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, 31 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 millennia. *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.

Keywords: *Lycium*, Taxonomy, Traditional medicine, Ethnobotany, Chinese medicine, TCM, Pharmacopoeia

Contents:

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). 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 Tab 1.

Tab 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 to 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 (2017).	*Lycium*

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 suvery" 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 to 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, et al., 2001; Miller, et al., 2011; 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, et al., 2001; Miller, 2002; Yin, et al., 2005; Levin and Miller, 2005; Levin, et al., 2009a; Levin, et al., 2009b; Miller, 2011; Levin, et al., 2011).

Tab 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 & Warmelo, 1930; Lev & 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 & 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 & 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; Deeb, et al., 2013; MPNS,2017; Quattrocchi, 2012
L. berberioides Corre ll	US	NM	NM	-
L. berlandieri Dunal	US, Mexico, Germany	Fruit as food	Plant as medicine	FEIS, 2016; PFAF, 2016; Kearney, et al., 1960; Powell, A.M., 1988; Newton, 2013
L. berlandieri var. *pa rviflorum* (A. Gray) A. Terracc.	US, Mexico	Fruit as food	Plant as medicine	Hodgson, 2001
L. bosciifolium Schin z	Namibia, South Africa, Botswana, Angola, Zimbabwe	Leaf as food	NM	Dithi & 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 Walt er	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; Quattrocchi, 2012
L. chinense var. *potan inii* (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, 2010; Toledo, 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	-
L. cylindricum Kuang & A. M. Lu	China	NM	NM	-
L. dasystemum Pojark .	China, Iran	Fruit as food	Fruit as medicine	Ali, 1980; Azadi, 2007; Li, et al., 2001;
L. decumbens Welw. ex Hiern	South Africa, Namibia, Angola	NM	NM	-
L. densifolium Wiggi ns	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 Wiggin s	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., 2010; Trillo, et al., 2014.
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 & Yaniv, 1994; Said et al., 2002; El Hamrouni, 2001; Boullard, 2001; Pieroni, et al., 2002; Al-Quran, 2007; El-Mokasabi, 2014; Turker, 2012; Leporatti, et al., 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 Mier s	Australia, South Africa, New Zealand, Morocco, Namibia, US, Lesotho, Spain, Norfolk Island, Tunisia	Fruit as food	Plant for detoxication of narcotic poisoning	Watt & Breyer-Brandwijk, 1962; Arnold, et al., 2002; ; MPNS,2017
L. fremontii A. Gray	US, Mexico	Fruit as food	NM	NAEB, 2003; PFAF, 2016; Watt & Breyer-Brandwijk, 1962; MPNS,2017
L. fuscum Miers	Argentina	NM	NM	-
L. gariepense A.M.V enter	South Africa, Namibia	NM	NM	-
L. gilliesianum Miers	Argentina, Chile	NM	NM	-
L. glomeratum Sendt n.	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 et al., 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.	Ecuador	NM	NM	-

Hitchc.				
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
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 Du	Chile	NM	NM	-

nal				
L. repens Speg.	Argentina, US	NM	NM	-
L. richii A. Gray	US, Mexico	Fruit as food	NM	Watson, 1888; Hodgson, 2001
L. ruthenicum Murra y	China, Iran, Afghanistan, India, Mexico, Pakistan, Russian, Turkmenistan, Georgia	Fruit as food	Fruit: ophthalmic, blindness (veterinary); leaf: remove blocked urine; diuretic	USDA, 1996-2016; 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 Da mmer	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, et al., 2009; Cherouana et al., 2013; Ghazanfar, 1994; Hassan-Abdallah, et al., 2013 ; Trabsa et al., 2015; Chermat et al., 2015; Sher et al., 2011; Gaweesh et al., 2015; Iwu, 2014; MPNS,2017; El-Ghazali, et al., 2010; Molla, 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 & 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 & 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.

According to our findings, at present ninety seven species and six varieties are recognized (Tab 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 Tab 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.

