae, 14 spp.), *Athyrium* (Athryiaceae, 12 spp.), *Asplenium* (Aspleniaceae, 10 spp.) and *Lygodium* (Lygodiaceae, 10 spp.), in terms of species numbers in each genus. However, the fern

Tab. 1 Ethnobotanical inventory of ferns used for food in China.

No.	Species Name	Family Name	Edible Parts	Preparation	Notes	References
1	<i>Allantodia dilatata</i> (Blume) Ching	Athyriaceae	Tender leaves	Stir-fry, soup	Fresh or dry use	[36]
2	<i>Allantodia gigantea</i> (Bak.) Ching	Athyriaceae	Tender leaves	Stir-fry, soup	Fresh or dry use	[36]
3	<i>Allantodia himalayensis</i> Ching	Athyriaceae	Tender leaves	Stir-fry, soup	Fresh or dry use	[36]
4	<i>Allantodia spectabilis</i> (Wall. et Mett.) Ching	Athyriaceae	Tender leaves	Stir-fry, soup	Fresh or dry use	[27,36]
5	<i>Allantodia viridissima</i> (H. Christ) Ching	Athyriaceae	Tender leaves	Cooked after processing with salt	Sour taste	[36]
6	<i>Alsophila spinulosa</i> (Hook.) Tryon	Cyatheaceae	Starch in stems	Made into cakes or mixed with other food	Substitute for staple food	[37,39,40]
7	<i>Ampelopteris prolifera</i> (Retz.) Cope.	Thelypteridaceae	Young leaves and shoots	Stir-fry, soup	Fresh or dry use	[36–39]
8	<i>Angiopteris esculenta</i> Hieron.	Angiopteridaceae	Starch in rhizomes	Made into cakes or mixed with other food	Substitute for staple food	[38–40]
9	<i>Angiopteris fokiensis</i> Hieron.	Angiopteridaceae	Starch in rhizomes	Made into cakes or mixed with other food	Substitute for staple food	[37–40]
10	<i>Asplenium unilaterale</i> Lam.	Aspleniaceae	Rhizomes	Snack, salad	Fresh use	[36]
11	<i>Athyrium brevifrons</i> Nakai ex Kitag.	Athyriaceae	Starch in rhizomes	Cakes, noodles	Starch content 40–50%	[38–40]
12	<i>Athyrium multidentatum</i> (Doll) Ching	Athyriaceae	Fronds	Stir-fry, cooked with other food, soup	Fragrant, tender	[38,39]
13	<i>Athyrium pachyphyllum</i> Ching	Athyriaceae	Fronds	Stir-fry, cooked with other food, soup	Fresh or dry use	[36,39]
14	<i>Athyrium yokoscense</i> (Franch. et Sav.) Chrsit	Athyriaceae	Fronds	Stir-fry, cooked with other food, soup	Fresh use or processing	[36,39]
15	<i>Athyriopsis japonica</i> (Thunb.) Ching var. <i>oshimensis</i> (Christ) Ching	Athyriaceae	Young leaves	Stir-fry, cooked with other food, soup	Fresh or dry use	[36,38]
