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Review

Lycium ruthenicum studies: Molecular biology, Phytochemistry and pharmacology

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ABSTRACT

Lycium ruthenicum has been used as ethnic medicine and nutraceutical food. Existing studies of *L. ruthenicum* can be classifies into three areas: (1) those in which molecular biology methods were used to study its origin, genetic variation and relationships with other species; (2) those in which phytochemical methods were used to extract, isolate, and identify compounds; and (3) those in which pharmacological methods were used to study active compounds. The purpose of this paper is to provide an overview of *L. ruthenicum* studies. This review will provide a useful bibliography for further investigations and applications of *L. ruthenicum* in medicines and foods.

1. Introduction

There is an overwhelming amount of research on berry fruits, and the dried fruits of *Lycium* plant (Fructus lycii, wolfberries, goji berries) are popular in Asia and other countries (Seeram, 2008). There are approximately 80 species of *Lycium* L. (Solanaceae) in the world (Hitchcock, 1932; Levin & Miller, 2005; Miller, 2002), and seven species and three varieties are found in China (Board, 1994). However, only three species (*L. barbarum*, *L. chinense* and *L. ruthenicum*) are used as medicine, and they are referred to as goji berries in China. There have been used as medicine and functional foods for at least 2000 years (Ulbricht et al., 2014; Zeng, Wu et al., 2014). Nearly 90% of all commercially available goji berries are *L. barbarum* (Zhong, Shahidi, & Naczk, 2013), and this species has been widely cultivated in northwest China for more than 600 years (Chen, Liu, Zhu, & Wang, 2013), especially in Ningxia province. In additional, Goji (*L. barbarum* L.) leaves as a functional tea or as dietary are a rich source of bioactive compounds with functional properties (Mocan et al., 2017). *L. ruthenicum*, a wild perennial thorny shrub, inhabits northwestern China (Han, Ye, & Suo, 2014). Its resistant to drought and salt stress makes it an ideal plant under conditions of soil desertification and for alleviating the degree of soil salinity-alkalinity, which is very important for the ecosystem (Zheng et al., 2011). It is used as medicine and has had a great influence on the development of Minority Medicine (Tian et al., 2016). Additionally, it is used as nutritional food and can be eaten as fruit or used as a raw material for beverages (Jin, Liu et al., 2015; Lv, Wang, Yang, Huang, & Wang, 2013).

L. ruthenicum has been described in the Tibetan medical classics *Jing Zhu Ben Cao* and *Si Bu Yi Dian* for the treatment of heart disease, abnormal menstruation and menopause (Dierma & Mao, 2012; Yutuo, 1987). It has also been described in *Pharmacography of Uighur* for the treatment of urethral and ureteral stones, tinea and furuncle, and gingival bleeding (Liu, 1999). Modern pharmacology research has confirmed that *L. ruthenicum* has many pharmaceutical effects such as antioxidant (Hu, Zheng, Li, & Suo, 2014), anti-fatigue (Ni et al., 2013), immuno-enhancement (Gong, Wu, & Li, 2015), radio-resistance (Duan et al., 2015), and anti-aging (Tian, Jiang, & Fan, 2015) effects. Its berries contain abundant anthocyanins (Zheng et al., 2011), which are a kind of water-soluble natural pigment. The pigments extracted from the berries are widely used as natural food colorants (Hu et al., 2014). Additionally, *L. ruthenicum* is endemic to northwestern China. It is important for controlling erosion because of its high tolerance to salt, drought, strong winds, cold temperatures and petroleum contamination (Chen et al., 2013; Jalali, Akbarian, Rhoades, & Yousefzadeh, 2012; Xi, Zhang, Mao, & Yan, 2003; Zhang, Yin, & Pan, 2013). Therefore, *L. ruthenicum* plays important roles in ethnic medicine, nutritional food and

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the restoration of desert ecosystems.

The aim of this paper is to provide an overview of *L. ruthenicum* research, focusing on its genetics, chemical composition and pharmacology. The most relevant results from the published studies are summarized, analyzed and discussed.

