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The genus *Lycium* as food and medicine: A botanical, ethnobotanical and historical review

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ABSTRACT

Ethnopharmacological relevance: *Lycium* is widely distributed in the arid to semi-arid environments of North and South America, Africa, and Eurasia. In recent years, *Lycium barbarum* and *L. chinense* have been advertised as "superfood" with healthy properties. Despite of its popularity, there is a lack of an integrated and critical appraisal of the existing evidence for the use of *Lycium*.

Aim of the study: There is a need to understand: 1) Which species were used and how the uses of *Lycium* developed spatially and over time, 2) how uses differ among regions with different culture backgrounds, and 3) how traditional and current therapeutic and preventive health claims correlate with pharmacological findings.

Methods: Information was retrieved from floras, taxonomic, botanical, and ethnobotanical databases, research articles, recent editions of historical Chinese herbals over the last 2000 years, and pharmacopoeias.

Results: Of totally 97 species, 35 have recorded uses as food and/or medicine worldwide. Usually the fruits are used. While 85% of the *Lycium* species occur in the Americas and Africa, 26% of them are used, but 9 out of 14 species in Eurasia. In China, seven species and two varieties of the genus *Lycium* occur, of which four species have been used by different ethnic groups. Only *L. barbarum* and *L. chinense* have been transformed into globally traded commodities. In China, based on the name "枸杞", their use can be traced back over the last two mil-lennia. *Lycium* fruits for anti-aging, improving eyesight and nourishment were documented already in 500 C.E.(*Mingyi Bielu*). Recent findings explain the pharmacological foundations of the traditional uses. Especially polysaccharides, zeaxanthin dipalmitate, vitamins, betaine, and mixed extracts were reported to be responsible for anti-aging, improving eyesight, and anti-fatigue effects.

Conclusions: The integration of historical, ethnobotanical, botanical, phytochemical and pharmacological data has enabled a detailed understanding of *Lycium* and its wider potential. It highlights that the focus so far has only been on two species and that the genus can potentially yield a wide range of other products with different properties.

1. Introduction

Plant-based products are important sources of both food and medicine. Whether a plant is used as food or medicine depends on a wide range of factors, but is not necessarily intrinsic to its pharmacological or nutritional properties (Leonti, 2011; Jennings et al., 2015). In the last decades the variety of consumed crops has increased globally, especially of local agricultural varieties and species collected from the wild. These are becoming more important for human nutrition and for medicinal uses (Heywood, 2011). This increase is often based on traditional knowledge, which is defined as knowledge innovations and practices of indigenous and local communities embodying traditional lifestyles relevant for the conservation and sustainable use of biological diversity (Xue, 2011). Traditional knowledge on plants can be used as a starting point to develop new medicines, e.g., the discovery of artemisinin (Tu, 2015), while it should be protected subject to the Nagoya Protocol (Ngo et al., 2013; Buch and Hamilton, 2011). Therefore, traditional knowledge on plants continues to play an important role in human lives for both food and medical purposes.

The fruit, leaf, root bark, and young shoot of many species of the genus *Lycium* L. have long been used as local foods and/or medicines. Recently, *Lycium* fruits, known as goji or wolfberry, have become increasingly popular in the western world because of their nutritional properties (Qian et al., 2017; Amagase, 2010; Potterat, 2010; Amagase and Farnsworth, 2011); they are even advertised as "superfood" in Europe and North America (Wolfe, 2010; Chang and So, 2015).

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Table 1
Data sources used.

Themes	Data sources	Key words
Taxonomy & Systematics	The Plant List (2013), http://www.theplantlist.org/; GBIF (Global Biodiversity Information Facility), 2017, https://demo.gbif.org/; IPNI (The International Plant Names Index), 2015, http://www.ipni.org/; LycieaeWeb (2017), http://jsmiller.people.amherst.edu/LycieaeWeb/Project_Lycieae.html; African Plant Database (version 3.4.0), 2017. http://www.ville-ge.ch/musinfo/bd/cjb/africa/; EuroPlusMed PlantBase (2011), http://ww2.bgbm.org/; eFloras (2017). http://www.efloras.org; Flora of China (Vol. 17), 1994. http://foc.eflora.cn/; Flora of China (Vol. 67), 1994; Flora of Victoria, 2015, https://vicflora.rbg.vic.gov.au/; Neotropical Flora (2017), http://hasbrouck.asu.edu/neotrop/plantae/index.php; Flora of Israel (2017), http://flora.org.il/plants/; Flora of Pakistan, 1980; Flora of the great plains, 1986; Flora of North America (2009), http://luirig.altervista.org/flora/taxa/north-america.php; NPGS (National Plant Germplasm System), 2016. https://npgsweb.ars-grin.gov/; Flora of Argentina (1992). http://www.floraargentina.edu.ar/; and scientific articles of Google scholar, science direct, web of science, NCBI (National Center for Biotechnology Information), and NEBIS (Network of Libraries and Information Centers in Switzerland).	*Lycium*, and the specific species names.
Traditional uses globally	Dr. Duke's Phytochemical and Ethnobotanical Databases, 1992–2016, http://phytochem.nal.usda.gov/; NPGS (National Plant Germplasm System), 2016. https://npgsweb.ars-grin.gov/; FEIS (Fire Effects Information System), 2016, http://www.feis-crs.org/feis/; NAEB (Native American Ethnobotany Database), 2003. http://naeb.brit.org/; PFAF (Plants for a Future), 2016, http://www.pfaf.org/; ETHMEDmmm (The Data Base of Ethno-medicines in the world), 2016, http://ethmed.u-toyama.ac.jp; Medicinal Plant Names Services (2017) (http://mpns.kew.org); and scientific articles of Google scholar, science direct, web of science, NCBI (National Center for Biotechnology Information), and NEBIS (Network of Libraries and Information Centers in Switzerland).	*Lycium*, the specific species names, Traditional use, food, medicine, ethnobotanical survey.
Use history in Chinese medicine	Chinese herbals and agronomy monographs (from ca. C.E. 100–2006; see S1); regional books of ethnobotany and herbal medicine in China. (Search with" nationality + 医药" in google book (https://books.google.com/).	"杞","地骨皮"
Pharmacopoeias	Chinese Pharmacopoeia (2015, vol. 1), European Pharmacopoeia (9.0), Japanese Pharmacopoeia (16th), Korean Pharmacopoeia (9th), Taiwan TCM Pharmacopoeia (2013), Vietnam Pharmacopoeia (4th), Ayurveda API (Vol. 6); all editions of Chinese Pharmacopoeia (1953–2015) British Pharmacopoeia Commision (2017).	*Lycium*

Phytochemical studies indicate that the richness in numerous constitutions of different classes, such as polysaccharides, carotenoids, flavonoids, alkaloids, amides, terpenoids, and so on, endows *Lycium* species with a variety of biological activities (Qian et al., 2017; Yao et al., 2011). Also, pharmacopoeias adopted the most popular species, *L. barbarum* and/or *L. chinense*, as herbal medicines (Wagner et al., 2011).

Thus, species of the genus *Lycium* serve as widely used source of food and medicine. Despite of its popularity, there is a lack of an integrated and critical appraisal of the existing evidence for the use of *Lycium*. From a botanical and ethnopharmacological perspective, there is a need to understand: 1) Which species were used and how the uses of *Lycium* developed spatially and over time, 2) how uses differ among regions with different culture backgrounds, and 3) how traditional and current therapeutic and preventive health claims correlate with pharmacological findings.

To answer these questions we started with a botanical overview of the genus and its accepted species, and did a comprehensive study and analysis of a large body of literature and databases.

2. Methods

Overall, information was obtained from floras, taxonomic, botanical, and ethnobotanical databases, research articles, recent editions of historical Chinese herbals, and pharmacopoeias. All sources used to extract information as well as the applied keywords are given in Table 1.

For species names and synonyms we relied on The Plant List (2013) and local floras. Distribution data and biogeographic information were obtained from IPNI (2015), GBIF (2017), LycieaeWeb (2017) and research articles. Morphological characters were extracted from the regional floras and type specimens in the Chinese National Herbarium (PE) were consulted for verification.

To gather information about the use of *Lycium* species at a global level, the following strategy was used: 1) "*Lycium*" was used as key word to search within the ethnobotanical databases (Table 1). 2) In google scholar, "*Lycium*" and "traditional" or "ethnobotany" or "medicine" or "food" or "herb" were searched. 3) The validated species names were searched within the ethnobotanical databases and google scholar. And 4) the words "ethnobotanical survey" were searched, then "*Lycium*" was searched in the texts. 5) "*Lycium*" was also searched in regional ethnobotanical and herbal medicine monographs. Results were integrated with species data.

For the history of *Lycium's* use we focused on China, both because a continuous documentation over the last two millennia is available, and the current boom of goji use originated in China. We relied on modern translations of classical Chinese herbals. At least one herbal per dynasty was included. If several contemporary herbals existed, the most comprehensive one and herbals adding new information were used. In total, 32 herbals from ca. C.E. 100–2006 were considered.

In order to find scientific evidence for traditional uses, we did a literature search on the phytochemistry and pharmacology of *Lycium* species. The main bioactivities and the related compounds or extracts were listed in one table.

To compare *Lycium* records in pharmacopoeias of different regions, "*Lycium*" was searched in the pharmacopoeias listed in the Index of the World Pharmacopoeias and Pharmacopoeial Authorities (document QAS/11.453/ Rev.6) published by WHO in 2016. *Lycium* was only found in the pharmacopoeias of seven Asian countries and regions.

In order to study the change of the records over time, all editions (from 1953 to 2015) of the Chinese pharmacopoeia were consulted.

Additionally, all the parameters for *Lycium* fruit and *Lycium* root included in the pharmacopoeias were extracted and analyzed with a cluster analysis to understand the relationships among pharmacopoeias. R and the package "ape" was employed (R Core Team, 2017; Paradis et al., 2004) for cluster analysis.

3. Results

3.1. Botany

The genus *Lycium* (Solanaceae) widely grows in arid to semi-arid environments of the temperate zones (Fukuda, 2001; Miller et al., 2011;

Table 2
The distribution of *Lycium* species and their uses as food and medicine.

Species name	Distribution	Food use	Medicine use	References[a] for plant uses
L. acutifolium E. Mey. ex Dunal	South Africa, Madagascar, Lesotho	Starch of root recommended as famine food for extending bread flour; bark as condiment.	Pounded bark to keep a person in good health	USDA (1992–2016); Dhar et al. (2011); Watt and Warmelo (1930); Lev and Amar (2006); MPNS, 2017
L. afrum L.	South Africa, France, Tunisia, Sweden, Germany, Netherlands, medieval Cairo	Fruit: food	Leaves, fruits, roots for eye diseases, cough	USDA, 1992–2016; PFAF (2016); Middleditch (2012); Lev and Amar (2006); MPNS, 2017
L. ameghinoi Speg.	Argentina	NM (not mentioned)	NM	–
L. americanum Jacq.	Bahamas; Cuba; Haiti; Dominican Republic; Islas de Barlovento; Venezuela; Colombia; Costa Rica; Ecuador; Peru; Bolivia; Paraguay; Argentina	fruit as food	NM	Arenas and Scarpa (2007)
L. amoenum Dammer	South Africa, Namibia	NM	NM	–
L. anatolicum A.Baytop & R.R.Mill	Turkey, Armenia	NM	NM	–
L. andersonii A. Gray	US, Mexico	Fruit as food	NM	NAEB (2003); PFAF (2016); Saunders (1920); Crosswhite (1981); Hodgson (2001); Newton (2013)
L. andersonii var. *deserticola* (C.L. Hitchc.) Jeps.	US, Mexico	NM	NM	–
L. arenicolum Miers	South Africa, Lesotho, Botswana, United States	NM	NM	–
L. athium Bernardello	Argentina	NM	NM	–
L. australe F.Muell.	Australia	Fruit as food	NM	PFAF (2016); Jeanes (1999); Clarke (1998)
L. barbarum L.	Widely distributed in Asia, Europe, North America, and Austria; also appears in Africa and South America	Fruit, shoot, leaf as food	Fruit, root, leaf, calyx, bark, and whole plant as medicines for a variety of diseases	USDA, 1992–2016; PFAF (2016); Lim (2012); Liu et al. (2004); Li et al. (2001); Ali (1964); ETHMEDmm, 2016; Koleva et al. (2015); Duke (2002); Deeb et al. (2013); MPNS, 2017; Quattrocchi (2012)
L. berberioides Correll	US	NM	NM	–
L. berlandieri Dunal	US, Mexico, Germany	Fruit as food	Plant as medicine	FEIS (2016); PFAF (2016); Kearney et al. (1960); Powell, 1988; Newton (2013)
L. berlandieri var. *parviflorum* (A. Gray) A. Terracc.	US, Mexico	Fruit as food	Plant as medicine	Hodgson (2001)
L. bosciifolium Schinz	Namibia, South Africa, Botswana, Angola, Zimbabwe	Leaf as food	NM	Ndithia and Perrin, 2006
L. brevipes Benth.	US, Mexico	NM	NM	–
L. californicum A. Gray	US, Mexico, Jamaica	NM	NM	–
L. carinatum S. Watson	Mexico, Jamaica	NM	NM	–
L. carolinianum Walter	US, Mexico, Cuba, Easter Island, West Indies	fruit as food	NM	PFAF (2016)
L. carolinianum var. *quadrifidum* (Moc. & Sessé ex Dunal) C.L. Hitchc.		NM	NM	–
L. cestroides Schltdl.	Argentina, Bolivia, Uruguay, Brazil, Australia, Germany, UK	NM	Analgesic	Rondina et al. (2008); MPNS, 2017
L. chanar Phil.	Argentina, Bolivia, Chile	NM	NM	–
L. chilense Bertero	Argentina, Chile, Paraguay, Bolivia, UK, Brazil, Switzerland, Ecuador, France	NM	Fruit as medicine	NPGS (2016); USDA, 1992–2016
L. chinense Mill.	Widely distributed in Asia, Europe, North America, and Austria	Fruit, leaf and young shoot as food; seed for coffee; leaf as tea	Fruit, root, leaf, bark, and whole plant as medicines	NPGS (2016); PFAF (2016); USDA, 1992–2016; Lim (2012); ETHMEDmm, 2016; MPNS,2017; Duke (2002); Quattrocchi (2012)
L. chinense var. *potaninii* (Pojark.) A.M.Lu	China	NM	Root bark as medicine	Li et al. (2001)
L. ciliatum Schltdl.	Argentina, Brazil, Bolivia	NM	Leaf as medicine for digestive and stomach inflammations	Trillo et al. (2010); Toledo et al. (2014)
L. cinereum Thunb.	South Africa, Botswana, Namibia, Lesotho	Fruit as food	Treat headache and rheumatism; root: anodyne, kidney disease, perfume	Iwu (2014); Dhar et al. (2011); Van Damme (1998); MPNS, 2017
L. cooperi A. Gray	Mexico, US	NM	NM	–
L. cuneatum Dammer	Argentina, Paraguay, Bolivia	NM	NM	–
L. cyathiformum C.L. Hitchc.	Bolivia, Argentina	NM	NM	–

(*continued on next page*)

Table 2 (*continued*)