Tab 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 1-1.5cm. 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. Seeds more than 20.	Pedicel 1-1.8 cm. 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.	ca. 1.5 m tall. Stems much branched; branches grayish white, yellowish, or rarely brown-red, stout, young branches slender, elongate. 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.
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) x 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, et al., 1986; Ali, 1980)

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 (Tab 2). The number of native species of the different continents used as food and medicine are shown in Fig. 1.

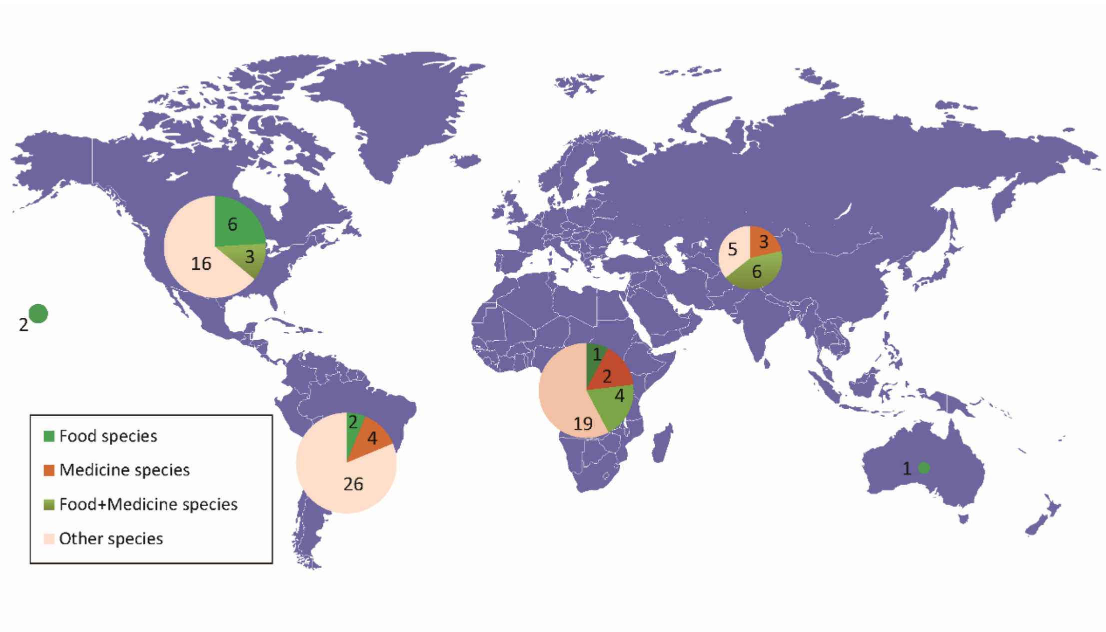

Fig. 1 *Lycium* species used as food and/or medicine on the different continents

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 & 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. 1400s to B.C.E. 1100s), 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. 1100s to B.C.E. 300s) (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.