2. Molecular biology

Most *Lycium* species are found in southern South America, southern African and southwestern North America. In addition, a number of species are distributed in the Mediterranean and across Asia, and one species is apparently native to Australia (Levin, Shak, Miller, Bernardello, & Venter, 2007). Researchers studying the biogeographical history of *Lycium* have relay on chloroplast DNA (cpDNA) analysis, which has been frequently used to reconstruct the phylogenetic relationships of a wide range of land plants. The analysis showed that *Lycium* almost certainly originated in American, and it suggested a single dispersal from the Americas to southern Africa, Australia and Eurasia (*Lycium chinense*, *L. europaeum*, *L. barbarum* and *L. ruthenicum*). The Eurasian species are monophyletic (Fukuda, Yokoyama, & Ohashi, 2001; Levin & Miller, 2005; Miller, 2002; Miller, Levin, & Feliciano, 2007), and are most widely distributed in China. RAPD was used to construct a phylogeny, and the common bands in the fingerprints generated from the OPC-2 and OPAM-2 (Sequences (5′-3′): GTG AGG CGTC and ACT TGA CGG G, respectively) primers indicated that homologous sequences are present in *Lycium*. The unique bands illustrate that the individual species have their own characteristics, such as unique bands at 480 bp and 580 bp in the *L. chinense* and *L. ruthenicum* RAPD fingerprint generated from OPC-2, respectively (Yin, Fang, Liang, Wong, & Ha, 2005; Zhang, Leung, Yeung, & Wong, 2001).

L. ruthenicum is an endangered and medically important species. RAPD, SRAP, cpDNA and SSR were successfully used to study its genetic diversity and genetic structure (Chen, Zeng, Yonezawa, Ren, & Zhong, 2014; Liu et al., 2012; Zhang et al., 2001; Chen & Zhong, 2014). At the species level, it has a relatively high genetic diversity (He = 0.2112) compared to the average solanaceae plant (He = 0.0940) (Hamrick & Godt, 1996). However, it has a relatively low genetic diversity compared to *L. chinense* (He = 0.3792), which is widely distributed species in China (Zhao et al., 2010). Additionally, the genetic differences were found mainly within populations, in which gene exchange was relatively high (Chen, Zeng, Yonezawa, Ren, & Zhong, 2014; Liu et al., 2012). In addition, this species has weak phylogeographic structure, as suggested by the chloroplast DNA genetic structure (G_{ST} = 0.351, N_{ST} = 0.304, $N_{ST} \leq G_{ST}$). The divergence times of different lineages were consistent with the rapid uplift phase of the Qinghai-Tibetan Plateau and the initiation and expansion of deserts in northern China, which suggest that the origin and evolution of *L. rythenicum* were strongly influenced by Quaternary environment changes (Chen, Zeng et al., 2014).

Gene expression was analyzed for *L. barbarum* and *L. ruthenicum*, which indicated that no candidate reference gene was consistently expressed across different tissues or species. *EF1α* was the most stable reference genes in *L. ruthenicum* fruits. Additionally, *H2B1* and *GAPDH1* + *PGK1* for *L. ruthenicum* and *SAMDC2* + *H2B1*for *L. barbarum* were the best single and/or combined reference genes (Zeng, Liu et al., 2014). The expression patterns of both regulatory and structural genes and the transcriptional ratio of branch node structural genes F3′5′H/F3′H may determine the phenotypic difference in anthocyanin biosynthesis between *L. ruthenicum* and *L. barbarum* fruits (Zeng, Liu et al., 2014). In addition, 1913 up-regulated and 536 down-regulated genes that showed at least a twofold change were identified by high throughput RNA-sequencing analysis of *L. ruthenicum* with and without UV-B exposure, and the activities of antioxidant enzyme related genes, the secondary metabolism genes and defense response genes were down-regulated. The analysis also illustrated that UV-B stress could affect several biological pathways related to biotic and abiotic stress (Chen, Feng et al., 2014). Virus-induced gene silencing (VIGS) is a power approach for conducting loss of function assays to study gene function in plants. VIGS has shown that there is a difference in silencing efficiency due to genetic background. *L. ruthenicum* was found to be more susceptible than *L. barbarum*. Additionally, TRV-based VIGS could be used to silence endogenous genes of the related *L. barbarum* and *L. ruthenicum* (Liu, Sun et al., 2014; Liu, Zeng et al., 2014).