Species name	Distribution	Food use	Medicine use	References[a] for plant uses
L. cylindricum Kuang & A. M. Lu	China	NM	NM	–
L. dasystemum Pojark.	China, Iran	Fruit as food	Fruit as medicine	Ali (1980); Azadi et al. (2007); Li et al. (2001);
L. decumbens Welw. ex Hiern	South Africa, Namibia, Angola	NM	NM	–
L. densifolium Wiggins	Mexico	NM	NM	
L. depressum Stocks	Iran, Russia, Israel, Turkmenistan, Iraq, Palestinian Territory, Afghanistan, Turkey, Pakistan, Jordan	NM	Leaf and fruit for kidney problems	Tabaraki et al. (2013); Ghasemi et al. (2013)
L. deserti Phil.	Chile	NM	NM	–
L. dispermum Wiggins	Mexico	NM	NM	–
L. distichum Meyen	Peru, Bolivia, Chile	NM	NM	–
L. divaricatum Rusby	Peru, Bolivia	NM	NM	–
L. edgeworthii Miers	India, Pakistan, Iran	NM	NM	–
L. eenii S. Moore	Namibia	NM	NM	–
L. elongatum Miers	Argentina	NM	Leaf for digestive	Toledo et al., 2014; Trillo et al., 2010.
L. europaeum L.	Spain, France, Israel, Palestinian Territory, Algeria, Portugal, India, Tunisia, Egypt	Fruit and young shoot as food	Fruit, leaf, bark, and whole plant are used for a variety of treatments	PFAF (2016); Fratkin (1996); Dafni and Yaniv (1994); Said et al. (2002); El Hamrouni, 2001; Boullard (2001); Pieroni et al. (2002); Al-Quran (2007); El-Mokasabi (2014); Turker et al. (2012); Leporatti and Ghedira (2009); Licata et al. (2016); MPNS, 2017
L. exsertum A. Gray	US, Mexico	Fruit as food	NM	NAEB (2003); Hodgson (2001); Newton (2013); Nabhan et al. (1982)
L. ferocissimum Miers	Australia, South Africa, New Zealand, Morocco, Namibia, US, Lesotho, Spain, Norfolk Island, Tunisia	Fruit as food	Plant for detoxication of narcotic poisoning	Watt and Breyer-Brandwijk (1962); Arnold et al. (2002); MPNS, 2017
L. fremontii A. Gray	US, Mexico	Fruit as food	NM	NAEB (2003); PFAF (2016); Watt and Breyer-Brandwijk (1962); MPNS, 2017
L. fuscum Miers	Argentina	NM	NM	–
L. gariepense A.M.Venter	South Africa, Namibia	NM	NM	–
L. gilliesianum Miers	Argentina, Chile	NM	NM	–
L. glomeratum Sendtn.	Argentina, Paraguay, Bolivia, Brazil, China	NM	NM	–
L. *grandicalyx* Joubert & Venter	South Africa, Namibia	NM	NM	–
L. hantamense A.M.Venter	South Africa	NM	NM	–
L. hassei Greene	US	NM	NM	–
L. hirsutum Dunal	South Africa, Namibia, Botswana	NM	NM	–
L. horridum Thunb.	South Africa, Namibia, Madagascar, Botswana, Lesotho, Angola, Iran, Mauritius, Turkey	NM	NM	–
L. humile Phil.	Chile, Argentina	NM	NM	–
L. infaustum Miers	Argentina, Colombia, Bolivia, Ecuador, Dominican, Turks And Caicos Islands, Jamaica, Peru, Portugal, Paraguay	NM	NM	–
L. intricatum Boiss.	Spain, Morocco, Portugal, Mauritania, Algeria, Egypt, Saudi Arabia, Tunisia, Tunisia, Italy	NM	Seed: helminthiasis, digestive; fruit: eye diseases	Abouri et al. (2012); Ouhaddou,. et al. (2014); Boulila and Bejaoui (2015); Abdennacer et al. (2015); MPNS, 2017
L. isthmense F. Chiang	Mexico	NM	NM	–
L. leiostemum Wedd.	Chile, Peru, Mexico	NM	NM	–
L. macrodon A. Gray	US, Mexico	NM	NM	–
L. makranicum Schonebeck-Temesy	Pakistan	NM	NM	–
L. martii Sendtn.	Brazil, Cuba	NM	NM	–
L. mascarenense A.M. Venter & A.J. Scott	Mauritius, Madagascar, South Africa, Mozambique, Reunion	NM	NM	–
L. megacarpum Wiggins	Mexico	NM	NM	–
L. minimum C.L. Hitchc.	Ecuador	NM	NM	–
L. minutifolium Remy	Chile, Argentina, Mauritius	NM	NM	–
L. morongii Britton	Argentina, Paraguay, Bolivia	NM	NM	–
L. nodosum Miers	Argentina, Mexico, Paraguay, Ecuador, Venezuela, Bolivia, Peru	NM	NM	–
L. oxycarpum Dunal	South Africa, Namibia, Angola, US	NM	Used as medicine, no details	Arnold et al. (2002); MPNS, 2017

(*continued on next page*)

Table 2 (*continued*)

Species name	Distribution	Food use	Medicine use	References[a] for plant uses
L. pallidum Miers	US, Mexico	Fruit as food	Plant and root as medicine, for toothache and chickenpox	NAEB (2003); FEIS (2016); PFAF (2016); Kindscher et al. (2012); Saunders (1920); McClendon (1921); Powell (1988); Vines (1960); Hodgson (2001); Middleditch (2012); MPNS, 2017; Quattrocchi (2012)
L. parishii A. Gray	US, Mexico	Fruit as food	NM	Nabhan et al. (1982); Hodgson (2001)
L. parishii var. *modestum* (I.M. Johnst.) F. Chiang	Mexico	NM	NM	–
L. petraeum Feinbrun	Italy, Jordan; *EuroPlusMed PlantBase*	NM	NM	–
L. pilifolium C.H. Wright	South Africa, Namibia, Botswana	NM	NM	–
L. prunus-spinosa Dunal	South Africa, Namibia	NM	Used as medicine, no details	Arnold et al. (2002); MPNS, 2017
L. puberulum A. Gray	US, Mexico	NM	NM	–
L. pubitubum C.L.Hitchc.	US, Mexico	NM	NM	–
L. pumilum Dammer	South Africa, Namibia	NM	NM	–
L. rachidocladum Dunal	Chile	NM	NM	–
L. repens Speg.	Argentina, US	NM	NM	–
L. richii A. Gray	US, Mexico	Fruit as food	NM	Watson (1888); Hodgson (2001)
L. ruthenicum Murray	China, Iran, Afghanistan, India, Mexico, Pakistan, Russian, Turkmenistan, Georgia	Fruit as food	Fruit: ophthalmic, blindness (veterinary); leaf: remove blocked urine; diuretic	USDA (, 1992–, 2016); PFAF (2016); Ballabh et al. (2008); Gairola et al. (2014); MPNS, 2017
L. sandwicense A. Gray	Islands across the Pacific (Easter Island, Hawaiian Islands, Ogasawara Islands and Daitou Island)	Fruit as food	NM	PFAF (2016); Middleditch (2012)
L. schizocalyx C.H. Wright	South Africa, Botswana, Namibia, Mozambique	NM	NM	–
L. schreiteri F.A.Barkley	Argentina	NM	NM	–
L. schweinfurthii Dammer	Spain, Israel, Morocco, Greece, Portugal, Algeria, Egypt, Tunisia, Mauritania, Cyprus	NM	Leaf and fruit are used for stomach ulcer	PFAF (2016); Auda (2011); Jamous et al. (2015)
L. shawii Roem. & Schult.	Israel, Palestinian Territory, Saudi Arabia, Ethiopia, Oman, Egypt, Jordan, South Africa, Botswana, Yemen	Fruit and young shoot as food	Leaf, fruit, aerial part, and stem are used for a variety of treatments	Seifu (2004); Soltan and Zaki (2009); Cherouana et al. (2013); Ghazanfar (1994); Hassan-Abdallah et al. (2013); Trabsa et al. (2015); Chermat and Gharzouli (2015); Alkuwari et al. (2012); Sher and Alyemeni (2011); Gaweesh et al. (2015); Iwu (2014); MPNS, 2017; El-Ghazali et al. (2010); Molla et al. (2011); Dahech et al. (2013)
L. shockleyi A. Gray	US, Mexico	NM	NM	–
L. stenophyllum J. Rémy	Chile, Peru, Argentina	NM	NM	–
L. strandveldense A.M. Venter	South Africa	NM	NM	–
L. tenuispinosum S.B. Jones & W.Z. Faust	Argentina, Chile, Paraguay	NM	NM	–
L. tenuispinosum var. *friesii* (Dammer) C.H. Hitchc.	Argentina	NM	NM	–
L. tetrandrum Thunb.	Namibia, South Africa, Angola	Fruit as food	NM	Watt and Breyer-Brandwijk (1962); MPNS, 2017
L. texanum Correll	US, Mexico	NM	NM	–
L. torreyi A. Gray	US, Mexico	Fruit as food	Whole plant and root as medicine, for chickenpox and toothache	NAEB (2003); FEIS (2016); Kearney et al. (1960); Powell (1988); Vines (1960); Hodgson (2001); MPNS, 2017; Quattrocchi (2012)
L. truncatum Y.C. Wang	China	NM	Root bark as medicine *digupi*	Li et al. (2001)
L. tweedianum Griseb.	Colombia, Ecuador, Dominican, Tuks And Caicos Islands, Jamaica, Bolivia, Bahamas, Cuba, Paraguay, Virgin Island	Fruit as food	NM	Roth and Lindorf (2002)
L. verrucosum Eastw.	US	NM	NM	–
L. villosum Schinz	South Africa, Namibia, Botswana	NM	NM	–
L. vimineum Miers	Argentina, Uruguay	NM	NM	–
L. yunnanense Kuang & A.M. Lu	China	NM	NM	–

[a] Species distribution and valid plant name information sources are not included, which are extracted from: The plant list (2013); IPNI (2015); GBIF (2017); eFloras (2017); African Plant Database (Conservatory and Botanical Garden of Geneva and South African National Biodiversity Institute), 2017; EuroPlusMed PlantBase (2011); Flora of North America (2009); VicFlora (2015); Flora of Argentina (1992); Flora of Israel (2017); Flora of China (1994). If no sources are given, no references for this species' food or medicine uses.

Table 3
Main morphological characters of commonly used *Lycium* species of all continents.

Species	Berry	Flower	Stem and leaf
L. ruthenicum Murray	Purple-black, globose, or emarginate. Seeds brown.	Pedicel 5–10 mm. Calyx narrowly campanulate, 4–5 mm, regularly 2–4-lobed, lobes sparsely ciliate. Corolla pale purple, funnel form, ca. 1.2 cm; lobes oblong ovate, 1/3-1/2 as long as corolla tube, not ciliate.	0.2–1 m tall. Stems much branched. Leaves subsessile, solitary on young branches, leaf blade grayish, succulent, linear or sub-cylindric, rarely linear-oblanceolate,
L. truncatum Y.C. Wang	Red or orange-yellow. Oblong or oblong-ovoid, mucronated. Seeds orange.	Pedicel 1–1.5 cm. Calyx campanulate, 3–4 × 3 mm, 2- or 3- lobed or truncate, sometimes circumscissile and only base persistent. Corolla purple or reddish purple, tube ca. 8 mm; lobes ca. 4 mm, not ciliate.	1–1.5 m tall, sparingly armed. Branches flexible. Leaves solitary on long shoots, clustered on short shoots; leaf blade linear-lanceolate or lanceolate.
L. dasystemum Pojark.	Red, ovoid, or oblong.	Pedicel 1–1.8 cm.	ca. 1.5 m tall. Stems much branched; branches grayish white, yellowish, or rarely brown-red, stout, young branches slender, elongate.
	Seeds more than 20.	Calyx campanulate, ca. 4 mm, often 2- or 3-divided halfway. Corolla purple, funnelform, 0.9–1.3 cm; tube sparingly villous inside; lobes ovate, half as long as corolla tube, ciliolate.	Leaf blade lanceolate, oblanceolate, or broadly lanceolate.
L. barbarum L.	Red or orange-yellow, oblong or ovoid,. Seeds usually 4–20, brown-yellow, ca. 2 mm.	Pedicel 1–2 cm. Calyx campanulate, 4–5 mm, usually 2-lobed, lobes 2- or 3-toothed at apex. Corolla purple, funnelform; tube8-10 mm, obviously longer than limb and lobes; lobes 5–6 mm, spreading, margin glabrescent.	0.8–2 m tall. Stems and branches glabrous, branches thorny. Leaves solitary or fasciculate, lanceolate or long elliptic
L. cylindricum Kuang & A. M. Lu	Berry ovoid. Seeds few.	Pedicel ca.1 cm. Calyx campanulate, ca.3 × 3 mm, usually (2-or) 3-divided to halfway, lobes sometimes with irregular teeth. Corolla tube cylindric, obviously longer than lobes, 5-6mm, ca. 2.5 mm in diam.; lobes broadly ovate, ca. 4 mm, margin pubescent.	Branches inflexed, with thorns 1–3 cm. Leaves solitary or in clusters of 2 or 3 on short shoots; leaf blade lanceolate, base cuneate, apex obtuse.
L. chinense Mill.	Red, ovoid or oblong. Seeds numerous, yellow, 2.5–3 mm.	Pedicel 1–2 cm. Calyx campanulate, 3–4 mm, 3–5-divided to halfway, lobes densely ciliate. Corolla pale purple, 0.9-l.2 cm; tube funnel-form, shorter than or subequaling lobes, lobes pubescent at margin.	0.5–2 m tall. Stems much branched; branches pale gray, slender, curved or pendulous, with thorns 0.5–2 cm. Leaves solitaryor in clusters of 2–4; leaf blade ovate, rhombic, lanceolate, or linear-lanceolate.
L. yunnanense Kuang & A.M. Lu	Globose, yellow-red when ripe, with an obvious longitudinal furrow on drying. Seeds ca. 20, pale yellow, orbicular, pitted.	Pedicel 4–6 mm. Calyx campanulate, ca. 2 mm, usually 3-lobed or 3- or 4-dentate, tomentose at apex. Corolla pale blue-purple, purple, or occasionally white, funnel form, 5–7 mm; tube 3–4 mm; lobes 2–3 mm, glabrescent.	ca. 0.5 m tall. Branch lets yellow-brown, thorny at apex. Leaves solitary on long shoots, sometimes on thorns or fasciculate on tubercular short shoots; petiole short; leaf blade narrowly ovate to lanceolate, base narrowly cuneate, apex acute.
L. europaeum L.	Reddish	Flowers solitary or in c1usters of 2(−3). Calyx 2–3 mm, 5-dentate or 2-lipped. Corol1a 11–13 mm, narrowly infundibuliform, pink or white; lobes 3–4 mm. Stamens usually exserted; filaments glabrous, somewhat unequa1.	1–4 m tall; branches rigid, very spiny; spines stout. Leaves 20–50 × 3–10 mm, usually oblanceolate.
L. intricatum Boiss.	Orangc-red or black	Plant Flowers solitary or in c1usters of 2–3. Calyx 1.5–2 mm, shallowly 5-dentate. Corolla 13–18 mm, narrowly infundibuliform, blue-violet, purple, lilac, pink or white; lobes 2–3 mm. Stamens inc1uded; filaments glabrous.	0.3–2 m, much-branched, very spiny; spines stout, rigid. Leaves 3–15 × 1–6 mm, oblanceolate.
L. afrum L.	Purplish	Calyx 5–7 mm, deeply 5-dentate. Corolla 20–22 mm, subcylindrical, purplish-brown; lobes ca. 2 mm. Stamens included; filaments with dense tuft of hairs at base.	1–2 m; branches rigid, very spiny; spines stout. Leaves 10–23 × 1–2 mm, very narrowly oblanceolate.
L. berlandieri Dunal	Red, globose to ovoid, glabrous.	Solitary or in pairs, pedicels 3–20 mm long; calyx cup-shaped, 1–2 mm long, (3)4- or 5-1obed, the lobes usually shorter than the tube, glabrous except for a tuft of hair at the tip of each lobe; corolla blue, pale lavender, or ochroleucous, campanulate-funnelform, 6–7 mm long, the limb 4- or 5-1obed.	Erect shrub to 2.5 m tall, armed with needlelike spines on the younger shoots or nearly unarmed; branches somewhat crooked, glabrous. Leaves 1–3 in a fascicle, linear to elliptic-spatulate, glabrous, apex rounded to acute, margins entire, base attenuate to a short petiole or subsessile.
L. pallidum Miers	Red (drying blackish or purplish), glaucous, subglobose to ovoid, glabrous. Seeds yellowish, widely ovate to subreniform, minutely pitted.	Solitary or occasionally in pairs, pedicel 8–18 mm long; calyx campanulate, 5–9 mm long, 5-1obed, the lobes about equaling or slightly longer than the tube, glabrous; corolla greenish-white, sometimes tinged with purple, funnelform, 15–20 mm long, the limb 5-1obed.	Upright-spreading, much-branched shrubs to 20 dm tall, branches lightly pubescent to glabrous, sparingly armed with stout spines. Leaves mostly fascicled, except on young growth; blade oblanceolate or spatulate, 1–4 cm long, (3)5–15 mm wide, glabrous, apex acute to obtuse, margins entire, base attenuate; petiole 5–10 mm long.