16	<i>Blechnum orientale</i> L.	Blechnaceae	Fronds and young red leaves	Fried or stir-fried	Fresh or dry use	[36,39]
17	<i>Callipteris esculenta</i> (Retz.) J. Sm. ex Moore et Houlst	Athyriaceae	Fronds	Stir-fry, soup, salad	Fresh	[27,36,38]
18	<i>Callipteris esculenta</i> (Retz.) J. Sm. ex Moore et Houlst. var. <i>pubescens</i> (Link) Ching	Athyriaceae	Fronds	Stir-fry, soup, salad	Fresh	[36,39]
19	<i>Ceratopteris thalictroides</i> (L.) Brongn.	Parkeriaceae	Young leaves	Stir-fry	Fresh	[27,37–39]
20	<i>Cibotium barometz</i> (L.) J. Sm.	Dicksoniaceae	Starch in rhizomes	Cakes, liquor	Substitute for staple food	[37–40]
21	<i>Coniogramme emeiensis</i> Ching et Shing	Hemionitiaceae	Fronds, starch in rhizomes	Cooked leaves as vegetable; noodles		[36,39]
22	<i>Coniogramme intermedia</i> Hieron.	Hemionitiaceae	Fronds, starch in rhizomes	Cooked leaves as vegetable; noodles		[36,39]
23	<i>Coniogramme intermedia</i> Hieron. var. <i>glabra</i> Ching	Hemionitiaceae	Fronds, starch in rhizomes	Cooked leaves as vegetable; noodles		[36,39]
24	<i>Coniogramme japonica</i> (Thunb.) Diels	Hemionitiaceae	Fronds, starch in rhizomes	Cooked leaves as vegetable; noodles		[36,39]
25	<i>Coniogramme jingangshanensis</i> Ching et Shing	Hemionitiaceae	Fronds, starch in rhizomes	Cooked leaves as vegetable; noodles		[36,39]
26	<i>Coniogramme robusta</i> Christ	Hemionitiaceae	Fronds, starch in rhizomes	Cooked leaves as vegetable; noodles		[36,39]
27	<i>Coniogramme rosthornii</i> Hieron.	Hemionitiaceae	Fronds, starch in rhizomes	Cooked leaves as vegetable; noodles		[36,39]
28	<i>Coniogramme simillima</i> Ching ex Shing	Hemionitiaceae	Fronds, starch in rhizomes	Cooked leaves as vegetable; noodles		[36,39]
29	<i>Coniogramme taipaishanensis</i> Ching et Y. T. Hsieh	Hemionitiaceae	Fronds, starch in rhizomes	Cooked leaves as vegetable; noodles		[36,39]
30	<i>Coniogramme wilsoni</i> Hieron.	Hemionitiaceae	Fronds, starch in rhizomes	Cooked leaves as vegetable; noodles		[36,39]
31	<i>Cornopteris decurrenti-alata</i> (Hook.) Nakai	Athyriaceae	Fronds	Stir-fry, soup	Fresh or dry use	[39]