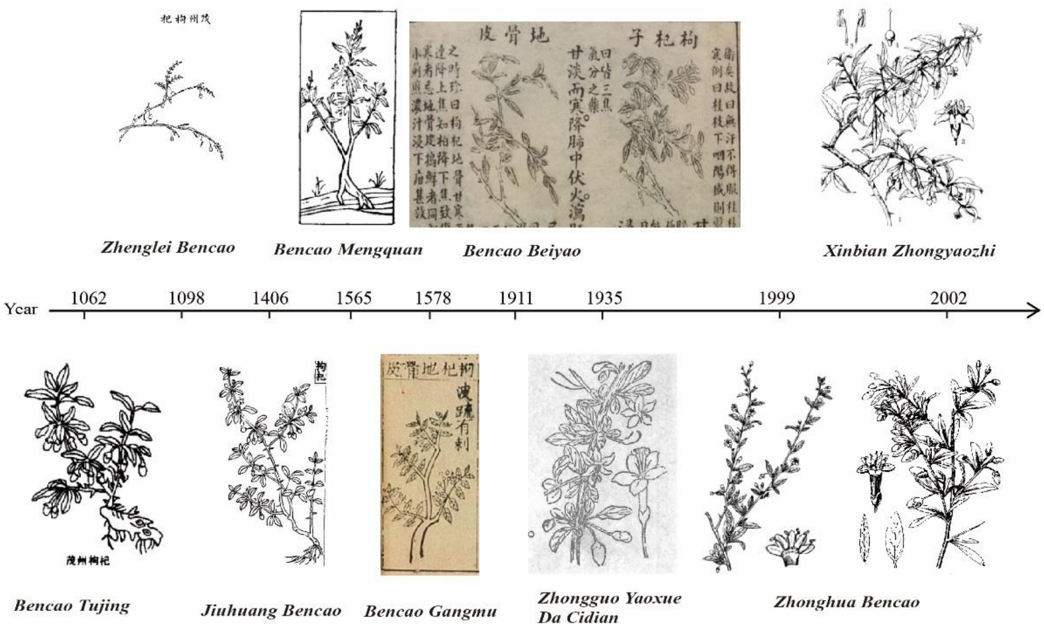

Fig. 2 Illustrations of *Lycium* in Chinese herbals over time

New in the *Song* Dynasty (960 - 1279) was the detailed morphological description of the plant accompanied by illustrations. *Bencao 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, 1988; Chen, 1985; Chen, 2008; Du, 1975; Jiang, 1911; Kou, 1990; Liu, 1956; Lu, 1986; Ni, 2005; Wang, 1987;Wu,1987; Wu, 1959; 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 Broad, 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 minorities of China (Tab 4).

Tab 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 & 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 & Li, 2005
		L. dasystemum	Fruit	Heart hot, gynecopathy	Jia & Li, 2005
		L. ruthenicum	Fruit	Heart diseases, gynecopathy	Dimaer, 1986; Jia & Li, 2005
维吾尔族 Uighur	*Xinjiang*	*L. barbarum/ L. chinense*	Fruit	Hyposexuality, blurry vision, neurasthenia, hyperlipidemia, oligospermia	*Zhonghua Bencao* 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 & Li, 2005; *Zhonghua Bencao* Editorial Board, 2004
苗族	*Guizhou, Hunan,*	*L. chinense*	Root	Fever, night sweat, dysphoric,	*Zhonghua Bencao*

Miao	*Hubei, Sichuan, Yunnan, Guangxi, Hainan*		bark, fruit, leaf, whole plant	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 & 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 & Xu, 2002; Jia & 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 & Li, 2005
德昂族 De'ang	*Yunnan*	*L. barbarum*	Fruit	Blurry vision, kidney deficiency, blood deficiency, neurasthenia	Jia & Li, 2005
彝族 Yi	*Yunnan, Guizhou, Sichuan, Guangxi*	*L. chinense*	Whole plant	Pruritus, sore and ulcer diseases	Jia & Li, 2005
朝鲜族 Korean	*Heilongjiang, Jilin, Liaoning*	*L. chinense*	Fruit	Blurry vision, kidney deficiency, backache, neurasthenia, vomiting blood	Jia & Li, 2005
瑶族 Yao	*Guangxi, Hunan, Yunan, 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 bloоding	Jia & Li, 2005

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.

Tab 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 & Zhou, 2007; Li, et al. 2007; Bai, et al., 2008; Donno, et al., 2015; Benchennouf, 2017; Chung, et al., 2014 ; Wang et al., 2010
Spermatogenesis	Polysaccharides (fruit of *L. barbarum*)	Luo, et al., 2014; Qian & Yu, 2016; Shi, et al., 2017
Retinal protection	Zeaxanthin and/or lutein,	Tang, et al., 2011; Mi, et al., 2012b; Song, et al., 2012; Chu,

	polysaccharides	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., 2014a; Xiao, et al., 2014b; 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, 2012; Chen, et al., 2012; Chen, et al., 2008; Chen, et al., 2009a; Chen, et al., 2009b; 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, 2012; Hu, et al., 1994; Gan, et al., 2004; Liu, et al., 2000
Skin care	Polysaccharides, juice, glycoconjugate	Reeve, et al., 2012; Liang & Zhang, 2007; Zhao, et al., 2005
Anti-microbial	Lyciumoside I, AcOEt-soluble fraction	Terauchi, et al., 1998; Lee, et al., 2005; Dong-Hyun, 2000
Anti-diabetic	Water extract, polysaccharides, organic acids, and alkaloids	Ye, et al., 2008; Song, et al., 2012; Li, et al., 2004; Li, 2007; Luo, et al., 2004 ; Jia et al., 2003
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 & Guo, 2015; Kim & Baek, 2014

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.