(*continued on next page*)

Table 3 (*continued*)

Species	Berry	Flower	Stem and leaf
L. shawii Roem. & Schult.	Orange-red, 4 mm broad. Seeds ca. 1.5 mm broad, reniform, brown.	Solitary or paired, white or purple-suffused. Pedicel 3–4 mm long, pilose. Calyx narrow tubular, pilose; lobes 0.5–1 mm long, acute, pubescent. Corolla tube 10–12 mm long; lobes 2.0 mm long, acute, minutely pubescent. Filaments glabrous at the base, subexserted.	A spiny branched shrub 100–180 cm tall, shoots white-tomentose. Spines tomentose towards the base. Leaves 4–25 (−30) × 2.5–6 mm, elliptic-oblong to narrow oblong, cuneate, obtuse or acute, pilose to tomentose.

Flora of China Editorial Committee (1994), Tutin (1972), McGregor and Barkley (1986) and Ali (1980).

Levin et al., 2011; GBIF, 2017). It was first published by Linnaeus, and three species (viz. *L. europaeum*, *L. barbarum*, and *L. afrum*) were described in Species Plantarum (Linnaeus, 1753). In 1932, Hitchcock published a systematic taxonomic study on 43 *Lycium* species from the western hemisphere based on morphology (Hitchcock, 1932). Recently, molecular markers of different genome parts were used to elaborate the phylogenetic relationship within the genus as well as biogeographic events: *Lycium* originated from the Americas, and then dispersed to Africa and Eurasia; the diversity centers are the Americas and Africa (Olmstead et al., 1999; Fukuda, 2001; Miller, 2002; Yin et al., 2005; Levin and Miller, 2005; Levin et al., 2009a, 2009b; Miller, 2011; Levin et al., 2011).

According to our findings, at present ninety seven species and six varieties are recognized (Table 2). Among them, 32 are native to South America, 24 to North America, 24 to Africa, and 12 to Eurasia; two occur in Eurasia as well as Africa. *Lycium australe* is the only species endemic to Australia, and L. *sandwicense* is native to the Pacific islands. *L. carolinianum* occurs in North America as well as the Pacific islands.

Lycium species are shrubs or small trees, often with thorns on the stem and simple, entire leaves. Usually they are differentiated through the thorn on the stem, the shape and size of leaves, the corolla length, the length of stamen, colour of the fruit, the taste of the fruits, and the size and number of seeds. Morphological characters of the typical frequently used species of different continents are summarized in Table 3. However, the commercial *Lycium* products are always without these characteristic traits as they are only few parts of the plant, e.g., fruit, root bark and leaf, therefore, morphological techniques solely were not sufficient for the authentication of *Lycium* products. For example, fruits of *L. barbarum* and *L. chinense*, the two most commonly used goji, are difficult to distinguish by eye (Xin et al., 2013), which is a challenge for quality assessment in trading.

3.2. Traditional uses

3.2.1. Traditional uses worldwide

Of all 97 species, 35species and 2 varieties were found to be used as food and/or medicine (Table 2). The number of native species of the different continents used as food and medicine are shown in Fig. 1.

Although the richness of *Lycium* species differs in South America, North America, Africa and Eurasia, the numbers of species used are similar. Therefore, the species use ratios are dramatically different. In Eurasia, nine (64%) of the 14 species, and one variety, are used. While 86% of the *Lycium* species occur in the Americas and Africa, only 31% (26 species) of them are used as food and/or medicine. The Australian species as well as the two Pacific Island species are all used as food.

Of 28 species the plant parts used are the fruits, both for food and medicine, indicating that the fruit is worldwide the most commonly used plant part; of the other species also the leaves and root bark are used, and in some cases the whole plant. Leaves and root bark are usually used as medicine, while young shoots may also be prepared as food. *Lycium barbarum,* L. *chinense,* and L. *ruthenicum* are the most often reported species in the literature for China, *L. europeaum*, *L. intricatum*, and *L. shawii* for the Mediterranean and Middle East, L. *pallidum* for North America, and L. *afrum* for Africa. Usually the fresh or dried fruits are consumed, and the fresh leaves are cooked as food or used as tea. Of them, *L. barbarum* and *L. chinense* have been introduced as "superfood" from China to Europe, the Americas, and Australia. They are typically consumed as food supplement.

3.2.2. Use of Lycium in China over time

Today, the dried fruits and the root bark of *L. chinense* and *L. barbarum*, called *Gouqi Zi* and *Digu Pi*, are commonly used in Chinese medicine and diet (Wagner et al., 2011; Chang and So, 2015; Tan et al., 2017). Whether the same or different species have been used in the past is not easy to deduce from the historical herbals, as the species concept did not exist in earlier times; and in the older herbals, even the plant parts used were not recorded. Therefore, information has to be inferred from the Chinese characters and the plant figures in the historical herbals.

The Chinese characters "枸杞" *(gǒu qǐ)* means *Lycium*, although sometimes the word means the fruit of *Lycium* only. However, in the ancient literature the character "杞" alone was often referring to *Lycium*. "杞" was also present in the oracle bone script, a script which was used in *Shang* Dynasty (B.C.E. 1400 s to B.C.E. 1100 s), indicating that the use of *Lycium* has a long history in China. It also appeared in later scripts, like bronze inscription and seal script. The earliest record of using *Lycium* in China was found in the Book of Songs (诗经 , *shī jīng*), which consisted of poems written in the *Zhou* Dynasty (B.C.E. 1100 s to B.C.E. 300 s) (Gao, 1980). In the 74 poems of the chapter *Xiaoya* (小雅 , *xiǎo yǎ*), "杞" was mentioned six times. The sentences, "南山有杞 (*nán shān yǒu qǐ*)" and "言采其杞 (*yán cǎi qí qǐ*)", describe people harvesting *Lycium* plants growing in the mountains.

Records of *Lycium* in the Chinese herbals over time are listed in S1, while Fig. 2 shows *Lycium* illustrations. The earliest record of *Lycium* as medicine was in *Shennong's* Herbal (ca. C.E. 100) (Shang, 2008). The original herbal does not exist anymore, and the present edition was compiled from later citations. The text mentions the flavour, effects, common names, and habitat of *Lycium* briefly, but not the plant parts used (Li, 1954). Deduced from the given flavour, it might be the root; from the effects, it could be both fruits and roots; from the recorded common name "枸杞", it might be both fruits and roots, as some later herbals also used the same name for root and/or fruit.

In the *Jin* Dynasty (C.E. 266 − 420), *Ge Hong* (284 − 364) published two herbals, *Baopuzi* (Ge, 1995) and *Zhouhou Beiji Fang* (Ge, 1999), both of which included *Lycium*. The later was the first herbal with formulas, and *Lycium* fruit, root, and juice were recorded separately in different formulas. *Leigong Paozhi Lun* (ca. 420 − 479) (Lei, 1985), the first monograph on processing of *materia medica*, recorded the manufacture of the root bark, while the fruit decoction was used for processing another drug. *Mingyi Bielu* (Tao, 1986), published around C.E. 500, is commonly regarded as the first herbal describing the use of *Lycium* fruits; however, according to our research, *Lycium* fruits and root had already been used separately in earlier times (*Jin* Dynasty by *Ge Hong*).

Lycium was first recorded as food in *Bencaojing Jizhu* (ca. C.E. 500) (Tao, 1994). In *Xinxiu Bencao* (659) (Su, 1981) and *Shiliao Bencao* (ca. 700) (Meng, 1984), *Lycium* was also recorded as food, with several medicated diet recipes of the fruits, root, and leaves. Later, in *Qianjin Yifang* (682) (Sun, 1998), cultivation techniques of *Lycium* were described, beside its medicinal usages.

New in the *Song* Dynasty (960 − 1279) was the detailed morphological description of the plant accompanied by illustrations. *Bencao*

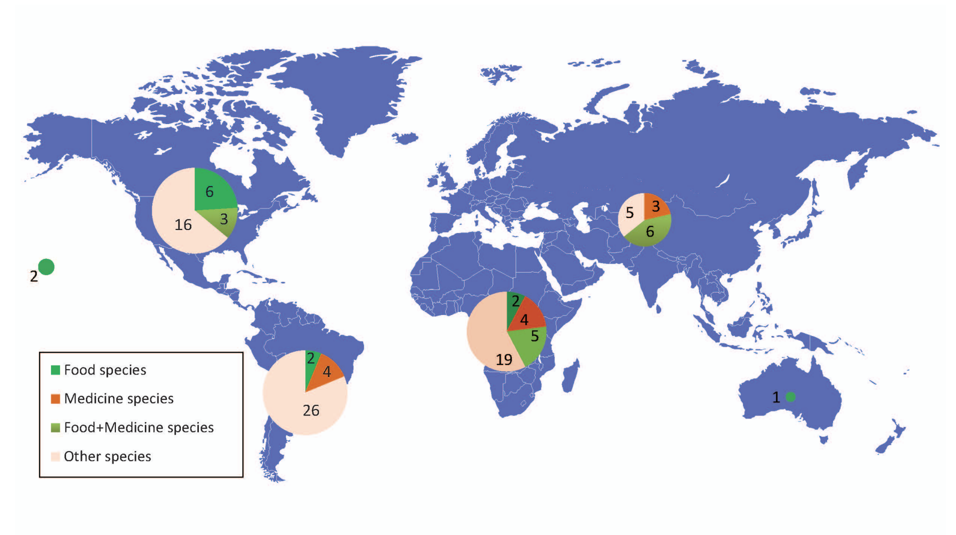

Fig. 1. *Lycium* species used as food and/or medicine on the different continents.

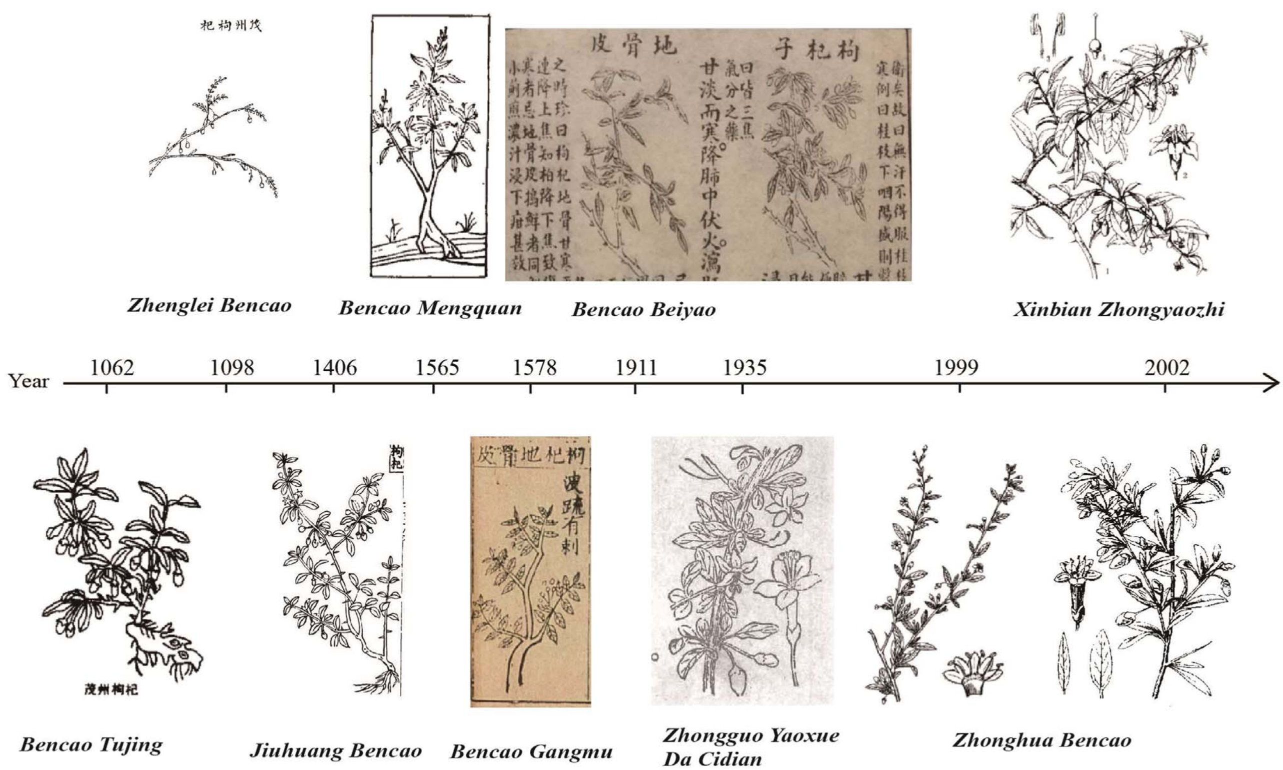

Fig. 2. Illustrations of *Lycium* in Chinese herbals over time.

Tujing (Su, 1994) and *Zhenglei Bencao* (Tang, 1982) were the most important herbals during *Song*, and *Lycium* was recorded in both.

In the *Yuan* Dynasty (1271 – 1368), the recipes of tea, porridge, and wine using the fruit or the leaves were recorded in the medicated diet monograph *Yinshan Zhengyao* (Hu, 2009).

Bencao Gangmu (1596) (Li, 1954), also known as Compendium of *Materia Medica*, discussed the habitat, the use history, manufacturing, and usage of *Lycium*, offering a review of former information as well as *Li Shizhen*'s (1518 – 1593) understanding of its use. In the *Ming* and *Qing* Dynasty (1644 – 1912), many formulas containing *Lycium* emerged and were described in various herbals. In 1935, the herbal *Zhongguo Yaoxue Da Cidian* (Chen, 1935), for the first time published the scientific name *Berberis lycium* for 枸杞. This was later found to be a misidentification, and was replaced by *Lycium.* Besides the key herbals described above, there were still many interesting ones published in different times (Chen, 1985, 1988, 2008; Du, 1975; Jiang, 1911; Kou, 1990; Liu, 1956; Lu, 1986; Ni, 2005; Wang, 1987; Wu, 1959, 1987; Yan, 1958; Yang, 1958; Zhu, 2008); as a result, these herbals conserved the food and medicine use history of *Lycium* in China.

The contemporary herbals, such as *Zhonghua Bencao* (Zhonghua Bencao Editorial Board, 1999), *Xinbian Zhongyao Zhi* (Xiao, 2002), and *Zhongyao Da Cidian* (Nanjing TCM University, 2006), refer to both L. *chinense* and L. *barbarum*. Precise botanical descriptions are provided and usages are combined with scientific findings and pharmacological evidence and guidance for use.