Tab. 1 (continued)

No.	Species Name	Family Name	Edible Parts	Preparation	Notes	References
32	<i>Cyrtomium fortunei</i> J. Sm.	Dryopteridaceae	Fronds	Stir-fry, soup	Processed for storage	[36,39]
33	<i>Drynaria baronii</i> (Christ) Diels	Dryopteridaceae	Starch in rhizomes	Source of starch		[39,40]
34	<i>Drynaria fortunei</i> (Kunze) J. Sm.	Drynariaceae	Starch in rhizomes	Cakes, liquor		[36,39,40]
35	<i>Lunathyrium acrostichoides</i> Ching	Athyriaceae	Fronds	Stir-fry, soup		[39]
36	<i>Lunathyrium coreanum</i> (Christ) Ching	Athyriaceae	Fronds	Stir-fry, soup		[39]
37	<i>Lygodium japonicum</i> (Thunb.) Sw.	Lygodiaceae	Young leaves	Stir-fry, soup		[27,37,39]
38	<i>Marsilea quadrifolia</i> L.	Marsileaceae	Young leaves	Stir-fry, soup		[27,36–39]
39	<i>Matteuccia intermedia</i> C. Chr.	Onocleaceae	Fronds	Stir-fry, soup		[36,39]
40	<i>Matteuccia orientalis</i> (Hook.) Trev.	Onocleaceae	Fronds	Stir-fry, soup		[36,39]
41	<i>Matteuccia struthiopteris</i> (L.) Todaro	Onocleaceae	Fronds, starch in rhizomes	Stir-fry, soup; starch for noodle-making	Delicious vegetable; starch content in rhizomes reaches 40–50%	[27,38–40]
42	<i>Nephrolepis auriculata</i> (L.) Trimen.	Nephrolepidaceae	Young leaves, tubers	Cooked as vegetable, tuber eaten as snack	Young tubers with sweetener	[36,39,40]
43	<i>Neottopteris nidus</i> (L.) J. Sm.	Aspleniaceae	Young leaves	Stir-fry, soup	Bitter taste	[36]
44	<i>Ophioglossum polyphyllum</i> A. Braun	Ophioglossaceae	Fronds	Soup	Fresh or dry use	[25]
45	<i>Osmunda japonica</i> Thunb.	Osmundaceae	Fronds, starch in rhizomes	Stir-fried or cooked with other food, soup; starch for making noodles, liquor	Fresh or dry uses, or processing. Delicious taste. Leaves contain starch, too	[37–40]
46	<i>Osmundastrum cinnamomeum</i> (L.) Presl.	Osmundaceae	Fronds	Stir-fried or cooked with other food, soup	Delicious taste	[37–40]
47	<i>Polypodiodes niponica</i> (Mett.) Ching	Polypodiaceae	Tender leaves	Cooked as vegetable	Bitter taste	[39]
48	<i>Pteridium aquilinum</i> L. var. <i>latiusculum</i> (Desv.) Underw.	Pteridiaceae	Fronds, starch in rhizomes	Stir-fried or cooked with other food, or processed. Starch used to make noodles, liquor, cakes and other products	Commonly called juecai. Fronds should be cooked in boiled water and then washed for a few hours. Widely distributed species in many areas	[27,37–40]
49	<i>Pteridium revolutum</i> (Bl.) Nakai	Pteridiaceae	Fronds, starch in rhizomes	Stir-fried or cooked with other food, or processed. Starch used to make liquor or cakes	Makes similar products as juecai	[27,37–40]
50	<i>Pteris wallichiana</i> Agardh	Pteridaceae	Tender leaves	Stir-fry	Fresh use	[27,37]
51	<i>Woodwardia japonica</i> (L. f.) J. Sm.	Blechnaceae	Starch in rhizomes	Cakes, noodles, liquor		[36–40]
52	<i>Woodwardia unigemmata</i> (Makino) Nakai	Blechnaceae	Starch in rhizomes	Cakes, noodles, liquor		[36,39]

products from these groups are rarely sold in local markets or are less consumed by the local people.

Traditional fern cuisines

The Chinese people in different areas have developed various methods to make fern dishes and food varieties. The most common dish is made of stir-fried fresh or dry fern fronds of *Pteridium aquilinum* var. *latiusculum* (“juecai”). There are various stir-fried dishes created by adding other food to the fern fronds. For example, chili peppers, Chinese leeks (*Allium tuberosum*), ham, or chicken can be stir-fried with fern fronds. Other species, like *Allantodia gigantea*, *Athyrium yokoscense*, *Callipteris esculenta*, *Lygodium japonicum*, *Matteuccia struthiopteris*, *Osmunda japonica* and *Osmundastrum cinnamomeum* have also been cooked following a similar formula.

Another popular dish is made of fern slices made from starch, either fried or steamed. The starch was usually extracted from the rhizomes of *Pteridium aquilinum* var. *latiusculum*. The slices could be prepared like Chinese bread, and then cooked in pots. Fern cakes are also common, made from fern starch. In the famine years, people collected the rhizomes in the mountains and extracted the starch as a substitute for staple food.

Both fern fronds and starch are used to make porridge (congee), together with rice or millet. The fronds can be either fresh or dried, but need to be cut into small slices.

Fern food products in China

Both in local markets and supermarkets, there are a lot of fern food products in China. These products can be

Tab. 2 List of all edible fern genera in China.