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 (Tab 6). *Lycium* has not been included in the pharmacopoeia of USA, Russia, Africa, Australia, Brazil, Argentina, Switzerland, Iran, and India.

Tab 6 *Lycium* records in current pharmacopoeias of the world

Region	Pharmacopoeia	Species	Used parts	Description	Identification	Examination
China	Chinese Pharmacopoeia (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 (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	*L. barbarum/ L. chinense*	Fruit	Morphologic, odour, taste	TLC	Foreign matters ≤ 3%, total ash ≤ 6%, betaine ≥ 0.5%.

	(11th)(2014)	*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)	*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)	*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)(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%)

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 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, 1953, 1963, 1977, 1985, 1990, 1995, 2000, 2005, 2010, 2015). *Lycium* species described in the different editions are shown in Table 7.

Tab 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	NM	Foreign matter ≤ 2%

			or air dry, odour, taste, macroscopic, indications, storage		
	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%

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.

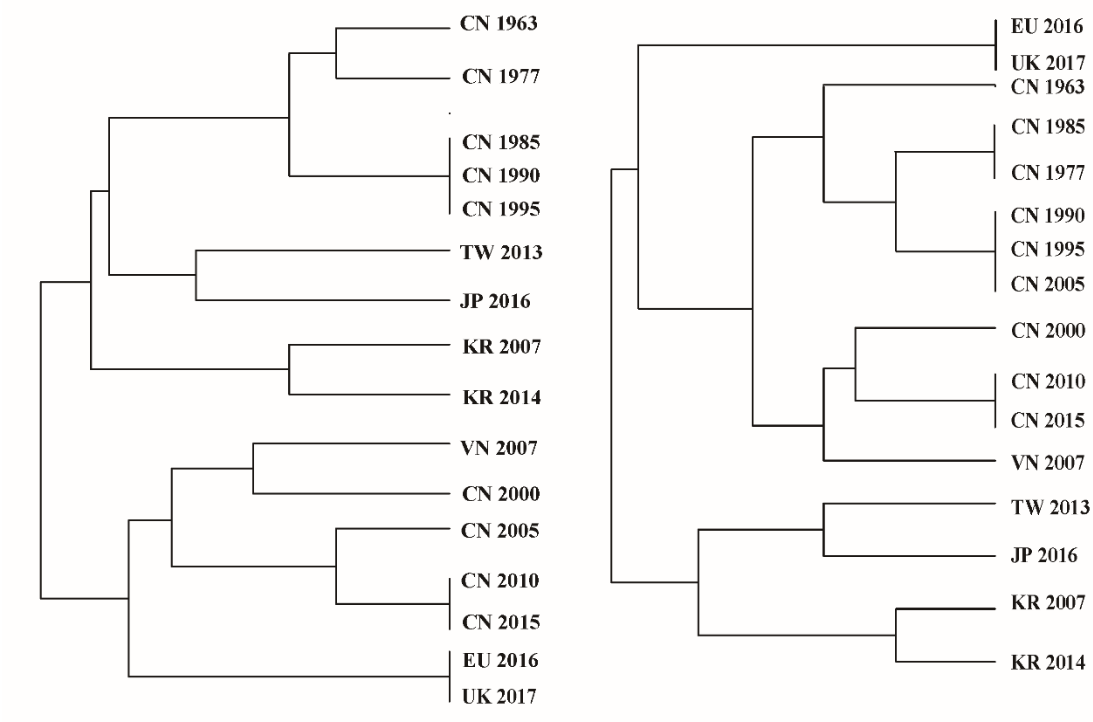

Fig. 3 Clustering based on parameters of *Lycium* fruit (left) and *Lycium* root bark (right) in different pharmacopoeias

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 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).

Historical documentary evidences are good basis for ethnobotanical study (Heinrich, et al., 2006; Heinrich, et al., 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.