3.2.3. *Traditional uses by Chinese ethnic minorities*

In China, seven species and two varieties of the genus *Lycium* occur, of which four species have been used by different ethnic groups. We found use records for twelve of the officially recognized 55 ethnic

Table 4
Lycium spp. used in Chinese ethnic medical traditions.

Ethnic group	Distribution provinces	Species	Used parts	Indications and usages	References
藏族*Tibetan*	*Tibet, Sichuan, Yunnan, Qinghai, Gansu*	*L. barbarum*	Fruit, root, bark, leaf	Cough, *xiaoke* (similar to diabetes), dizziness, fever, gynecopathy, night sweat, lumbar genu aching and limp, leukorrhea, headache, amnesia, agrypnia, tuberculosis, spermatorrhea	Jia and Li (2005); Yu (1996)
		L. chinense	Fruit	Deficiency of the kidney and liver, anemia, cough, *xiaoke*, headache, heart hot, amnesia, agrypnia, gynecopathy	Zhonghua Bencao Editorial Board (2002); Jia and Li (2005)
		L. dasystemum	Fruit	Heart hot, gynecopathy	Jia and Li (2005)
		L. ruthenicum	Fruit	Heart diseases, gynecopathy	Dimaer (1986); Jia and Li (2005)
维吾尔族*Uighur*	*Xinjiang*	*L. barbarum/ L. chinense*	Fruit	Hyposexuality, blurry vision, neurasthenia, hyperlipidemia, oligospermia	Editorial Board (2005a)
蒙古族*Mongol*	*Inner Mongol, Heilongjiang, Jilin, Liaoning, Xinjiang, Hebei, Qinghai*	*L. barbarum*	Fruit	*Xiaoke*, giddy dazzled, tinnitus, lumbar genu aching and limp, deficiency of the kidney and liver, fever, stasis, amenorrhea, blurry vision	Jia and Li (2005); Zhonghua Bencao Editorial Board (2004)
苗族*Miao*	*Guizhou, Hunan, Hubei, Sichuan, Yunnan, Guangxi, Hainan*	*L. chinense*	Root bark, fruit, leaf, whole plant	Fever, night sweat, dysphoric, cough and asthma, *xiaoke*, bleeding, eumatism, dizziness, swell, tuberculosis, blurry vision, deficiency of the kidney and liver, backache, fatigue, finger inflammation; medicated diet included	Editorial Board (2005b); Jia and Li (2005)
畲族*She*	*Fujian, Zhejiang*	*L. chinense*	Fruit, root, leaf, root bark	Sore throat, blurry vision, kidney deficiency and backache, male infertility, *xiaoke*, palpitation, insomnia, tears; medicated diet included	Song and Xu (2002); Jia and Li (2005)
土家族*Tujia*	*Hubei, Hunan, Chongqing, Guizhou*	*L. chinense*	Fruit, root bark	Blurred vision, giddy dazzled, spermatorrhea	Zhu et al. (2006)
景颇族*Jingpo*	*Yunnan*	*L. barbarum*	Fruit	Blurry vision, kidney deficiency, blood deficiency, neurasthenia	Jia and Li (2005)
德昂族*De'ang*	*Yunnan*	*L. barbarum*	Fruit	Blurry vision, kidney deficiency, blood deficiency, neurasthenia	Jia and Li (2005)
彝族*Yi*	*Yunnan, Guizhou, Sichuan, Guangxi*	*L. chinense*	Whole plant	Pruritus, sore and ulcer diseases	Jia and Li (2005)
朝鲜族*Korean*	*Heilongjiang, Jilin, Liaoning*	*L. chinense*	Fruit	Blurry vision, kidney deficiency, backache, neurasthenia, vomiting blood	Jia and Li (2005)
瑶族*Yao*	*Guangxi, Hunan, Yunnan, Guangdong*	*L. chinense*	Root bark	Fever, night sweat, *xiaoke*, hyperlipidemia, tuberculosis	Liu (2002)
侗族*Dong*	*Guizhou, Hunan, Guangxi, Hubei*	*L. chinense*	Fruit	Gum erosion and blooding	Jia and Li (2005)

minorities of China (Table 4).

Four species have been used in Tibetan medicine, while both *L. barbarum* and *L. chinense* by the Uighurs and either of them by the other ethnic groups. Fruits as well as root bark and leaves have been commonly used. The whole plant has been used by the *Miao* and *Yi* for different purposes: *Miao* use it as a tonic, while *Yi* use it for sores and itching. The *Miao's* usages are similar to the ancient Chinese herbals' records.

In general, *Lycium* spp. have often been used for the treatments of blurry vision, fever, night sweat, kidney deficiency, cough and asthma, diabetes, heart diseases, gynecopathy, and neurasthenia. However, the *Yi* and *Dong* use them differently, i.e. the fruits of L. *chinense* are for bleeding gums, while the whole plant as antipruritic drug. They were also used as medicinal food by the *Miao* and *Yi*.

3.2.4. Comparison of traditional uses with recent pharmacological studies

Different *Lycium* species, foremost *L. barbarum* and *L. chinense*, were phytochemically analyzed and hundreds of compounds were isolated and identified (Qian et al., 2017). Bioactivities and pharmacological effects of crude extracts or compounds were assessed in pharmacological studies and it turns out that many of the traditional uses are supported by these studies. For example, the anti-aging effect of *Lycium* (probably the whole plant of *L. chinense* or *L. barbarum*) has been recorded since *Shennong's* Herbal (ca. C.E. 100); recent studies demonstrated that polysaccharides, vitamins, pigments, and crude extracts of *Lycium* fruits are benefitting age-related lesions (Bucheli et al., 2011; Li et al., 2007; Kim et al., 1997; Tao et al., 2008; Yi et al., 2013). Use for improving eyesight was mentioned in herbals as well, and Zeaxanthin, lutein, and polysaccharides were found to have retinal protection activities (Tang et al., 2011; Mi et al., 2012b; Song et al., 2012; Chu et al., 2013; Pavan et al., 2014). ***Xiaoke*** is a term used in ancient herbals, describing symptoms similar to present diabetes (Li et al., 2004); Studies on root bark and fruits of L. *chinense* and *L. barbarum* found that water extract, polysaccharides, organic acids, and alkaloids have an effect on lipid metabolism and oxidative restoring of diabetic animals (Ye et al., 2008; Li, 2007; Luo et al., 2004). Also, an anti-fatigue and hepatoprotective effect of *Lycium* fruits and root bark has been shown recently (Alharbi et al., 2017; Xiao et al., 2012; He et al., 2012; Cui et al., 2012), and has been recorded in herbals too.

Since *L. barbarum* and *L. chinense* are widely used species, most phytochemical and pharmacological studies have been focusing on the fruits and root bark of these two species. As a result, there are scientific evidences for their medical use, which in turn have been increasing again their popularity. Therefore, they have been adopted in pharmacopoeias of many countries and regions. For example, in the current Chinese pharmacopoeia (2015), there are 75 prescriptions containing fruits of *L. barbarum*. They were also allowed to be used as cosmetic materials in China. In contrast, only a few studies focused on other *Lycium* species, which are less widely used (Table 5).

3.3. Lycium in current pharmacopoeias

3.3.1. Lycium in recent pharmacopoeias of the world

As sources of common herbal medicines, *Lycium* species have been incorporated into several pharmacopoeias, including China, Europe, Japan, Korea, Taiwan, UK, and Vietnam (Table 6). *Lycium* has not been included in the pharmacopoeia of USA, Russia, Africa, Australia, Brazil, Argentina, Switzerland, Iran, and India.

The fruit and/or root bark of *L. barbarum* and/or *L. chinense* are the most frequently used materials mentioned in the pharmacopoeias, although the aerial part of *L. barbarum* and *L. europeaum* are recorded by the Indian Ayurveda pharmacopoeia. The European pharmacopoeia only includes the dried fruit of *L. barbarum*.

Lycium fruits (*Lycii Fructus*) and *Lycium* root bark (*Lycii Radices Cortex*) are used in several regions officially, however, the quality criteria differ. Firstly, the species used as *Lycii Fructus* differ. *Lycium*

Table 5
General bioactivities of compounds or extracts of *Lycium* spp.

Bioactivity	Compounds, extracts, or plant materials	References
Antioxidant	Flavonoids, polysaccharides, pigments, mixed extracts, fatty acid	Le et al. (2007); Li and Zhou (2007); Li et al. (2007); Bai et al. (2008); Donno et al. (2015); Benchennouf et al. (2017); Wang et al. (2010); Chung et al. (2014)
Spermatogenesis	Polysaccharides (fruit of *L. barbarum*)	Luo et al. (2014); Qian and Yu (2016); Shi et al. (2017)
Retinal protection	Zeaxanthin and/or lutein, polysaccharides	Tang et al. (2011); Mi et al. (2012b); Song et al. (2012); Chu et al. (2013); Pavan et al. (2014)
Hepatoprotective	Zeaxanthin dipalmitate, polysaccharides, betaine, flavonoids, fruit	Alharbi et al. (2017); Xiao et al. (2012); Xiao et al. (2014b); Xiao et al. (2014a); Zhang et al. (2010); Ahn et al. (2014); Ha et al. (2005)
Anti-aging	Fruit, polysaccharides, vitamins, pigments	Bucheli et al. (2011); Li et al. (2007); Kim et al. (1997); Tao et al. (2008); Yi et al. (2013)
Immunomodulation	Polysaccharides-protein complex, polysaccharides, pigments	Zhang et al. (2014); Tang et al. (2012); Chen et al. (2012); Chen et al. (2008); Chen et al. (2009a), (2009b); Xie et al. (2016); Gan et al. (2004)
Anti-tumor	Polysaccharides-protein complex, polysaccharides, mix extract, scopoletin and AA−2βG	He et al. (2012); Cui et al. (2012); Tang et al. (2012); Hu et al. (1994); Gan et al. (2004); Liu et al. (2000)
Skin care	Polysaccharides, juice, glycoconjugate	Reeve, et al., 2010; Liang and Zhang (2007); Zhao et al. (2005)
Anti-microbial	Lyciumoside I, AcOEt-soluble fraction	Terauchi et al. (1998); Lee et al. (2005); Kim et al. (2000)
Anti-diabetic	Water extract, polysaccharides, organic acids, and alkaloids	Ye et al. (2008); Song et al. (2012); Li et al. (2004); Li (2007); Jia et al. (2003); Luo et al. (2004)
Anti-atherosclerosis	Seed oil, polysaccharides	Jiang et al. (2007); Ma et al. (2009)
Hypotensive	Water extract, polysaccharides	Kim et al. (1997); Mi et al. (2012a); Mi et al. (2012b)
Neuroprotective	Water extract, polysaccharides, alkaline extract	Ho et al. (2007); Chan et al. (2007);Ho et al. (2010); Mi et al. (2013); Wang et al. (2014)
Anti- fatigue	Polysaccharides, betaine	Wu and Guo (2015); Kim and Baek (2014)

Table 6
Lycium records in current pharmacopoeias of the world.

Region	Pharmacopoeia	Species	Used parts	Description	Identification	Examination
China	Chinese Pharmacopoeia (Pharmacopoeia Commission, 2015)	*L. barbarum*	Fruit	Harvest, process, air dry, odour, taste, macroscopic, storage, indication	Microscopic, TLC	Loss on drying ≤ 13.0%, total ash ≤ 5.0%, water extract content ≥ 55%, polysaccharides ≥ 1.8%, betaine ≥ 0.30%, heavy metals
		L. barbarum/ L. chinense	Root bark	*Yinpian*; harvest, process, odour, taste, macroscopic, storage, indication	Microscopic, TLC	Loss on drying ≤ 11%, total ash ≤ 11%, acid-insoluble ash ≤ 3%
EU	European Pharmacopoeia (9.0) (2016)	*L. barbarum*	Fruit	Dried, whole, ripe fruit	Macroscopic, microscopic, TLC	Loss on drying ≤ 13%, total ash ≤ 5%, extract content ≥ 55%
UK	British Pharmacopoeia Commision (2017)	*L. barbarum*	Fruit	Dried, whole, ripe fruit	Macroscopic, microscopic, TLC	Loss on drying ≤ 13%, total ash ≤ 5%, extract content ≥ 55%
Japan	Japanese Pharmacopoeia (17th)(2016)	*L. barbarum/ L. chinense*	Fruit	Morphologic, odour, taste, storage	TLC	Foreign matters ≤ 2%, total ash ≤ 8%, acid-insoluble ash ≤ 1%, extract content (dilute ethanol) ≥ 35%
		L. barbarum/ L. chinense	Root bark	Morphologic, odour, microscopic, taste, storage	TLC	Heavy metals, arsenic, loss on drying ≤ 11.5%, total ash ≤ 20%, acid-insoluble ash ≤ 3%, extract content (dilute ethanol) ≥ 10%
Korea	Korean Pharmacopoeia (11th)(2014)	*L. barbarum/ L. chinense*	Fruit	Morphologic, odour, taste	TLC	Foreign matters ≤ 3%, total ash ≤ 6%, betaine ≥ 0.5%.
		L. barbarum/ L. chinense	Root bark	Morphologic, microscopic	Colour test, TLC	Loss on drying ≤ 12%, foreign matters ≤ 5%, total ash ≤ 18%, acid-insoluble ash ≤ 3%, extract content(dilute ethanol) ≥ 8%
	Korean Pharmacopoeia (9th) (2007) (Korea Food and Drug Administration, 2007)	*L. barbarum/ L. chinense*	Fruit	Morphologic, odour, taste	Colour test	Foreign matters ≤ 3%, total ash ≤ 6%, betaine ≥ 0.5%.
		L. barbarum/ L. chinense	Root bark	Morphologic, microscopic	Colour test, TLC	Loss on drying ≤ 12%, foreign matters ≤ 5%, total ash ≤ 18%, acid-insoluble ash ≤ 3%, extract content(dilute ethanol) ≥ 8%
Taiwan	Taiwan TCM Pharmacopoeia (2nd)(2013)	*L. barbarum/ L. chinense*	Fruit	Macroscopic, indication, microscopic, storage	TLC	Total ash ≤ 11%, acid-insoluble ash ≤ 2%, aflatoxin ≤ 15.0 ppb, extract content (dilute ethanol ≥ 35%, water ≥40%)
		L. barbarum/ L. chinense	Root bark	Macroscopic, microscopic, storage, indication	TLC	Loss on drying ≤ 14%, total ash ≤ 15%, heavy metal ≤ 10 ppm, As ≤ 6 ppm, extract content (dilute ethanol ≥ 8%, water ≥ 10%)
Vietnam	Vietnam Pharmacopoeia (4th) (2007) (Ministry of Health, 2010)	*L. barbarum*	Fruit	Macroscopic, microscopic, process, storage, indication	TLC	Loss on drying ≤ 11.0%, total ash ≤ 5.0%, extract content ≥ 55%, foreign matters ≤ 1%
		L. barbarum/ L. chinense	Root bark	Macroscopic, microscopic, process, storage, indication	Macroscopic, microscopic, TLC	Loss on drying ≤ 11%, foreign matter ≤ 2%, total ash ≤ 11%
India	Ayurveda API (Vol. 6) (Department of Ayush New Delhi, 2008)	*L. barbarum/ L. europeaum*	Aerial part	Macroscopic, microscopic	TLC	Foreign matters ≤ 2%, total ash ≤ 15%, acid-insoluble ash ≤ 2%, extract content (dilute ethanol ≥ 4.5%, water ≥ 20%)

chinense is accepted by the pharmacopoeias of Japan, Korea, and Taiwan, but not included in the pharmacopoeias of China, Europe, UK, and Vietnam; while they are not morphologically distinguishable, practically, both of them are consumed widely. Secondly, the descriptions are different. Indications are only included in pharmacopoeias of China, Taiwan, and Vietnam; macroscopic and microscopic traits are included to different degrees. Thirdly, the identification techniques differ. Colour test as primary identification tool, which could be used for detecting some chemical groups, is only used by the Korean pharmacopoeia; TLC, which is much more specificity based on chemical fingerprint and sufficient for species differentiation, is used widely. However, it was not included in the Korean pharmacopoeia until 2012. Lastly, the quality examination indexes and their thresholds differ as well. While betaine, a bioactive compound in *Lycii Fructus*, is used as index in the pharmacopoeia of China and Korea only, contents of polysaccharides are exclusively mentioned in the Chinese one.