3. Phytochemistry

Lycium typically produces many seeds, yellow to red (sometimes black), fleshy berries (Levin & Miller, 2005). The compounds found in berry fruits mainly include carotenoids, vitamin C and phenolic compounds such as anthocyanins, phenolic acids, stilbenes, and flavonols (Szajdek & Borowska, 2008; Toyoda-Ono et al., 2004). *L. ruthenicum* mainly grows in the salinized desert of northeast of China, it has black berries that are used as a nutritional food and folk medicine. Chemical composition research illustrated that the compounds in *L. ruthenicum* include flavonoids (Wu, Lv, Wang, & Wang, 2016; Zhang, Chen, Zhao, & Xi, 2016; Zhao, Xu, Ji, & Li, 2014), anthocyanins (Jin, Liu, Yang et al., 2015; Jin, Liu, Guo et al., 2015; Jin, Zhao et al., 2015; Tian et al., 2016; Wu et al., 2016; Zhao et al., 2014; Zheng et al., 2011), polysaccharides (Lv et al., 2013; Peng, Xu, Yin, Huang, & Du, 2013; Peng, Lv et al., 2012; Peng, Song et al., 2012), phenolic acids (Wu et al., 2016; Zhang et al., 2016; Zhao et al., 2014), carotenoids (Peng et al., 2005; Zhang et al., 2016), alkaloids (Jin, Zhao et al., 2015; Wu et al., 2016; Zhao et al., 2014), essential oils (Altintas, Kosar, Kirimer, Baser, & Demirci, 2006), and fatty acids (Chi, Xiao, Dong, Yang, & Hu, 2016).

3.1. Flavonoids

The total flavonoid (TF) is significant differences between gouji genotypes. The TF levels ranged from 36.1 to 54.7 mg rutin equivalents (RE)/g fresh weight (FW). *L. barbarum* (Ningji No.1) has the highest levels (54.7 ± 3.2 mg RE/g FW), while *L. ruthenicum* has the lowest (36.1 ± 2.8 mg RE/g FW). *L. barbarum* (Baihua) (48.2 ± 5.3 mg RE/g FW), *L. chinese* (45.3 ± 2.6 mg RE/g FW), *L. yunnanense* (43.9 ± 2.9 mg RE/g FW), *L. barbarum* (42.6 ± 4.3 mg RE/g FW) has significantly higher TF contents than *L. barbarum* var. auranticarpum (38.5 ± 3.8 mg RE/g FW), *L. chinese* var. potaninii (37.2 ± 3.5 mg RE/g FW) (Zhang et al., 2016). Forty-six flavonoids, include thirty-seven anthocyanins, were isolated and identified in the fruits of *L. ruthenicum* (Table 1). Quercetin-rhamno-di-hexoside (934.3 ± 87.7 μg/g FW) is the most abundant flavonoid (Zhang et al., 2016). Anthocyanins, a class of flavonoids, are widespread in *L. ruthenicum* fruits (Jin, Liu et al., 2015).

3.1.1. Anthocyanins

Anthocyanins, natural pigments found in plants, are responsible for brilliant colors (red, blue and purple) (Zhao et al., 2014). So colors are changed along with plasma treatment influences on anthocyanins stability, such as in cloudy pomegranate juice (Bursać et al., 2016) and chokeberry juice (Kovačević et al., 2016). Anthocyanins have been widely used in the fields of medicine, cosmetics and natural food coloring. Research has shown that *L. ruthenicum* fruits, which are black, contain abundant, and they are the main active ingredients in this species. And anthocyanins contents in dried *L. ruthenicum* from different origins are different (Tian et al., 2016). These anthocyanins have attracted great interest from many researchers. Researchers have isolated and identified 37 anthocyanins from *L. ruthenicum* fruits (Table 1), including derivatives of peonidin, petundin, pelargonidin, cyanidin, malvidin, and delphinidin (Jin, Liu, Yang et al., 2015; Jin, Liu, Guo et al., 2015; Jin, Zhao et al., 2015; Tian et al., 2016; Wu et al., 2016; Zhao et al., 2014; Zheng et al., 2011). There are many *cis-trans* isomeric anthocyanins in the fruits (Jin, Liu, Yang et al., 2015). Petunidin

Table 1
The identified compound of L. *ruthenicum*.