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.

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S1 *Lycium* records in Chinese herbals of all dynasties

Year	Herbal Title	Used parts	Usages	Notes	Reference
Ca. C.E. 100	*神农本草经* *Shennong Bencao Jing*	Unclear	Treat evil qi, heat, *xiaoke*, and arthralgia; physical strengthen, anti-aging	Flavor bitter, temperature cold	Shang, 2008
Ca. 208-239	*吴普本草* *Wupu bencao*	Unclear	NM	With 2 names: 杞芭 *qiba*,羊乳 *yangru*	Wu, 1987
Ca. 350	*抱朴子* *Baopuzi*	Unclear	Extend longevity	Only name mentioned	Ge, 1995
Ca. 350	*肘后备急方* *Zhouhou Beiji Fang*	Root, fruit	Anti-fatigue, deodorant and antiperspirant, mania of dog	Formulas included	Ge, 1999
Ca. 420-479	*雷公炮炙论* *Leigong Paozhi Lun*	Root, fruit	NM	Process method of root; fruit was used for processing the herb *巴戟天 bajitian*	Lei, 1985
Ca. 492-500	*本草经集注* *Bencaojing Jizhu*	Root, leaf, stem, fruit	Treat rheumatism, headache, evil qi, heat, *xiaoke*, arthralgia; physical strengthen, anti-aging; leaf porridge	Root, fruit were separate. Collecting times of root, leaf, fruit	Tao, 1994

Ca. 502-536	*名医别录* *Mingyi Bielu*	Root, leaf, stem, fruit	Rheumatism, headache, physical strengthen, anti-aging, enhance *yin*	Root, fruit were separate. Collecting times of root, leaf, fruit	Tao, 1986
659	*新修本草* *Xinxiu Bencao*	Root, fruit, leaf	Treat rheumatism, headache, evil qi, heat, *xiaoke*, arthralgia; physical strengthen, anti-aging; leaf porridge	Root, fruit were separate; collecting times of root, leaf, fruit	Su, 1981
682	*千金翼方* *Qianjin Yifang*	Fruit, leaf, root,	Treat evil qi, heat, *xiaoke*, and arthralgia, eye, calculus, spasm; food use, physical strengthen, anti-fatigue, tooth regeneration, enhance *yin*	Harvesting, cultivation were included; different parts were used solely or in formulas	Sun, 1998
Ca. 618-907	*食疗本草* *Shiliao Bencao*	Fruit, root, leaf	Treat rheumatism, headache, evil qi, heat, *xiaoke*, arthralgia, eye problem; physical strengthen, nourish, leaf tea enhance male's sexual performance	Recipes of medicated diet, leaf juice was used on eye	Meng, 1984
1062	*本草图经* *Bencao Tujing*	Leaf, fruit, root	Treat rheumatism, headache, evil qi, heat, *xiaoke*, arthralgia, eye problem; physical strengthen	Plant descriptions with illustration, identification by morphology	Su, 1994
1098	*证类本草* *Zhenglei Bencao*	Leaf, fruit, root	Treat rheumatism, headache, evil qi, heat, *xiaoke*, arthralgia; physical strengthen, anti-aging; leaf for tea and cooking as medicated food	Plant descriptions with illustration, identification by morphology; not to be used with cheese	Tang, 1982
1119	*本草衍义*	Bark, fruit,	NM	Plant description, and comments on	Kou, 1990