3.3.2. Lycium in Chinese pharmacopoeias

Since 1949, there have been 10 editions of the Chinese pharmacopoeia (Chinese Pharmacopoeia Commission, 1963, 1977, 1985, 1990, 1995, 2000, 2005, 2010, 2015). *Lycium* species described in the different editions are shown in Table 7.

Lycium was not included in the first edition of the Chinese pharmacopoeia which was published in 1953. While in 1963 *L. barbarum* and *L. chinense* were mentioned for their fruits and *L. chinense* for its root bark. This changes afterwards and *L. barbarum* was documented for its fruits while both, *L. chinense* and *L. barbarum* were used for their root barks.

The descriptions of *Lycii Fructus* and *Lycii Radices Cortex* of all editions were similar, but macroscopic traits became more and more detailed over time. Identification and examination indexes, however, changed greatly. In the 1963 edition, the identification was based on macroscopic traits only, later, microscopic, total ash, TLC, loss on drying, impurities, contents of extracts, acid-insoluble ash, and heavy metals were included in succession. The development of pharmacopoeial monographs indicates the progress of quality control of herbal medicines.

Besides the pharmacopoeia, there are still some regional medicinal criteria which are published by provinces of China. Since the environments and the customs may differ among provinces, the records are diverse. For example, in *Ningxia*, the pedicel of the fruit and leaves of *L. barbarum* are officially used; in *Xinjiang*, the fruit of *L. dasystemum* has been accepted; in *Gansu*, the root bark of *L. truncatum* has been an official source of *Lycii Radices Cortex* (Li, 2001).

Accordingly, in China the quality criteria of *Lycii Fructus* and *Lycii Radices Cortex* have experienced notable developments over time, and they vary by geographic regions.

3.3.3. Comparison of Lycium records among pharmacopoeias

As demonstrated above, the fruits and/or root bark were adopted by pharmacopoeias of many countries and regions, as well as Chinese pharmacopoeias of different times; however, the descriptions and quality requirements were different. In order to understand the relationship of these pharmacopoeias, we extracted the parameters which were used for the identification of *Lycium*. The Indian Ayurveda pharmacopoeia was not included as it describes the aerial parts of the plant as a medicine, and the Chinese pharmacopoeia 1953 was excluded since it does not record *Lycium*. The results are shown in Fig. 3.

By the parameters of fruit, pharmacopoeias are firstly categorized into two groups: those of Taiwan, Japan, and Korea are with the earlier editions of Chinese pharmacopoeia, while European pharmacopoeia 9.0 (shown as EU 2016), British Pharmacopoeia Commision (2017) (UK 2017, which is the same as EU 2016), and Vietnam pharmacopoeia IV (shown as VN 2007) are similar to the later editions of Chinese pharmacopoeias (2000–2015). The difference between KR 2007 and KR 2014 is that the later includes TLC as an identification technique, and they have a lower similarity with others. Pharmacopoeia of Taiwan and Japan are closely related and are separated from the earlier Chinese editions. The clustering also shows the development of Chinese pharmacopoeias over time: the ones before 2000 are separated from the ones since 2000; the reason is probably that the later include more examination items such as moisture and total ash.

By the data of root bark, EU 2016 and UK 2017 are separated from others since it does not adopt root bark. Pharmacopoeias of Taiwan, Japan, and Korea are in the same branch excluded from the Chinese ones. Like the result from the fruit, pharmacopoeias of Taiwan and Japan are again in the same group; VN 2007 is similar to the later Chinese ones since 2000 (except for the 2005 edition). If we consider the Chinese ones, the development is also presented by the clustering. However, the one of 2005 is grouped with the earlier ones; this may be because TLC was omitted.

Accordingly, the clustering is a practical tool to study the development of pharmacopoeia over time, as well as to reveal the relationship among pharmacopoeias of different regions.

4. Discussion

According to our study, 35 out of 97 *Lycium* species worldwide have been recorded to be used as food and / or medicine. The species use ratio in the Americas is rather low, maybe because there are many species available there. Alternatively, it would be worth to investigate the abundance of different species in the relevant regions in order to better understand the potential access to these resources. The thorny *Lycium* species are generally ignored. In order to make better use of less-used *Lycium* species, phytochemical and pharmacological studies are needed.

Only *L. barbarum* and *L. chinense* have been transformed into globally traded commodities and are marketed worldwide as a “super food”. In China, based on the Chinese name “枸杞” their use can be traced back over the last two millennia. However, identification of the plant species and plant parts used is often not possible with certainty. Nevertheless, the use of *Lycium* fruits for anti-aging, improving eyesight and nourishing can be traced back at least C.E. 500 in *Mingyi Bielu*, and these usages still continue until today in Chinese medicine.

The diversity of plant usages offers opportunities for the development of new food and or medicine products. However, challenges for the quality control will have to be overcome. According to our study, different parts of *Lycium* species are used, and both of the botanical resources and traditional knowledge are primary materials for developing traditional herbal products (Jütte et al., 2017; Tu, 2015; Ngo et al., 2013). On the other hand, those differences set obstacles with regards to the quality control of the products, and the quality criteria differ greatly among regions. Along with the popularity of the fruits of *L. barbarum* and *L. chinense*, they become global consumables. However, almost all the goji are produced in China, and the exporters have to adjust their products to meet the diverse quality requirements of different regions; the different quality criteria among regions will probably obstruct the international trading. Therefore, a relative uniform quality criterion is recommended.

In general, recent pharmacological findings on *L. barbarum* and *L. chinense* largely support traditional uses as described in ancient herbals. Especially polysaccharides, zeaxanthin dipalmitate, vitamins, betaine, and mixed extracts were reported to be responsible for anti-aging, improving eyesight, anti-fatigue effects. It is obvious that detailed pharmacognostical studies lay a solid foundation for the wide acceptance of the plants and their products. Therefore, researches also need to focus on those less well-studied species but with interesting biological activities (Yao et al., 2011; Qian et al., 2017) as potential new sources of (healthy) foods or medicines. Due to the complexity of herbal preparations, quality control using only few chemical indicators is insufficient. Instead, the metabolomic approaches need to be developed (Donno et al., 2016).

Table 7
Lycium records in Pharmacopoeias of China.

Year/ edition	species	Used part	Description	Identification	Examination
1953	NM	NM	NM	NM	NM
1963	*L. barbarum/ L. chinense*	Fruit	Harvest, process, odour, taste, indications, storage	Macroscopic	NM
	L. chinense	Root bark	Harvest, process, odour, taste, indications, storage	Macroscopic	NM
1977	*L. barbarum*	Fruit	Harvest, process, odour, taste, macroscopic, indications, storage	NM	NM
	L. barbarum/ L. chinense	Root bark	Harvest, process, odour, taste, indications, storage	Microscopic	NM
1985	*L. barbarum*	Fruit	Harvest, process, odour, taste, macroscopic, indications, storage	NM	Foreign matter ≤ 1%
	L. barbarum/ L. chinense	Root bark	Harvest, process, odour, taste, macroscopic, indications, storage	Microscopic	NM
1990	*L. barbarum*	Fruit	Harvest, process, odour, taste, macroscopic, indications, storage	NM	Foreign matter ≤ 1%
	L. barbarum/ L. chinense	Root bark	Harvest, process, odour, taste, macroscopic, indications, storage	Microscopic	Total ash ≤ 11%
1995	*L. barbarum*	Fruit	Harvest, process, sun dry or air dry, odour, taste, macroscopic, indications, storage	NM	Foreign matter ≤ 2%
	L. barbarum/ L. chinense	Root bark	Harvest, process, odour, taste, macroscopic, indications, storage	Microscopic	Total ash ≤ 11%
2000	*L. barbarum*	Fruit	Harvest, process, air dry, odour, taste, macroscopic, indications, storage	TLC	Loss on drying ≤ 13.0%, total ash ≤ 5.0%, foreign matters ≤ 0.5%
	L. barbarum/ L. chinense	Root bark	Harvest, process, odour, taste, macroscopic, indications, storage	Microscopic, TLC	Total ash ≤ 12%
2005	*L. barbarum*	Fruit	Harvest, process, air dry, odour, taste, macroscopic, indications, storage	Microscopic, TLC	Loss on drying ≤ 13.0%, total ash ≤ 5.0%, water extract content ≥ 55%, polysaccharides ≥ 1.8%, betaine ≥ 0.30%
	L. barbarum/ L. chinense	Root bark	Harvest, process, odour, taste, macroscopic, indications, storage	Microscopic	Total ash ≤ 11%
2010	*L. barbarum*	Fruit	Harvest, process, air dry, odour, taste, macroscopic, indications, storage	Microscopic, TLC	Loss on drying ≤ 13.0%, total ash ≤ 5.0%, water extract content ≥ 55%, polysaccharides ≥1.8%, betaine ≥ 0.30%, heavy metals
	L. barbarum/ L. chinense	Root bark	Harvest, process, odour, taste, macroscopic, indications, storage	Microscopic, TLC	Loss on drying ≤ 14%, total ash ≤ 10%, acid-insoluble ash ≤ 3%
2015	*L. barbarum*	Fruit	Harvest, process, air dry, odour, taste, macroscopic, indications, storage	Microscopic, TLC	Loss on drying ≤ 13.0%, total ash ≤ 5.0%, water extract content ≥ 55%, polysaccharides ≥ 1.8%, betaine ≥ 0.30%, heavy metals
	L. barbarum/ L. chinense	Root bark	Harvest, process, odour, taste, macroscopic, indication, storage	Microscopic, TLC	Loss on drying ≤ 11%, total ash ≤ 11%, acid-insoluble ash ≤ 3%

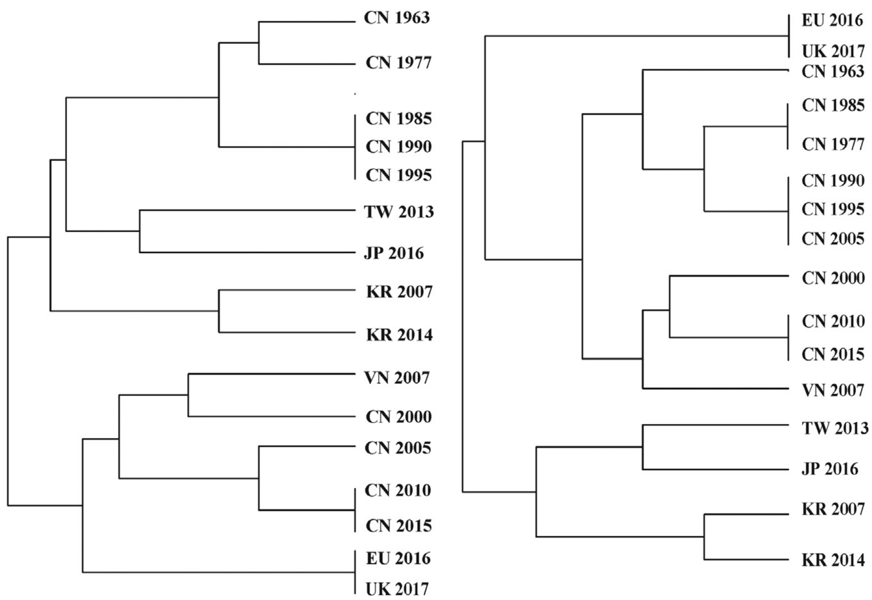

Fig. 3. Clustering based on parameters of *Lycium* fruit (left) and *Lycium* root bark (right) in different pharmacopoeias.

Historical documentary evidences are good basis for ethnobotanical study (Heinrich et al., 2006, 2012; Jütte et al., 2017). The historical continuity of Chinese medical herbals showcase the evolution of peoples' medical knowledge and offer ideas for treatment options for current diseases. In this study, the use history of *Lycium* in China was mapped out using the herbals, and some of the reported effects involved, such as anti-aging, retinal protection, and anti-fatigue, have been demonstrated experimentally. However, there are gaps between the descriptions in Chinese herbals and modern concepts: 1) the species are often not properly described as most of them were not written by botanists but doctors; 2) the terms of diseases and the description of symptoms are difficult to understand because of the difference of medical concepts; 3) the herbals contain historical "clinical data" and both the right and inaccurate information are included. As a result, the herbals are important sources of medicinal and nutritional researches, but they need to be used dialectically.

5. Conclusions

A comprehensive understanding of a species' characteristics, which includes taxonomy, geographic distribution, traditional use, phytochemistry, pharmacology, knowledge evolution, and quality control, is indispensable for finding new sources for food and/or medicine. This article highlights the need for a very sound understanding of the multi-contextual basis of what is commonly termed a species 'traditional use'. The research approach used had to be transdisciplinary and the integration of historical, modern ethnobotanical, botanical, phytochemical and pharmacological data has enabled a much more detailed understanding of the genus as a whole and its wider potential. It also highlights that the focus so far has only been on two species and that the genus can potentially yield a wide range of other products with different properties.

This research has relied heavily on historical documentary evidences and such sources are good starting points for ethnopharmacological studies. In the present work, a set of time-continuous historical herbals of Chinese medicine generated a database on its usage and has allowed us to better understand the evolution of knowledge about *Lycium*. Hopefully, this ethnobotanical review incorporating both space and time dimensions will serve as a model for studying traditional food or medicine plants.

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Author contributions

All authors developed the concept for the study; R. Yao conducted the literature survey and drafted the paper. C.S. Weckerle and M. Heinrich supervised the work, and revised the manuscript.

Appendix A. Supporting information

Supplementary data associated with this article can be found in the online version at http://dx.doi.org/10.1016/j.jep.2017.10.010.

References

Abdennacer, B., Karim, M., Nesrine, R., Mouna, D., Mohamed, B., 2015. Determination of phytochemicals and antioxidant activity of methanol extracts obtained from the fruit and leaves of Tunisian *Lycium intricatum* Boiss. Food Chem. 174, 577–584.
Abouri, M., El Mousadik, A., Msanda, F., Boubaker, H., Saadi, B., Cherifi, K., 2012. An ethnobotanical survey of medicinal plants used in the Tata Province, Morocco. Int. J. Med. Plants Res. 1 (7), 99–123.
Ahn, M., Park, J.S., Chae, S., Kim, S., Moon, C., Hyun, J.W., Shin, T., 2014. Hepatoprotective effects of *Lycium chinense* Miller fruit and its constituent betaine in CCl_4-induced hepatic damage in rats. Acta Histochem. 116 (6), 1104–1112.
Alharbi, B.K., Mousa, H.M., Ibrahim, Z.H., El-Ashmawy, I.M., 2017. Hepatoprotective effect of methanolic extracts of *Prosopis farcta* and *Lycium shawii* against carbon tetrachloride-induced hepatotoxicity in rats. J. Biol. Sci. 17, 35–41.
Ali, A., 1964. Medicinal Plants of Iraq. 15 Iraq Ministry ofAgriculture, Baghdad.
Ali, S.I., 1980. Flora of Pakistan. Pakistan Agricultural Research Council, Islamabad.
Alkuwari, A.D., Al-Naemi, M.Y., Vito, P., Stilo, R., Ahmed, A.T., Naemi, A.H., 2012. Biological activities of *Lycium shawii* leaves extract. Int. J. Pharm. Biol. Sci. Arch. 3 (3), 697–700.
Al-Quran, S., 2007. Ethnobotany of folk medicinal aquatic plants in Jordan. Bot. Rev. 73 (1), 51–65.
Amagase, H., 2010. Comparison of *Lycium barbarum*-containing liquid dietary supplements to caffeinated beverages on energy/caloric metabolism activity and salivary adrenocortical hormone levels in healthy human adults. FASEB J. 24 (S1), 540–553.
Amagase, H., Farnsworth, N.R., 2011. A review of botanical characteristics, phytochemistry, clinical relevance in efficacy and safety of *Lycium barbarum* fruit (Goji). Food Res. Int. 44 (7), 1702–1717.
Arenas, P., Scarpa, G.F., 2007. Edible wild plants of the chorote Indians, Gran Chaco, Argentina. Bot. J. Linn. Soc. 153 (1), 73–85.