No.	Chemical compound	Molecular formula	Classes	References
1	Peonidin3-O-[6-O-(4-O-E-p-coumaroyl-O-α -rhamnopyranosyl)-β-glucopyranoside]-5-O-β -glucopyranoside	$C_{43}H_{48}O_{22}^{+}$	anthocyanin	Zhao et al. (2014)
2	peonidin3-O-[6-O-(4-O-E-p-coumaroyl-O-α -rhamnopyranosyl)-β-glucopyranoside]-5-O-β -glucopyranoside	$C_{43}H_{48}O_{23}^{+}$	anthocyanin	Zhao et al. (2014)
3	Petundin-3-O-galactoside-5-O-glucoside	$C_{28}H_{33}O_{16}^{+}$	anthocyanin	Tian et al. (2016), Zheng et al. (2011)
4	Petundin-3-O-glucoside-5-O-glucoside	$C_{28}H_{33}O_{17}^{+}$	anthocyanin	Tian et al. (2016), Zheng et al. (2011)
5	Pentunidin-3-O-rutinoside (cis-p-coumaroyl)-5-O-glucoside	$C_{43}H_{37}O_{23}^{+}$	anthocyanin	Jin et al. (2015a), Tian et al. (2016), Zheng et al. (2011)
6	Petunidin-3-O-rutinoside(glucosyl-cis-p-coumaroyl)-5-O-glucoside	$C_{49}H_{53}O_{28}^{+}$	anthocyanin	Jin et al. (2015a), Zheng et al. (2011)
7	Pentunidin-3-O-rutinoside (trans-p-coumaroyl)-5-O-glucoside	$C_{43}H_{37}O_{23}^{+}$	anthocyanin	Jin et al. (2015a), Tian et al. (2016), Zheng et al. (2011)
8	Petunidin-3-O-rutinoside(glucosyl-trans-p-coumaroyl)-5-O-glucoside	$C_{49}H_{53}O_{28}^{+}$	anthocyanin	Jin et al. (2015a), Zheng et al. (2011)
9	Petunidin-3-O-rutinoside(caffeoyl)-5-O-glucoside	$C_{43}H_{37}O_{24}^{+}$	anthocyanin	Jin et al. (2015a), Tian et al. (2016), Zheng et al. (2011)
10	Petunidin-3-O-rutinoside-5-O-glucoside	$C_{34}H_{43}O_{21}^{+}$		
11	Pentunidin-3-O-glucoside (maloyl)-5-O-glucoside	$C_{31}H_{35}O_{19}^{+}$	anthocyanin	Tian et al. (2016), Zheng et al. (2011)
12	Pentunidin-3-O-glucoside (feruloyl)-5-O-glucoside	$C_{38}H_{41}O_{20}^{+}$	anthocyanin	Zheng et al. (2011)
13	Petunidin-3-O-rutinoside(feruloyl)-5-O-glucoside	$C_{44}H_{51}O_{24}^{+}$	anthocyanin	Jin et al. (2015a), Tian et al. (2016)
14	Pentunidin-3-O-[6-O-(4-O-(4-O-cis-(β-D-glucopyranoside)-p-coumaroyl)-α-L-rhamnopyranosyl)-β-D-glucopyranoside]-5-O-[β-D-glucopyranoside]	$C_{49}H_{59}O_{28}^{+}$	anthocyanin	Jin et al. (2015b), Wu et al. (2016)
15	Pentunidin-3-O-[6-O-(4-O-(4-O-trans-(β-D-glucopyranoside)-p-coumaroyl)-α-L-rhamnopyranosyl)-β-D-glucopyranoside]-5-O-[β-D-glucopyranoside]	$C_{49}H_{59}O_{28}^{+}$	anthocyanin	Jin et al. (2015b), Wu et al. (2016)