	Bencao Yanyi	root bark		the current use	
Ca. 1238-1248	*汤液本草* *Tangye Bencao*	Root	Cited the former herbals, add meridian tropism	Only the root was mentioned	Wang, 1987
Ca. 1314-1320	*饮膳正要* *Yinshan Zhengyao*	Fruit, leaf	Extend longevity, anti-aging, anti-fatigue, enhance *yang* by medicated diets.	Fruit tea, goji wine, leaf lamb soup	Hu, 2009
1406	*救荒本草* *Jiuhuang Bencao*	Fruit, leaf	Fruit as food, leaf for tea	Include plant descriptions with illustration	Zhu, 2008
1505	*本草品汇精要* *Bencao Pinhui Jingyao*	Leaf, fruit, seedling	Treat evil qi, heat, *xiaoke*, and arthralgia; physical strengthen, anti-aging, antipyretic	Add incompatibility with other drugs	Liu, 1956
1565	*本草蒙荃* *Bencao Mengquan*	Seedling, fruit, root	Nourish *yin* and *yang*, protect eyesight, mind tranquilizing, calm blood, seedling as vegetable	Adulteration with honey, include identification of plant	Chen, 1988
1596	*本草纲目* *Bencao Gangmu*	Leaf, fruit, root, flower seedling,	Food and medicine, Summary of earlier herbals	Summary of earlier herbals, with Li's personal comments.	Li, 1954
1598	*药鉴*	Fruit, root	Fruit sweet-bitter, nourish *yin* and *yang*, improve	Root bark and fruit were recorded	Du, 1975

	Yaojian	bark	eyesight and hearing, mind tranquilizing, kidney; root bark bitter, calm blood, relief hectic fever	as 2 individual drugs separately	
1624	*本草汇言* *Bencao Huiyan*	Fruit, root bark	Fruit ascending or descending, root bark descending	Summary of former herbals, with formulas, lei include fruit processing	Ni, 2005
Ca. 1644-1911	*本草撮要* *Bencao Cuoyao*	Fruit, root bark	Fruit sweet and cold, nourish liver, root bark relief fever	With several compatibilities	Chen, 1985
1647	*本草乘雅半偈* *Bencao Chenya Banji*	Fruit, root bark	Treat evil qi, heat, *xiaoke*, and arthralgia; physical strengthen, anti-aging	With plant description, add the habit of growth and development	Lu, 1986
1691	*本草新编* *Bencao Xinbian*	Fruit, root bark	Fruit improves *yang*, while root bark improves *yin;* the dose of root bark was demonstrated	Sweet-bitter, TCM theory was added	Chen, 2008
1761	*得配本草* *Depei Bencao*	Fruit, seedling and leaf, root bark	The compatibilities with other herbs, contraindications, was discussed; as medicine, tea, and medicated diet	Sweet, warm	Yan, 1958
1833	*本草述钩元* *Bencao Shu Gouyuan*	Seedling, root, fruit	Antipyretic, nourish, anti-fatigue, treat sores; with formulas, and the theory were discussed; medicine,	Sweet, flat	Yang, 1958

			food, tea		
1848	*植物名实图考* *Zhiwu Mingshi Tukao*	Leaf, fruit, root	Tea, food, medicine use	Excerpt of herbals and dictionaries	Wu, 1959
1911	*补图本草备要* *Butu Bencaobeiyao*	Fruit, root	With illustrations of plants, by which the plant could not be identified; summary of before	Sweet, flat, TCM theory	Jiang, 1911
1935	*中国药学大辞典* *Zhongguo Yaoxue Dacidian*	Fruit, root bark	A summary of former herbals, introduced the concept of scientific name, however a wrong name was used	Summarize the earlier by time; Theory, recipes were included	Chen, 1935
1999	*中华本草* *Zhonghua Bencao*	Fruit, root bark, leaf	Immuno-modulatory, anti-aging, anti-cancer, hepatoprotective, hematogenesis, hypoglycemic, treat sterilitas virilis; toxicity and contraindication was mentioned; prescriptions were included	The plants and the *materia medica* used were precisely described with illustration and microscopic characteristics; pharmacological evidences were included	*Zhonghua Bencao* Editorial Board, 1999
2002	*新编中药志* *Xinbian Zhongyaozhi*	Fruit	Immuno-modulatory, anti-aging, anti-cancer, hepatoprotective; TLC was introduced for identification; identification key of the used species were included	The identification technology was improved	Xiao, 2002

2006	*中药大辞典* *Zhongyao Da Cidian*	Fruit, root bark, leaf	Immuno-modulatory, anti-aging, anti-cancer, hepatoprotective, hematogenesis, hypoglycemic, antibacterial; with medicine formulas and medicated diet recipes; clinic reports were added	Description is clear and usages are practical	Nanjing TCM University, 2006