Arnold, T.H., Prentice, C.A., Hawker, L.C., Snyman, E.E., Tomalin, M., Crouch, N.R., Pottas-Bircher, C., 2002. Medicinal and magical plants of southernAfrica: an annotated checklist. Natl. Bot. Inst. 129–130.
Auda, M.A., 2011. An ethnobotanical uses of plants in the middle area, Gaza strip, Palestine. Adv. Environ. Biol. 5 (11), 3681–3688.
Azadi, N., Nazeri, V., Shoushtari, A., Osaloo, S.K., 2007. *Lycium dasystemum* Pojark. (Solanaceae), a new record from Iran. Iran. J. Bot. 13 (2), 109–111.
Bai, H., Zhou, Z., Du, H., Xu, Q., 2008. Study on free radical scavenging activity of M ethanol extract from the leaf of *Lycium ruthenicum* Murr. *Lishizhen* Med. Mater. Med. Res. 19 (2), 326–327.
Ballabh, B., Chaurasia, O.P., Ahmed, Z., Singh, S.B., 2008. Traditional medicinal plants of cold desert Ladakh–used against kidney and urinary disorders. J. Ethnopharmacol. 118 (2), 331–339.
Benchennouf, A., Grigorakis, S., Loupassaki, S., Kokkalou, E., 2017. Phytochemical analysis and antioxidant activity of *Lycium barbarum* (Goji) cultivated in Greece. Pharm. Biol. 55 (1), 596–602.
Boulila, A., Bejaoui, A., 2015. *Lycium intricatum* Boiss.: an unexploited and rich source of unsaturated fatty acids, 4-desmethylsterols and other valuable phytochemicals. Lipids Health Dis. 14 (1), 59.
Boullard B., 2001. Plantes médicinales du monde réalités et croyance. Paris Editions Estem, Paris.
British Pharmacopoeia Commision, 2017. Br. Pharm. 4, 91–92 (London, UK).
Bucheli, P., Vidal, K., Shen, L., 2011. Goji berry effects on macular characteristics and plasma antioxidant levels. Optom. Vision. Sci. 88 (2), 257–262.
Buck, M., Hamilton, C., 2011. The Nagoya Protocol on access to genetic resources and the fair and equitable sharing of benefits arising from their utilization to the Convention on Biological Diversity. Rev. Eur. Comp. Int. Environ. 20 (1), 47–61.
Chan, H.C., Chang, R.C.C., Ip, A.K.C., Chiu, K., Yuen, W.H., Zee, S.Y., So, K.F., 2007. Neuroprotective effects of *Lycium barbarum* L. on protecting retinal ganglion cells in an ocular hypertension model of glaucoma. Exp. Neurol. 203 (1), 269–273.
Chang, R.C.C., So, K.F., 2015. *Lycium Barbarum* and Human Health. Springer, Dordrecht.
Chen, C.R., 1935. Zhongguo Yaoxue Da Cidian. 1 ShanghaiShuju Press, Shanghai.
Chen, J.M., 1988. Bencao Mengquan. People's Health Press, Beijing.
Chen, J.R., Li, E.Q., Dai, C.Q., Yu, B., Wu, X.L., Huang, C.R., Chen, X.Y., 2012. The inducible effect of LBP on maturation of dendritic cells and the related immune signaling pathways in hepatocellular carcinoma (HCC). Curr. Drug Deliv. 9 (4), 414–420.
Chen, Q.R., 1985. Collection of Rare Medical Books (Vol. 2): *Bencao Cuoyao*. 2 Shanghai Sci & Tech Press, Shanghai.
Chen, S.D., 2008. Bencao Xinbian. China TCM Press, Beijing.
Chen, Z., Tan, B.K.H., Chan, S.H., 2008. Activation of T lymphocytes by polysaccharide–protein complex from *Lycium barbarum* L. Int. Immunopharmacol. 8 (12), 1663–1671.
Chen, Z., Lu, J., Srinivasan, N., Tan, B.K.H., Chan, S.H., 2009a. Polysaccharide-protein complex from *Lycium barbarum* L. is a novel stimulus of dendritic cell immunogenicity. J. Immunol. 182 (6), 3503–3509.
Chen, Z., Soo, M.Y., Srinivasan, N., Tan, B.K.H., Chan, S.H., 2009b. Activation of macrophages by polysaccharide-protein complex from *Lycium barbarum* L. Phytother. Res. 23 (8), 1116–1122.
Chermat, S., Gharzouli, R., 2015. Ethnobotanical study of medicinal flora in the North East of Algeria-An empirical knowledge in Djebel Zdimm (Setif). J. Mater. Sci. Eng. 5 (1–2), 50–59.
Cherouana, S., Touil, A., Rhouati, S., 2013. Two flavonoid glycosides from *Lycium arabicum*. Chem. Nat. Compd. 49 (5), 930–931.
Chinese Pharmacopoeia Commission, 1963. Chinese Pharmacopoeia 1. The Commercial Press, Beijing, pp. 98 (196-197).
Chinese Pharmacopoeia Commission, 1977. Chinese Pharmacopoeia 1. People's Health Press, Beijing, pp. 201–202 (402).
Chinese Pharmacopoeia Commission, 1985. Chinese Pharmacopoeia 1. People's Health Press & Chemical Industrial Press, Beijing, pp. 96–97 (199).
Chinese Pharmacopoeia Commission, 1990. Chinese Pharmacopoeia 1. People's Health Press & Chemical Industrial Press, Beijing, pp. 99 (204).
Chinese Pharmacopoeia Commission, 1995. Chinese Pharmacopoeia 1. People's Health Press & Chemical Industrial Press, Beijing, pp. 100 (202).
Chinese Pharmacopoeia Commission, 2000. Chinese Pharmacopoeia 1. Chemical Industrial Press, Beijing, pp. 93 (202-203).
Chinese Pharmacopoeia Commission, 2005. Chinese Pharmacopoeia 1. Chemical Industrial Press, Beijing, pp. 82 (174).
Chinese Pharmacopoeia Commission, 2010. Chinese Pharmacopoeia 1. China Medical Science Press, Beijing, pp. 115 (232-233).
Chinese Pharmacopoeia Commission, 2015. Chinese Pharmacopoeia 1. China Medical Science Press, Beijing, pp. 124 (249).
Chu, P.H., Li, H.Y., Chin, M.P., So, K.F., Chan, H.H., 2013. Effect of *Lycium barbarum* (wolfberry) polysaccharides on preserving retinal function after partial optic nerve transection. PloS One 8 (12), e81339.
Chung, I.M., Ali, M., Praveen, N., Yu, B.R., Kim, S.H., Ahmad, A., 2014. New polyglucopyranosyl and polyarabinopyranosyl of fatty acid derivatives from the fruits of *Lycium chinense* and its antioxidant activity. Food Chem. 151, 435–443.
Clarke,P.A., 1998. Early Aboriginal plant foods in southern South Australia. In proceedings of the nutrition society of Australia (Vol. 22). Nutrition Society of Australia, St Leonards, pp: 16-20.
Committee on Chinese Medicine and Pharmacy, 2013. Taiwan TCM Pharmacopoeia 163. Ministry of Health and Welfare, Taipei, pp. 90–91.
Conservatory and Botanical Garden of Geneva and South African National Biodiversity Institute, 2017. African Plant Database, version 3.4.0. ⟨http://www.ville-ge.ch/musinfo/bd/cjb/africa/⟩ [dataset].
Crosswhite, F.S., 1981. Desert plants, habitat and agriculture in relation to the major pattern of cultural differentiation in the O'odham people of the Sonoran desert. Desert Plants 47–76.
Cui, B., Chen, Y., Liu, S., Wang, J., Li, S., Wang, Q., Li, S., Chen, M., Lin, X., 2012. Antitumour activity of *Lycium chinensis* polysaccharides in liver cancer rats. Int. J. Biol. Macromol. 51 (3), 314–318.
Dafni, A., Yaniv, Z., 1994. Solanaceae as medicinal plants in Israel. J. Ethnopharmacol. 44 (1), 11–18.
Dahech, I., Farah, W., Trigui, M., Hssouna, A.B., Belghith, H., Belghith, K.S., Abdallah, F.B., 2013. Antioxidant and antimicrobial activities of *Lycium shawii* fruits extract. Int. J. Biol. Macromol. 60, 328–333.
Deeb, T., Knio, K., Shinwari, Z.K., Kreydiyyeh, S., Baydoun, E., 2013. Survey of medicinal plants currently used by herbalists in Lebanon. Pak. J. Bot. 45 (2), 543–555.
Department of Ayush New Delhi, 2008. Ayurveda Pharmacopoeia of India. Vol. 6, pp. 113–114.
Dhar, P., Tayade, A., Ballabh, B., Chaurasia, O.P., Bhatt, R.P., Srivastava, R.B., 2011. *Lycium ruthenicum*Murray: a less-explored but high-value medicinal plant from trans-Himalayan cold deserts of Ladakh, India. Plant Arch. 11 (2), 583–586.
Dimaer, D., 1986. Jingzhu Bencao. Shanghai Sci & Tech Press, Shanghai, pp. 66.
Donno, D., Beccaro, G.L., Mellano, M.G., Cerutti, A.K., Bounous, G., 2015. Goji berry fruit (*Lycium* spp.): antioxidant compound fingerprint and bioactivity evaluation. J. Func. Foods 18, 1070–1085.
Donno, D., Boggia, R., Zunin, P., Cerutti, A.K., Guido, M., Mellano, M.G., Prgomet, Z., Beccaro, G.L., 2016. Phytochemical fingerprint and chemometrics for natural food preparation pattern recognition: an innovative technique in food supplement quality control. J. Food Sci. Technol. 53 (2), 1071–1083.
Du, W.X., 1975. Yao Jian. People's Health Press, Beijing.
Duke, J.A., 2002. Handbook of Medicinal Herbs, 2nd ed. CRC Press, Florida.
eFloras, 2017. ⟨http://www.efloras.org⟩ [dataset].
El-Ghazali, G.E., Al-Khalifa, K.S., Saleem, G.A., Abdallah, E.M., 2010. Traditional medicinal plants indigenous to Al-Rass province, Saudi Arabia. J. Med. Plants Res. 4 (24), 2680–2683.
El-Hamrouni, A., 2001. Conservation des zones humides littorales et des écosystèmes côtiers du Cap-Bon. Rapport de diagnostic des sites, partie relative à la flore et à la végétation. Med Wet et Coast, République Tunisienne.
El-Mokasabi, F.M., 2014. Floristic composition and traditional uses of plant species at Wadi Alkuf, Al-Jabal Al-Akhder, Libya. Am.-Eurasia. J. Agric. Environ. Sci. 14 (8), 685–697.
European Directorate for the Quality of Medicines, 2016. Eur. Pharm. 9 (0), 1263–1264.
EuroPlusMed PlantBase, 2011. ⟨http://ww2.bgbm.org/⟩ [dataset].
FEIS, 2016. Fire Effects Information System. Syntheses about fire ecology and fire regimes in the United States. ⟨http://www.feis-crs.org/feis/⟩ [dataset].
Flora of Argentina, 1992. ⟨http://www.floraargentina.edu.ar/⟩ [dataset].
Flora of China, 1994. (Vol. 17). ⟨http://foc.eflora.cn/⟩ [dataset].
Flora of China Editorial Committee, 1994. Flora of China 67. Science Press/Missouri Botanical Garden Press, Beijing/St. Louis, pp. 8–18.
Flora of Israel, 2017. ⟨http://flora.org.il/plants/⟩ [dataset].
Flora of North America, 2009. ⟨http://luirig.altervista.org/flora/taxa/north-america.php⟩ [dataset].
Fratkin, E., 1996. Traditional medicine and concepts of healing among Samburu pastoralists of Kenya. J. Ethnobiol. 16, 63–98.
Fukuda, T., 2001. Phylogeny and biogeography of the genus *Lycium* (solanaceae): inferences from chloroplast DNA sequences. Mol. Phylogenet. Evol. 19 (2), 246–258.
Gairola, S., Sharma, J., Bedi, Y.S., 2014. A cross-cultural analysis of Jammu, Kashmir and Ladakh (India) medicinal plant use. J. Ethnopharmacol. 155 (2), 925–986.
Gan, L., Zhang, S.H., Yang, X.L., Xu, H.B., 2004. Immunomodulation and antitumor activity by a polysaccharide–protein complex from *Lycium barbarum*. Int. Immunopharmacol. 4 (4), 563–569.
Gao, H., 1980. The Book of Songs with Annotation. ShanghaiAncient Book Press, Shanghai.
Gaweesh, A., Sengab, A.E.N.B., El-Hefnawy, H.M., Osman, S.M., Abdou, A.M., 2015. Phytoconstituents, cytotoxic, antioxidant and hepatoprotective activities of the aerial parts of *Lycium shawii* R. growing in Egypt. Med. Aromat. Plants 4 (1), 180.
GBIF, 2017. Global Biodiversity Information Facility. GBIF Home Page. ⟨http://gbif.org⟩ [dataset].
Ge, H., 1995. Translation to *Baopuzi* Inner Chapter. Guizhou People's Press, Guizhou, pp. 262.
Ge, H., 1999. Collection of Chinese Medical Books. 8. Zhongyi Guji Press, Beijing, pp. 59.
Ghasemi, P.A., Momeni, M., Bahmani, M., 2013. Ethnobotanical study of medicinal plants used by Kurd tribe in Dehloran and Abdanan districts, Ilam province, Iran. Afr. J. Tradit. Complement. Altern. Med. 10 (2), 368–385.
Ghazanfar, S.A., 1994. Handbook of Arabian Medicinal Plants. CRC press, Florida.
Ha, K.T., Yoon, S.J., Choi, D.Y., Kim, D.W., Kim, J.K., Kim, C.H., 2005. Protective effect of *Lycium chinense* fruit on carbon tetrachloride-induced hepatotoxicity. J. Ethnopharmacol. 96 (3), 529–535.
Hassan-Abdallah, A., Merito, A., Hassan, S., Aboubaker, D., Djama, M., Asfaw, Z., Kelbessa, E., 2013. Medicinal plants and their uses by the people in the Region of Randa, Djibouti. J. Ethnopharmacol. 148 (2), 701–713.
He, N., Yang, X., Jiao, Y., Tian, L., Zhao, Y., 2012. Characterisation of antioxidant and antiproliferative acidic polysaccharides from Chinese wolfberry fruits. Food Chem. 133 (3), 978–989.
Heinrich, M., Kufer, J., Leonti, M., Pardo-de-Santayana, M., 2006. Ethnobotany and ethnopharmacology-Interdisciplinary links with the historical sciences. J. Ethnopharmacol. 107 (2), 157–160.
Heinrich, M., Barnes, J., Gibbons, S., Williamson, E.M., 2012. Fundamentals of Pharmacognosy and Phytotherapy E-Book. Elsevier Health Sciences.