16	petunidin3-O-[6-O-(4-O-(cis-pcoumaroyl)-α-L-rhamnopyranosyl)-β-D-glucopyranoside]-5-O-[β-D-glucopyranoside]	$C_{43}H_{49}O_{23}^{+}$	anthocyanin	Jin et al. (2015b), Wu et al. (2016)
17	petunidin3-O-[6-O-(4-O-(transp-coumaroyl)-α-L-rhamnopyranosyl)-β-D-glucopyranoside]-5-O-[β-D-glucopyranoside]	$C_{43}H_{49}O_{23}^{+}$	anthocyanin	Jin et al. (2015b), Wu et al. (2016)
18	petunidin3-O-[6-O-(4-O-(trans-p-caffeoyl)-α-L-rhamnopyranosyl)-β-D-glucopyranoside]-5-O-[β-D-glucopyranoside]	$C_{43}H_{49}O_{24}^{+}$	anthocyanin	Jin et al. (2015b), Wu et al. (2016)
19	petunidin-3-O-[6-O-α-L-rhamnopyranosyl-β-D-glucopyranoside]-5-O-[β-D-glucopyranoside]	$C_{34}H_{43}O_{21}^{+}$	anthocyanin	Jin et al. (2015c)
20	Pelargonidin -3-O-galactoside	$C_{21}H_{21}O_{10}^{+}$	anthocyanin	Tian et al. (2016)
21	Pelargonidin-3-O-diglucoside	$C_{27}H_{30}O_{14}^{+}$	anthocyanin	Tian et al. (2016)
22	Pelargonidin-3-O-glucoside	$C_{21}H_{21}O_{10}^{+}$	anthocyanin	Tian et al. (2016)
23	Cyanidin -3-O-galactoside	$C_{21}H_{21}O_{11}^{+}$	anthocyanin	Tian et al. (2016)
24	Cyanidin -3, 5-O-diglucoside	$C_{27}H_{31}O_{16}^{+}$	anthocyanin	Tian et al. (2016)
25	Cyanidin -3-O-glucoside	$C_{21}H_{21}O_{11}^{+}$	anthocyanin	Tian et al. (2016)
26	Malvidin	$C_{17}H_{15}O_{7}^{+}$	anthocyanin	Zhao et al. (2014)
27	Malvidin-3-O-rutinoside (cis-p-coumaroyl)-5-O-glucoside	$C_{44}H_{51}O_{23}^{+}$	anthocyanin	Jin et al. (2015a), Tian et al. (2016), Zheng et al. (2011)
28	Malvidin-3-O-rutinoside(glucosyl-cis-p-coumaroyl)-5-O-glucoside	$C_{50}H_{61}O_{28}^{+}$	anthocyanin	Jin et al. (2015a)
29	Malvidin-3-O-rutinoside(trans-p-coumaroyl)-5-O-glucoside	$C_{44}H_{51}O_{23}^{+}$	anthocyanin	Jin et al. (2015a)
30	Malvidin-3-O-rutinoside (p-coumaroyl)-5-O-glucoside	$C_{44}H_{51}O_{23}^{+}$	anthocyanin	Wu et al. (2016)
31	Malvidin-3-O-rutinoside-5-O-glucoside	$C_{35}H_{45}O_{21}^{+}$	anthocyanin	Jin et al. (2015a)
32	Malvidin-3-O-rutinoside(glucosyl-trans-p-coumaroyl)-5-O-glucoside	$C_{50}H_{61}O_{28}^{+}$	anthocyanin	Jin et al. (2015a)
33	Malvidin-3-O-rutinoside(feruloyl)-5-O-glucoside	$C_{45}H_{53}O_{24}^{+}$	anthocyanin	Jin et al. (2015a), Tian et al. (2016)