No.	Genus Name	Family Name	Edible Parts	Species No. in China	Edible species (estimated number)
1	<i>Allantodia</i> R. Br. emend. Ching	Athyriaceae	Young leaves	73	30
2	<i>Alsophila</i> R. Br.	Cyatheaceae	Starch in stems	14 (incl. 2 varieties)	14
3	<i>Ampelopteris</i> Kunze	Thelypteridaceae	Young leaves	1	1
4	<i>Angiopteris</i> Hoffn.	Angiopteridaceae	Rhizomes	20	18
5	<i>Asplenium</i> L.	Aspleniaceae	Young leaves	110	10
6	<i>Athyrium</i> Roth	Athyriaceae	Young leaves	82	12
7	<i>Athyriopsis</i> Ching	Athyriaceae	Young leaves	10	3
8	<i>Blechnum</i> L.	Blechnaceae	Fronds	1	1
9	<i>Callipteris</i> Bory.	Athyriaceae	Young leaves	3 (incl. 1 variety)	2
10	<i>Ceratopteris</i> Brongn.	Parkeriaceae	Young leaves	2	2
11	<i>Cibotium</i> Kaulf.	Dicksoniaceae	Starch in rhizomes	2	1
12	<i>Coniogramme</i> Fee	Hemionitiaceae	Young leaves, starch in rhizomes	20	15
13	<i>Cornopteris</i> Nakai	Athyriaceae	Fronds	11	6
14	<i>Cyrtomium</i> Presl.	Dryopteridaceae	Fronds,	40	4
15	<i>Drynaria</i> (Bory) J. Sm.	Drynariaceae	Starch in rhizomes	9	8
16	<i>Gymnosphaera</i> Bl.	Cyatheaceae	Starch in stems	9	9
17	<i>Lunathyrium</i> Ching	Athyriaceae	Fronds	48 (incl. 10 varieties)	5
18	<i>Lygodium</i> Sw.	Lygodiaceae	Young leaves	10	10
19	<i>Marsilea</i> L.	Marsileaceae	Young leaves	3	1
20	<i>Matteuccia</i> Todaro	Onocleaceae	Fronds	3	3
21	<i>Metapolypodium</i> Ching	Polypodiaceae	Leaves	1	1
22	<i>Nephrolepis</i> Schott	Nephrolepidaceae	Young leaves, tubers	6	2
23	<i>Neottopteris</i> Schott	Aspleniaceae	Young leaves	11	2
24	<i>Ophioglossum</i> L.	Ophioglossaceae	Fronds	5	1
25	<i>Osmunda</i> L.	Osmundaceae	Young leaves, starch in rhizomes	3	3
26	<i>Osmundastrum</i> Presl.	Osmundaceae	Young leaves, starch in rhizomes	2	2
27	<i>Polypodiodes</i> Ching	Polypodiaceae	Tender leaves	12	3
28	<i>Pteris</i> L.	Pteridaceae	Tender leaves	50	20
29	<i>Sphaeropteris</i> Bernh	Cyatheaceae	Starch in stems	2	2
30	<i>Woodwardia</i> Smith	Blechnaceae	Starch in rhizomes	5	5

stored or preserved for later. Common products include dried fronds, salted fronds, packaged fronds, fern starch, fern starch noodles, fern starch cakes, and fern leaf tea. When making fern starch noodles and cakes, wheat flour can be added and mixed.

The fronds are mostly from two species, *Pteridium aquilinum* var. *latiusculum* ("juecai") and *Osmunda japonica* ("weicai"). The former occupies more than 80% of the fern food market. Both species are exported to international markets. The starch for making food products comes mainly from the rhizomes of *Pteridium aquilinum* var. *latiusculum*. The season for harvesting rhizomes is from September to November, when the aerial parts of the ferns become withered.

People use the fern starch to produce other products, such as liquor and soft drinks. Before they make liquor, other materials like rice, sweet potato or corn flour can be added to the fern starch.

Nowadays, many varieties of fern products have been developed. The canned ferns, spicily seasoned ferns, dehydrated ferns, salted ferns and other products can easily be brought in the markets in all seasons.

Chemical components of edible ferns and their bioactivities

Many researchers have reported the chemical constituents of different edible ferns. Nine compounds have been isolated

from the fronds of *Pteridium aquilinum* var. *latiusculum*, the most common edible fern in China. They are daucosterol, trans-tiliroside, adenosine, wallichoside, inkosterone, rutin, pterisin A, ponasterone A and quercetin [44].