Heywood, V.H., 2011. Ethnopharmacology, food production, nutrition and biodiversity conservation: towards a sustainable future for indigenous peoples. J. Ethnopharmacol. 137 (1), 1–15.
Hitchcock, C.L., 1932. A monographic study of the genus *Lycium* of the western hemisphere. Ann. Missouri Bot. Gard. 19, 179–374.
Ho, Y.S., Yu, M.S., Lai, C.S.W., So, K.F., Yuen, W.H., Chang, R.C.C., 2007. Characterizing the neuroprotective effects of alkaline extract of *Lycium barbarum* on β-amyloid peptide neurotoxicity. Brain Res. 1158, 123–134.
Ho, Y.S., Yu, M.S., Yang, X.F., So, K.F., Yuen, W.H., Chang, R.C.C., 2010. Neuroprotective effects of polysaccharides from wolfberry, the fruits of *Lycium barbarum*, against homocysteine-induced toxicity in rat cortical neurons. J. Alzheimers Dis. 19 (3), 813–827.
Hodgson, W.C., 2001. Food plants of the Sonoran Desert. University of Arizona Press, Arizona.
Hu, Q., Gao, T., Zhao, C., Zhang, Y., Xie, J., Sheng, L., Liu, M., 1994. The effect of Active components of *Lycium barbarum* and Garlic (LB-GO) on the synthesis of DNA and ultrastructure of U14 cervix cancer cells in mice. Chin. J. Cancer Res. 6 (4), 266–273.
Hu, S.H., 2009. Yinshan Zhengyao. China TCM Press, Beijing.
IPNI, 2015. The International Plant Names Index. 〈http://www.ipni.org/〉 [dataset].
Iwu, M.M., 2014. Handbook of African Medicinal Plants. CRC press, Florida.
Jamous, R.M., Zaitoun, S.Y.A., Husein, A.I., Qasem, I.B., Ali-Shtayeh, M.S., 2015. Screening for biological activities of medicinal plants used in traditional Arabic Palestinian herbal medicine. Eur. J. Med. Plants 9 (1), 1–13.
Japanese Pharmacopoeia Editorial Committee, 2016. Japanese Pharmacopoeia (17th). Ministry of Health, Labour and Welfare, Tokyo, pp. 1909–1910.
Jeanes, J.A., 1999. Cornaceae to AsteraceaE. Flora of Victoria 4 Inkata Press, Melbourne.
Jennings, H.M., Merrell, J., Thompson, J.L., Heinrich, M., 2015. Food or medicine? The food-medicine interface in households in Sylhet. J. Ethnopharmacol. 167, 97–104.
Jia, M.R., Li, X.W., 2005. Essentials of Chinese Ethnic Medicines. China Medical Science and Technology Press, Beijing.
Jia, W., Gao, W., Tang, L., 2003. Antidiabetic herbal drugs officially approved in China. Phytother. Res. 17 (10), 1127–1134.
Jiang, S., 1911. Butu Bencao Beiyao. 2 Zhangfuji Shuju Press, Shanghai.
Jiang, Y.D., Cao, J., Dong, Q.Z., Wang, S.R., 2007. Anti-atherosclerosis potency by *Lycium* seed oil and its possible mechanism of PKC and MMPs. West China J. Pharm. Sci. 22 (1), 9–12.
Jütte, R., Heinrich, M., Helmstädter, A., Langhorst, J., Meng, G., Niebling, W., Pommerening, T., Trampisch, H.J., 2017. Herbal medicinal products – evidence and tradition from a historical perspective. J. Ethnopharmacol. 207, 220–225.
Kearney, T.H., Peebles, R.H., Howell, J.T., McClintock, E., 1960. Arizona Flora. University of California Press, California.
Kim, D.H., Song, M., Bae, E.A., Han, M.J., 2000. Inhibitory effect of herbal medicines on rotavirus infectivity. Biol. Pharm. Bull. 23 (3), 356–358.
Kim, N.H., Baek, S.H., 2014. Effects of *Lycium chinense* Miller fruit and its constituent betaine on immunomodulation in Balb/c mice. Korean J. Environ. Agric. 33 (3), 189–193.
Kim, S.Y., Lee, K.H., Chang, K.S., Bock, J.Y., Jung, M.Y., 1997. Taste and flavor compounds in box thorn (*Lycium chinense* Miller) leaves. Food Chem. 58 (4), 297–303.
Kindscher, K., Long, Q., Corbett, S., Bosnak, K., Loring, H., Cohen, M., Timmermann, B.N., 2012. The ethnobotany and ethnopharmacology of wild tomatillos, *Physalis longifolia* Nutt., and related *Physalis* species: a review. Econ. Bot. 66 (3), 298–310.
Koleva, V., Dragoeva, A., Nanova, Z., Koynova, T., Dashev, G., 2015. An ethnobotanical study on current status of some medicinal plants used in Bulgaria. Int. J. Curr. Microbiol. Appl. Sci. 4, 297–305.
Korea Food and Drug Administration, 2007. Korean Pharmacopoeia (9th). Shinil Publishing Company (1058–1059).
Korea Food and Drug Administration, 2014. Korean Pharmacopoeia (11th). Shinil Publishing Company (1785, 1862–1863).
Kou, Z.S., 1990. Bencao Yanyi. 13. People's Health Press, Beijing, pp. 84–85.
Le, K., Chiu, F., Ng, K., 2007. Identification and quantification of antioxidants in *Fructus lycii*. Food Chem. 105 (1), 353–363.
Lee, D.G., Jung, H.J., Woo, E.R., 2005. Antimicrobial property of (+)-lyoniresinol-3α-O-β-D- glucopyranoside isolated from the root bark of *Lycium chinense* Miller against human pathogenic microorganisms. Arch. Pharm. Res. 28 (9), 1031–1036.
Lei, X., 1985. Leigong Paozhi Lun. Jiangsu Sci & Tech Press, Jiangsu, pp. 6–7.
Leonti, M., 2011. The future is written: Impact of scripts on the cognition, selection, knowledge and transmission of medicinal plant use and its implications for ethnobotany and ethnopharmacology. J. Ethnopharm. 134 (3), 542–555.
Leporatti, M.L., Ghedira, K., 2009. Comparative analysis of medicinal plants used in traditional medicine in Italy and Tunisia. J. Ethnobiol. Ethnomed. 5 (1), 1.
Lev, E., Amar, Z., 2006. Reconstruction of the inventory of *materia medica* used by members of the Jewish community of medieval Cairo according to prescriptions found in the Taylor–Schechter Genizah collection, Cambridge. J. ethnopharm. 108 (3), 428–444.
Levin, R.A., Miller, J.S., 2005. Relationships within tribe Lycieae (Solanaceae): paraphyly of *Lycium* and multiple origins of gender dimorphism. Am. J. Bot. 92 (12), 2044–2053.
Levin, R.A., Blanton, J., Miller, J.S., 2009a. Phylogenetic utility of nuclear nitrate reductase: a multi-locus comparison of nuclear and chloroplast sequence data for inference of relationships among American Lycieae (Solanaceae). Mol. Phylogenet. Evol. 50 (3), 608–617.
Levin, R.A., Whelan, A., Miller, J.S., 2009b. The utility of nuclear conserved ortholog set II (COSII) genomic regions for species-level phylogenetic inference in *Lycium* (Solanaceae). Mol. Phylogenet. Evol. 53 (3), 881–890.
Levin, R.A., Bernardello, G., Whiting, C., Miller, J.S., 2011. A new generic circumscription in tribe Lycieae (Solanaceae). Taxon 60 (3), 681–690.
Li, S.Z., 1954. Compendium of *Materia Medica*. People's Health Press, Beijing.
Li, W.L., Zheng, H.C., Bukuru, J., De Kimpe, N., 2004. Natural medicines used in the traditional Chinese medical system for therapy of diabetes mellitus. J. Ethnopharmacol. 92 (1), 1–21.
Li, X.L., Zhou, A.G., 2007. Evaluation of the antioxidant effects of polysaccharides extracted from *Lycium barbarum*. Med. Chem. Res. 15 (9), 471–482.
Li, X.M., 2007. Protective effect of *Lycium barbarum* polysaccharides on streptozotocin-induced oxidative stress in rats. Int. J. Biol. Macromol. 40 (5), 461–465.
Li, X.M., Ma, Y.L., Liu, X.J., 2007. Effect of the *Lycium barbarum* polysaccharides on age-related oxidative stress in aged mice. J. Ethnopharmacol. 111 (3), 504–511.
Li, Y.C., Wu, P.E., Zhou, J., 2001. Standards Collection of *Materia Medica*. Science and Technology Press, Chengdu, Sichuan.
Liang, G.E., Zhang, C.W., 2007. Experimental research on the skin aging function of *Lycium barbarum* polysaccharides. Chin. J. Aesthetic Med. 6, 734–736.
Licata, M., Tuttolomondo, T., Leto, C., Virga, G., Bonsangue, G., Cammalleri, I., Gennaro, C.M., Bella, L.S., 2016. A survey of wild plant species for food use in Sicily (Italy)-results of a 3-year study in four regional parks. J. Ethnobiol. Ethnomed. 12, 12.
Lim, T.K., 2012. Edible Medicinal and Non-medicinal Plants. 6 Springer Science + Business Media BV, New York.
Linnaeus, C., 1753. Species Plantarum 1, 191–192.
Liu, C., Tseng, A., Yang, S., 2004. Chinese Herbal Medicine: Modern Applications of Traditional Formulas. CRC Press, Florida.
Liu, W.T., 1956. Bencao Pinhui Jingyao. People's Health Press, Beijing, pp. 459–461.
Liu, X.L., Sun, J.Y., Li, H.Y., Zhang, L., Qian, B.C., 2000. Extraction and isolation of active component for inhibiting PC3 cell proliferation in vitro from the fruit of *Lycium barbarum* L. China J. Chin. Mater. Med. 25 (8), 481–483.
Liu, Y.H., 2002. Research on Yao's Medicine in Hu'nan. Hu'nan Sci & Tech Press, Changsha, pp. 307.
Lu, Z.Y., 1986. Bencao Chengya Banji. People's Health Press, Beijing, pp. 46–48.
Luo, Q., Cai, Y., Yan, J., Sun, M., Corke, H., 2004. Hypoglycemic and hypolipidemic effects and antioxidant activity of fruit extracts from *Lycium barbarum*. Life Sci. 76 (2), 137–149.
Luo, Q., Li, J., Cui, X., Yan, J., Zhao, Q., Xiang, C., 2014. The effect of *Lycium barbarum* polysaccharides on the male rats' reproductive system and spermatogenic cell apoptosis exposed to low-dose ionizing irradiation. J. Ethnopharmacol. 154 (1), 249–258.
LycieaeWeb, 2017. 〈http://jsmiller.people.amherst.edu/LycieaeWeb/Project_Lycieae.html〉 [dataset].
Ma, M., Liu, G., Yu, Z., Chen, G., Zhang, X., 2009. Effect of the *Lycium barbarum* polysaccharides administration on blood lipid metabolism and oxidative stress of mice fed high-fat diet in vivo. Food Chem. 113 (4), 872–877.
McClendon, J.F., 1921. Some American plants considered as sources of Vitamines and as parts of a diet favorable to the preservation of the teeth. J. Dent. Res. 3, 279–295.
McGregor, R.L., Barkley, T.M., 1986. Flora of the great plains. University Press of Kansas, Kansas.
Medicinal Plant Names Services, 2017. URL: 〈http://mpns.kew.org〉 [dataset].
Meng, X., 1984. Shiliao Bencao. People's Health Press, Beijing, pp. 16.
Mi, X.S., Chiu, K., Van, G., Leung, J.W.C., Lo, A.C.Y., Chung, S.K., Chang, R.C.C., So, K.F., 2012a. Effect of *Lycium barbarum* polysaccharides on the expression of endothelin-1 and its receptors in an ocular hypertension model of rat glaucoma. Neural Regen. Res. 7 (9), 645–651.
Mi, X.S., Feng, Q., Lo, A.C.Y., Chang, R.C.C., Lin, B., Chung, S.K., So, K.F., 2012b. Protection of retinal ganglion cells and retinal vasculature by *Lycium barbarum* polysaccharides in a mouse model of acute ocular hypertension. PLoS One 7 (10), e45469.
Mi, X.S., Zhong, J.X., Chang, R.C.C., So, K.F., 2013. Research advances on the usage of traditional Chinese medicine for neuroprotection in glaucoma. J. Integr. Med. 11 (4), 233–240.
Middleditch, B.S., 2012. Kuwaiti Plants: Distribution, Traditional Medicine, Pytochemistry, Pharmacology and Economic Value. 2 Elsevier, Amsterdam.
Miller, J.S., 2002. Phylogenetic relationships and the evolution of gender dimorphism in *Lycium* (Solanaceae). Syst. Bot. 27, 416–428.
Miller, J.S., Kamath, A., Damashek, J., Levin, R.A., 2011. Out of America to Africa or Asia: Inference of dispersal histories using nuclear and plastid DNA and the S-RNase self-incompatibility locus. Mol. Phylogenet. Evol. 28 (1), 793–801.
Ministry of Health, 2010. Vietnam Pharmacopoeia (4th), 〈http://tudien-thuoc.rhcloud.com/duocdien.html〉.
Molla, E.L., Asfaw, Z., Kelbessa, E., Van Damme, P., 2011. Wild edible plants in Ethiopia: a review on their potential to combat food insecurity. Afr. Focus 24 (2), 71–121.
Nabhan, G.P., Rea, A.M., Reichhardt, K.L., Mellink, E., Hutchinson, C.F., 1982. Papago influences on habitat and biotic diversity: Quitovac oasis ethnoecology. J. Ethnobiol. 2 (2), 124–143.
NAEB, 2003. Native American Ethnobotany Database, 〈http://naeb.brit.org/〉 [dataset].
Nanjing TCM University, 2006. Zhongyao Da Cidian, 2nd ed. Shanghai Sci & Tech Press, Shanghai, pp. 2246–2250.
Ndithia, H., Perrin, M.R., 2006. Diet and foraging behaviour of the Rosy-faced Lovebird *Agapornis roseicollis* in Namibia. Ostrich 77 (1–2), 45–51.
Neotropical Flora, 2017. 〈http://hasbrouck.asu.edu/neotrop/plantae/index.php〉.
Newton, D.R., 2013. The vascular flora of the Eagletail Mountain region. Desert Plants 29 (1), 1–52 (2013).
Ngo, L.T., Okogun, J.I., Folk, W.R., 2013. 21st century natural product research and drug development and traditional medicines. Nat. Prod. Rep. 30 (4), 584–592.
Ni, Z.M., 2005. Bencao Huiyan. Shanghai Sci & Tech Press, Shanghai, pp. 407–411.
NPGS, 2016. (National Plant Germplasm System). 〈https://npgsweb.ars-grin.gov/〉[dataset].
Olmstead, R.G., Sweere, J.A., Spangler, R.E., Bohs, L., Palmer, J.D., 1999. Phylogeny and