34	Delphinidin3-O-[6-O-(4-O-(trans-p-coumaroyl)-α-L-rhamnopyranosyl)-β-D-glucopyranoside]-5-O-[β-D-glucopyranoside]	$C_{42}H_{47}O_{23}^{+}$	anthocyanin	Jin et al. (2015b), Wu et al. (2016)
35	Delphinidin-3-O-rutinoside (cis-p-coumaroyl)-5-O-glucoside	$C_{42}H_{47}O_{23}^{+}$	anthocyanin	Jin et al. (2015a), Tian et al. (2016), Zheng et al. (2011)
36	Delphinidin-3-O-rutinoside (trans-p-coumaroyl)-5-O-glucoside	$C_{42}H_{47}O_{23}^{+}$	anthocyanin	Tian et al. (2016), Zheng et al. (2011)
37	Delphinidin-3-O-rutinoside(glucosyl-trans-p-coumaroyl)-5-O-glucoside	$C_{48}H_{57}O_{28}^{+}$	anthocyanin	Jin et al. (2015a)
38	Delphinidin -3-O-(6′-p-coumaryl) - glucoside	$C_{30}H_{27}O_{14}^{+}$	anthocyanin	Tian et al. (2016)
39	Protocatechuic acid	$C_7H_6O_4$	phenolic acid	Zhao et al. (2014)
40	Ferulic acid	$C_{10}H_{10}O_4$	phenolic acid	Zhao et al. (2014), Zhang et al. (2016)
41	p-coumarinic acid	$C_9H_8O_3$	phenolic acid	Zhao et al. (2014), Zhang et al. (2016)
42	Caffeic acid	$C_9H_8O_4$	phenolic acid	Zhang et al. (2016)
43	Vanillic acid	$C_8H_8O_4$	phenolic acid	Zhang et al. (2016)
44	Chlorogenic acid	$C_{16}H_{18}O_9$	phenolic acid	Zhang et al. (2016)
45	4-Caffeiclquinic acid	$C_{16}H_{18}O_9$	phenolic acid	Nzeuwa et al. (2017)
46	1,3-Dicaffeoylquinic acid	$C_{22}H_{28}O_{14}$	phenolic acid	Nzeuwa et al. (2017)
47	3,4-di-O-caffeoylquinic acid	$C_{25}H_{24}O_{12}$	phenolic acid	Wu et al. (2016)
48	3,5-di-O-caffeoylquinic acid	$C_{25}H_{24}O_{12}$	phenolic acid	Wu et al. (2016)
49	4,5-di-O-caffeoylquinic acid	$C_{25}H_{24}O_{12}$	phenolic acid	Wu et al. (2016)
50	trans-neochlorogenic acid	$C_{16}H_{18}O_9$	phenolic acid	Wu et al. (2016)
51	trans-chlorogenic acid	$C_{16}H_{18}O_9$	phenolic acid	Wu et al. (2016)
52	trans-crypto-chlorogenic acid	$C_{16}H_{18}O_9$	phenolic acid	Wu et al. (2016)
53	Rutin	$C_{27}H_{30}O_{16}$	flavonoid	Zhao et al. (2014), Zhang et al. (2016)
54	Quercetin	$C_{15}H_{10}O_7$	flavonoid	Zhao et al. (2014), Zhang et al. (2016)
55	Myricetin	$C_{15}H_{10}O_8$	flavonoid	Zhang et al. (2016)
56	Kaempferol	$C_{15}H_{10}O_6$	flavonoid	Zhang et al. (2016)
57	Quercetin-rhamnosid-dihexoside	$C_{33}H_{45}O_{13}$	flavonoid	Zhang et al. (2016)