Matteuccia struthiopteris is also a commonly consumed edible fern species. The compounds found in this species include 1-O- β -D-glucopyranosyl-(2S, 3R, 4E, 8z)-2-N-(2'-hydroxydocosanoyl) eicosasphinga-4,8-dienine, 1-O- β -galactosyl-(6 \rightarrow 1)- α - β -galactosyl-2,3-O-dihexadecanoyl-glycerol, succinic acid, D-mannitol, demethoxymatteucinol, matteucinol, pinosylvin, matteuorien, pinosylvin 3-O- β -D-glucopyranoside, matteuorienate A [45,46].

Many chemical compounds are reported in *Pteris* [47,48]. These are, for example, apigenin-7-O- β -D-glucopyranosyl-4'-O- α -L-rhamnopyranoside, luteolin-7-O- β -D-glucopyranoside, apigenin-7-O- β -D-glucopyranoside, apigenin, luteolin, naringenin-7-O- β -D-neohesperidoside, apigenin-7-O- β -D-neohesperidoside, apigenin-4'-O- α -L-rhamnopyranoside, (2S,3S)-pterisin C, isovanillic acid, ferulic acid, 2 β ,16 α -dihydroxy-ent-kaurane 2-O- β -D-glucoside, 2 β ,6 β ,15 α -trihydroxy-ent-kaur-16-ene, 9-hydroxy-15-oxo-ent-kaur-16-en-19-oic acid 19 β -D-glucoside, 2 β ,14 β ,15 α ,16 α ,17-pentahydroxy-ent-kaurane, and 9-hydroxy-ent-kaur-16-en-19-oic acid. Some extracts from *Pteris* showed antitumor, antifungal and antibacterial activity.

Some of the compounds had an inhibitory effect on platelet aggregation, as well as an anti-inflammatory effect [49].

Pterins, terpenoids, sterols, flavones, glucosides, aromatic, and pyrone compounds were isolated from *Cibotium barometz* [50]. Their pharmacological effects, such as anti-haemorrhagic, bacteriostatic, antiosteoporotic, anticancer, and hepatoprotective, have been tested [31].

A representative species in Athyriaceae, *Callipteris esculenta*, has also been studied phytochemically. Such compounds as β -sitosterol, stigmast-4-ene-6 β -ol-3-one, stigmast-4-ene-3,6-dione, benzenoacetic acid, glycerol-1,3-dihexadecanoate, 3 β -hydroxy-5 α ,8 α -epidioxyergosta-6,22-diene, stigmast-4-ene-3 β ,6 β -diol, stigmast-5-ene-3 β ,7 α -diol, stigmast-4-ene-6 α -ol-3-one, and daucosterol have been isolated from the fronds of this species [49].

Chemicals from *Nephrolepis cordifolia* have also been isolated. They were identified as β -sitosterol, fern-9(11)-ene, oleanolic acid, myristic acid octadecylester, hentriacontanoic acid and triacontanol [51].

Discussion and suggestions

Toxicity of *Pteridium aquilinum* var. *latiusculum*

Bracken fern, or *Pteridium aquilinum*, is the most controversial species. Its fronds and starch have been eaten by billions of people in the world. However, it is a problematic, dangerous and poisonous plant due to its special chemical composition, especially the content of ptaquiloside (PT), a highly carcinogenic compound. It has been found that PT is present in all parts of the plant, including fronds, leaves, rhizomes, and roots. The highest concentration of PT (average at 3800 $\mu\text{g/g}$) is in the frond growing season, while the PT contents of roots are the lowest (5–230 $\mu\text{g/g}$). In the rhizomes, the PT contents are less than 1200 $\mu\text{g/g}$ in general [52].

Different types of human carcinomas (oesophageal, gastric cancers, etc.) are produced by ingestion of bracken fern or milk from bracken-fed cattle [53]. Even nowadays, because of its wide distribution and easy accessibility, bracken fern has been collected as part of the diet by many poor people, from south Pacific islands to northern, temperate prairies.

Botanically, the taxon massively collected by local people in China as food is a variety of *Pteridium aquilinum*. Unfortunately, this lower taxon (*Pteridium aquilinum* var. *latiusculum*, in Chinese it is also called “juecai”, “longzhuacai” or “ruyicai” commonly) has also been proven to be poisonous because PT has been detected in this subspecies [54]. Thus, we should warn the public that “juecai” (including fronds, starch and their products) is poisonous and harmful to human health.