provisional classification of the Solanaceae based on chloroplast DNA. Solanaceae IV 1 (1), 1–137.
Ouhaddou, H., Boubaker, H., Msanda, F., El Mousadik, A., 2014. An ethnobotanical study of medicinal plants of the Agadir Ida Ou Tanane province (southwest Morocco). J. Appl. Biosci. 84 (1), 7707–7722.
Paradis, E., Claude, J., Strimmer, K., 2004. APE: analyses of phylogenetics and evolution in R language. Bioinformatics 20, 289–290.
Pavan, B., Capuzzo, A., Forlani, G., 2014. High glucose-induced barrier impairment of human retinal pigment epithelium is ameliorated by treatment with Goji berry extracts through modulation of cAMP levels. Exp. Eye Res. 120, 50–54.
PFAF, 2016. (Plants for a Future). 〈http://www.pfaf.org/〉 [dataset].
Pieroni, A., Nebel, S., Quave, C., et al., 2002. Ethnopharmacology of liakra: traditional weedy vegetables of the Arbëreshë of the Vulture area in southern Italy. J. Ethnopharmacol. 81 (2), 165–185.
Potterat, O., 2010. Goji (*Lycium barbarum* and *L. chinense*): phytochemistry, pharmacology and safety in the perspective of traditional uses and recent popularity. Planta Med. 76 (1), 7–19.
Powell, A.M., 1988. Trees & Shrubs of Trans-pecos Texas Including Big Bend and Guadalupe Mountains National Parks. Big Bend Natural History Association, Texas.
Qian, D., Zhao, Y., Yang, G., Huang, L., 2017. Systematic review of chemical constituents in the genus *Lycium* (Solanaceae). Molecules 22 (6), 911.
Qian, L., Yu, S., 2016. Protective effect of polysaccharides from *Lycium barbarum* on spermatogenesis of mice with impaired reproduction system induced by cyclophosphamide. Am. J. Reprod. Immunol. 76 (5), 383–385.
Quattrocchi, U., 2012. CRC World Dictionary of Medicinal nd Poisonous Plants: Common Names, Scientific Names, Eponyms, Synonyms, and Etymology. 3. CRC Press, pp. 841–842.
R Core Team, 2017. R: A language and environment for statistical computing. R Foundation for Statistical Computing, Vienna, Austria. URL: 〈https://www.R-project.org/〉.
Reeve, V.E., Allanson, M., Arun, S.J., Domanski, D., Painter, N., 2010. Mice drinking goji berry juice (*Lycium barbarum*) are protected from UV radiation-induced skin damage via antioxidant pathways. Photoch. Photobio. Sci. 9 (4), 601–607.
Rondina, R.V., Bandoni, A.L., Coussio, J.D., 2008. Argentine medicinal species with potential analgesic activity. Dominguezia 24 (1), 47–69.
Roth, I., Lindorf, H., 2002. South American Medicinal Plants: Botany, Remedial Properties and General Use. Springer Science & Business Media, Amsterdam.
Said, O., Khalil, K., Fulder, S., Azaizeh, H., 2002. Ethnopharmacological survey of medicinal herbs in Israel, the Golan Heights and the West Bank region. J. Ethnopharmacol. 83 (3), 251–265.
Saunders, C.F., 1920. Useful wild plants of the United States and Canada. RM McBride, New York.
Seifu, T., 2004. Ethnobotanical and ethnopharmaceutical studies on medicinal plants of Chifra district, Afar region, North Eastern Ethiopia. Thesis, Addis Ababa University.
Shang, Z.J., 2008. Classic of Shennong's Herbal with Annotation. Xueyuan Press, Beijing, pp. 58.
Sher, H., Alyemeni, M.N., 2011. Evaluation of anti-diabetic activity and toxic potential of *Lycium shawii* in animal models. J. Med. Plants Res. 5 (15), 3387–3395.
Shi, G., Zheng, J., Wu, J., Qiao, H., Chang, Q., Niu, Y., Sun, T., Li, Y.X., Yu, J., 2017. Beneficial effects of *Lycium barbarum* polysaccharide on spermatogenesis by improving antioxidant activity and inhibiting apoptosis in streptozotocin-induced diabetic male mice. Food Funct. 8 (3), 1215–1226.
Soltan, M.M., Zaki, A.K., 2009. Antiviral screening of forty-two Egyptian medicinal plants. J. Ethnopharmacol. 126 (1), 102–107.
Song, M.K., Roufogalis, B.D., Huang, T.H.W., 2012. Reversal of the caspase-dependent apoptotic cytotoxicity pathway by taurine from *Lycium barbarum* (Goji Berry) in human retinal pigment epithelial cells: potential benefit in diabetic retinopathy. Evid.-Based Compl. Alt. Med. 2012, e323784.
Song, W., Xu, Z., 2002. Sanming Shezu Minjian Yiyao. XiamenUniversity Press, Xiamen, pp. 231.
Su, J., 1981. Xinxiu Bencao. Anhui Sci & Tech Press, Anhui, pp. 320.
Su, S., 1994. Bencao Tujing. Anhui Sci & Tech Press, Anhui, pp. 356–357.
Sun, S.M., 1998. Qianjin Fang. China TCM Press, Beijing.
Tabaraki, R., Nateghi, A., Ahmady-Asbchin, S., 2013. In vitro assessment of antioxidant and antibacterial activities of six edible plants from Iran. J. Acupunct. Meridian Stud. 6 (3), 159–162.
Tan, F., Chen, Y., Tan, X., Ma, Y., Peng, Y., 2017. Chinese materia medica used in medicinal diets. J. Ethnopharmacol. 207 (1), 40–54.
Tang, L., Zhang, Y., Jiang, Y., Willard, L., Ortiz, E., Wark, L., Medeiros, D., Lin, D., 2011. Dietary wolfberry ameliorates retinal structure abnormalities in db/db mice at the early stage of diabetes. Exp. Biol. Med. 236 (9), 1051–1063.
Tang, S.W., 1982. Zhenglei Bencao. People's Health Press, Beijing, pp. 345–347.
Tang, W.M., Chan, E., Kwok, C.Y., Lee, Y.K., Wu, J.H., Wan, C.W., Chan, Y.R., Yu, H.P., Chan, S.W., 2012. A review of the anticancer and immunomodulatory effects of *Lycium barbarum* fruit. Inflammopharmacology 20 (6), 307–314.
Tao, D.Y., Chen, J.J., Chen, Y., Bai, H.J., 2008. Research in the anti-senile function of *Lycium ruthenicum* Murr. pigment in mice. J. Trad. Chin. Vet. Med. 27 (1), 11–13.
Tao, H.J., 1986. Mingyi Bielu. People's Health Press, Beijing, pp. 44–45.
Tao, H.J., 1994. Bencaojing Jizhu. People's Health Press, Beijing, pp. 228–229.
Terauchi, M., Kanamori, H., Nobuso, M., Fukuda, S., Yahara, S., Yamasaki, K., 1998. Antimicrobial components in leaves of *Lycium chinense* mill. Food Hyg. Safe. Sci. 39 (6), 399–405.
The Plant List, 2013. Version 1.1. 〈http://www.theplantlist.org/〉.
Toledo, B.A., Trillo, C., Grilli, M., Colantonio, S., Galetto, L., 2014. Relationships between land-use types and plant species used by traditional ethno-medical system. Eur. J. Med. Plants 4 (9), 998–1021.
Trabsa, H., Baghiani, A., Boussoualim, N., Krache, I., Khennouf, S., Charef, N., Arrar, L., 2015. Kinetics of inhibition of xanthine oxidase by *Lycium arabicum* and its protective effect against oxonate-induced hyperuricemia and renal dysfunction in mice. Trop. J. Pharm. Res. 14 (2), 249–256.
Trillo, C., Toledo, B.A., Galetto, L., Colantonio, S., 2010. Persistence of the use of medicinal plants in rural communities of the western arid Chaco. Open Comp. Med. J. 2, 80–89.
Tu, Y.Y., 2015. Nobelprize.org. Nobel Media AB 2014. Web. 13 Jan 2016. 〈http://www.nobelprize.org/nobel_prizes/medicine/laureates/2015/tu-lecture.html〉.
Turker, G., Kizilkaya, B., Cevik, N., Gonuz, A., 2012. Free radical scavenging activity and phenolic content of edible wild fruits from Kazdagi (Ida Mountains), Turkey. J. Med. Plants Res. 6 (36), 4989–4994.
Tutin, T.G., 1972. Flora Europaea. Cambridge University Press, Cambridge.
University of Toyama, ETHMEDmmm, 2016. The Data Base of Ethno-medicines in the world. 〈http://ethmed.u-toyama.ac.jp〉 [dataset].
USDA, 1992–2016. (U.S. Department of Agriculture),of Agriculture). Dr. Duke's Phytochemical and Ethnobotanical Databases. 〈http://phytochem.nal.usda.gov/〉 [data].
Van Damme, P., 1998. Wild Plants as Food Security in Namibia and Senegal. Springer, Amsterdam.
VicFlora, 2015. Flora of Victoria. 〈https://vicflora.rbg.vic.gov.au/〉 [dataset].
Vines, R.A., 1960. Trees, Shrubs, and Woody Vines of the Southwest. University of Texas Press, Texas.
Wagner, H., Bauer, R., Melchart, D., Xiao, P.G., Staudingeret, A., 2011. Chromatographic fingerprint analysis of herbal medicines. Springer, Berlin, pp. 511–534.
Wang, C.C., Chang, S.C., Stephen Inbaraj, B., Chen, B.H., 2010. Isolation of carotenoids, flavonoids and polysaccharides from *Lycium barbarum* L. and evaluation of antioxidant activity. Food Chem. 120 (1), 184–192.
Wang, H.G., 1987. Tangye Bencao. People's Health Press, Beijing, pp. 143–144.
Wang, T., Li, Y., Wang, Y., Zhou, R., Ma, L., Hao, Y., Jin, S., Du, J., Zhao, C., Sun, T., Yu, J., 2014. *Lycium barbarum* polysaccharide prevents focal cerebral ischemic injury by inhibiting neuronal apoptosis in mice. PloS One 9 (3), e90780.
Watson, S., 1888. Contributions to American botany. In Proceedings of the American Academy of Arts and Sciences (Vol. 24). American Academy of Arts & Sciences, Massachusetts.
Watt, J.M., Breyer-Brandwijk, M.G., 1962. The medicinal and poisonous plants of Southern and Eastern Africa: being an account of their medicinal and other uses, chemical composition, pharmacological effects and toxicology in man and animal. Livingstone, London, pp. 961.
Watt, J.M., Warmelo, N.V., 1930. The medicines and practice of a Sotho doctor. Bantu. Stud. 4 (1), 47–63.
Wolfe, D., 2010. Superfoods: the Food and Medicine of the Future. North Atlantic Books, California.
Wu M., Guo L., 2015. Anti-fatigue and anti-hypoxic effects of *Lycium barbarum* polysaccharides. International Conference on Advances in Energy, Environment and Chemical Engineering. Atlantis Press, Hong Kong.
Wu, P., 1987. Wu Pu's Herbal. People's Health Press, Beijing, pp. 60.
Wu, Q.J., 1959. Zhiwu Mingshi Tukao Changbian. Commercial Press, Beijing, pp. 1063–1067.
Xiao, J., Liong, E.C., Ching, Y.P., Chang, R.C.C., So, K.F., Fung, M.L., Tipoe, G.L., 2012. *Lycium barbarum* polysaccharides protect mice liver from carbon tetrachloride-induced oxidative stress and necroinflammation. J. Ethnopharmacol. 139 (2), 462–470.
Xiao, J., Xing, F., Huo, J., Fung, M.L., Liong, E.C., Ching, Y.P., Xu, A., Chang, R.C.C., So, K.F., Tipoe, G.L., 2014b. *Lycium barbarum* polysaccharides therapeutically improve hepatic functions in non-alcoholic steatohepatitis rats and cellular steatosis model. Sci. Rep. 4, 5587.
Xiao, J., Wang, J., Xing, F., Han, T., Jiao, R., Liong, E.C., Fung, M.L., So, K.F., Tipoe, G.L., 2014a. Zeaxanthin dipalmitate therapeutically improves hepatic functions in an alcoholic fatty liver disease model through modulating MAPK pathway. PloS One 9 (4), e95214.
Xiao, P.G., 2002. Xinbian Zhongyao Zhi. 2. Chemical Industry Press, Beijing, pp. 482–486.
Xie, J.H., Tang, W., Jin, M.L., Li, J.E., Xie, M.Y., 2016. Recent advances in bioactive polysaccharides from *Lycium barbarum* L., *Zizyphus jujuba* mill, *Plantago* spp., and *Morus* spp.: structures and functionalities. Food Hydrocoll. 60, 148–160.
Xin, T., Yao, H., Gao, H., Zhou, X., Ma, X., Xu, C., Chen, J., Han, J., Pang, X., Xu, R., Song, J., 2013. Super food *Lycium barbarum* (Solanaceae) traceability via an internal transcribed spacer 2 barcode. Food Res. Int. 54 (2), 1699–1704.
Xue, D., 2011. Analysis for the main elements and potential impacts of Nagoya protocol. Biodivers. Sci. 19 (1), 113–119.
Yan, X.T., 1958. Depei Bencao. Shanghai Sci & Tech Press,, Shanghai, pp. 185–186.
Yang, S.T., 1958. Bencao Shu Gouyuan. ShanghaiHealth Press, Shanghai, pp. 443–445.
Yao, X., Peng, Y., Xu, L.J., Li, L., Wu, Q.L., Xiao, P.G., 2011. Phytochemical and biological studies of *Lycium* medicinal plants. Chem. Biodivers. 8 (6), 976–1010.
Ye, Z., Huang, Q., Ni, H.X., Wang, D., 2008. *Cortex Lycii Radicis* extracts improve insulin resistance and lipid metabolism in obese-diabetic rats. Phytother. Res. 22 (12), 1665–1670.
Yi, R., Liu, X.M., Dong, Q., 2013. A study of *Lycium barbarum* polysaccharides (LBP) extraction technology and its anti-aging effect. Afr. J. Tradit. Complement. Altern. Med. 10 (4), 171–174.
Yin, X.L., Fang, K.T., Liang, Y.Z., Wong, R.N., Wyha, A., 2005. Assessing phylogenetic relationships of *Lycium* samples using RAPD and entropy theory. Acta Pharmacol. Sin. 26, 1217–1224.
Yu, H.A., 1996. Tibetan Medicines of China. Shanghai Health Press, Shanghai.
Zhang, R., Kang, K.A., Piao, M.J., Kim, K.C., Kim, A.D., Chae, S., Park, J.S., Youn, U.J., Hyun, J.W., 2010. Cytoprotective effect of the fruits of *Lycium chinense* Miller against

oxidative stress-induced hepatotoxicity. J. Ethnopharmacol. 130 (2), 299–306.

Zhang, X., Li, Y., Cheng, J., Liu, G., Qi, C., Zhou, W., Zhang, Y., 2014. Immune activities comparison of polysaccharide and polysaccharide-protein complex from *Lycium barbarum* L. Int. J. Biol. Macromol. 65, 441–445.

Zhao, H., Alexeev, A., Chang, E., Greenburg, G., Bojanowski, K., 2005. *Lycium barbarum* glycoconjugates: effect on human skin and cultured dermal fibroblasts. Phytomedicine 12 (1), 131–137.

Zhonghua Bencao Editorial Board, 1999. Zhonghua Bencao. 19. Shanghai Sci & Tech Press, Shanghai, pp. 267–278.

Zhonghua Bencao Editorial Board, 2002. Zhonghua Bencao 31. Shanghai Sci & Tech Press, Shanghai, pp. 244–245.

Zhonghua Bencao Editorial Board, 2004. Zhonghua Bencao 32. Shanghai Sci & Tech Press, Shanghai, pp. 295–297.

Zhonghua Bencao Editorial Board, 2005a. Zhonghua Bencao 33. Shanghai Sci & Tech Press, Shanghai, pp. 268–270.

Zhonghua Bencao Editorial Board, 2005b. Zhonghua Bencao 35. Shanghai Sci & Tech Press, Shanghai, pp. 406–408.

Zhu, G., Du, J., Zhang, J., 2006. Medicine of *Tujia*. TCM Ancient Press, Beijing, pp. 380–381.

Zhu, S., 2008. *Jiuhuang Bencao* with Annotation. China Agriculture Press, Beijing, pp. 277–278.