However, it is a strong part of traditional food culture to collect and eat ferns in the most rural regions of China. And “juecai” (*Pteridium aquilinum* var. *latiusculum*) is the most important food fern among all edible pteridophytes for both household consumption and commercial purposes. We cannot stop Chinese people eating juecai. The only solution is to remove toxins from “juecai” in an easy and cost-effective way.

Fortunately, PT is unstable in water. This compound will also decompose under acidic or alkaline conditions. This is the reason why very few people have suffered from eating “juecai”, because people usually wash it in water for hours or even a few days to remove the bitter flavor. Therefore detoxification is very easy when processing “juecai” and its products, even in the

countryside. It is strongly encouraged that the fresh fronds or starch from *Pteridium aquilinum* var. *latiusculum* are washed in water, or placed under acidic or alkaline conditions, for a few hours before eating or making products.

Further research

Among China's 196 edible fern species, including the potentially edible species (144 spp.) and those traditionally used as food (52 spp.), only 10% have been studied phytochemically. Chemical constituents of other edible fern species, in particular the possible toxins, should be examined carefully.

The contents of PT in the *Pteridium aquilinum* var. *latiusculum* (“juecai”) plant may be different from one place to another. Studies carried out in New Zealand, Australia, Costa Rica and Venezuela revealed that the PT contents for bracken fern fronds (from 12 stands of four geographically distinct habitats) were found between 210 and 2150 $\mu\text{g/g}$, this variation was positively correlated with development phases and altitudes [55]. Therefore, it is necessary to study the PT contents in different populations or geographical origins of “juecai”.

Most fern species grow slowly (“juecai” is an exception). It is necessary to grow edible ferns for commercial development artificially or semi-artificially. As ferns produce numerous spores, mass propagation and production of edible ferns from spores for commercial production should be studied. The micropropagation techniques of edible ferns (especially the rare species) can be encouraged, too.

Suggestions for production and toxicity examination of edible ferns

In China, there are thousands of companies producing edible fern products. The contents of PT and other poisonous compounds in edible ferns and fern products should carefully be examined before they appear in commercial markets. Those with higher PT content must not be allowed onto the market. Raw materials from *Pteridium aquilinum* var. *latiusculum* and allied species should be double-checked.

The governmental food and drug administrative authorities at different levels should issue criteria for quality/safety control of edible fern products. Every edible fern enterprise should follow the criteria, especially the content limitation of PT in the products.

It will be helpful to identify the origin of raw fern materials, because the contents of PT are very different based on their geographical locations. The practice of placing a certificate of origins with low PT contents on edible fern products should be encouraged.

Recommendations of a few fern species

Based on our investigation, we recommend the following edible fern species for future commercial development in China:

(i) *Athyrium multidentatum* is a common fern species in northeast China. It is called “houtui” in Chinese, which means monkey legs because of the yellow hairs on the petioles. The fronds of *Athyrium multidentatum* are very tasty and fragrant. Both fresh and processed fronds can be stir-fried or cooked for soup.

(ii) *Matteuccia struthiopteris* also occurs in northeast China. In Chinese it is called “Huanggua Xiang”, which means it has a cucumber (“Huanggua”) flavor. The young leaves can be cooked as a delicious dish or used to make dumplings.

(iii) *Osmunda japonica* is a widely distributed species. Its production, however, has decreased over the last two decades.

People overharvested it because the products made from its tasty fronds were exported to Japan as well as consumed in domestic markets. Artificial cultivation of this fern will hopefully meet the demands of international markets.

(iv) *Ophioglossum polyphyllum* is distributed in the tropical and subtropical areas. In Tibet it is eaten in summer as a vegetable but also dried and stored for further consumption in winter. Previous studies revealed that it contains high levels of essential amino-acids that can complement the local diet [25]. It can be developed as a cultivated species in southern China.

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