(continued on next page)

Table 1 *(continued)*

No.	Chemical compound	Molecular formula	Classes	References
58	Quercetin-3-O-rutinoside	$C_{27}H_{30}O_{16}$	flavonoid	Zhang et al. (2016), Wu et al. (2016)
59	Quercetin-3-Oquercetin-3-Orutinoside-hexose	$C_{33}H_{40}O_{21}$	flavonoid	Wu et al. (2016)
60	Kaempferol-3-O-rutinoside	$C_{27}H_{30}O_{15}$	flavonoid	Wu et al. (2016)
61	isorhamnetin-3-O-rutinoside	$C_{28}H_{32}O_{16}$	flavonoid	Wu et al. (2016)
62	Lutein	$C_{40}H_{56}O_2$	carotenoid	Zhang et al. (2016)
63	β-Cryptoxanthin	$C_{40}H_{56}O$	carotenoid	Zhang et al. (2016)
64	Zeaxanthin	$C_{40}H_{56}O_2$	carotenoid	Zhang et al. (2016)
65	Neoxanthin	$C_{40}H_{56}O_4$	carotenoid	Zhang et al. (2016)
66	β-Carotene	$C_{40}H_{56}$	carotenoid	Zhang et al. (2016)
67	Zeaxanthin Dipalmitate	$C_{72}H_{116}O_4$	carotenoid	Peng et al. (2005)
68	N,N-bis(dihydrocaffeoyl) spermine	$C_{28}H_{42}N_4O_6$	alkaloids	Wu et al. (2016)
69	N,N-bis(dihydrocaffeoyl) spermidine hexoside	$C_{31}H_{45}N_3O_{11}$	alkaloids	Wu et al. (2016)
70	(dihydrocaffeoyl) caffeoyl spermidine hexoside	$C_{31}H_{43}N_3O_{11}$	alkaloids	Wu et al. (2016)
71	N,N-dicaffeoyl-spermidine	$C_{25}H_{31}N_3O_6$	alkaloids	Wu et al. (2016)
72	Caffeoyl (dihydrocaffeoyl) spermidine isomers	$C_{25}H_{33}N_3O_6$	alkaloids	Wu et al. (2016)
73	N-Caffeoylspermidine	$C_{16}H_{25}N_3O_3$	alkaloids	Nzeuwa et al. (2017)
74	tris-(Dihydrocaffeoyl) spermine	$C_{37}H_{48}N_4O_9$	alkaloids	Nzeuwa et al. (2017)
75	N^1,N^{14}-bis-(Dihydrocaffeoyl) spermine	$C_{28}H_{43}N_4O_6$	alkaloids	Nzeuwa et al. (2017)
76	N-Caffeoyl, N'-dihydrocaffeoyl spermidine dihexose	$C_{37}H_{53}N_3O_{16}$	alkaloids	Nzeuwa et al. (2017)
77	N^1,N^{10}-bis-(Caffeoyl) spermidine dihexose	$C_{40}H_{49}N_4O_{13}$	alkaloids	Nzeuwa et al. (2017)
78	N^1,N^{10}-bis-(Caffeoyl) spermidine hexose	$C_{31}H_{43}N_3O_{11}$	alkaloids	Nzeuwa et al. (2017)
79	N^1-Caffeoyl, N^{10}-dihydrocaffeoyl spermidine hexose	$C_{31}H_{43}N_3O_{11}$	alkaloids	Nzeuwa et al. (2017)
80	N^1-Dihydrocaffeoyl, N^{10}-caffeoyl spermidine	$C_{25}H_{33}N_3O_6$	alkaloids	Nzeuwa et al. (2017)
81	N-Feruloylagmatine	$C_{15}H_{22}N_4O_3$	alkaloids	Nzeuwa et al. (2017)
82	N^1-Caffeoyl, N^{10}-dihydrocaffeoyl spermidine	$C_{25}H_{33}N_3O_6$	alkaloids	Nzeuwa et al. (2017)
83	N,N'-bis-(Caffeoyl) spermidine isomer	$C_{25}H_{33}N_3O_6$	alkaloids	Nzeuwa et al. (2017)
84	Ampelopsin glucoside	$C_{19}H_{20}N_3O_{12}$	alkaloids	Nzeuwa et al. (2017)
85	N^1-Dihydrocaffeoyl, N^{10}-coumaroyl spermidine	$C_{25}H_{33}N_3O_5$	alkaloids	Nzeuwa et al. (2017)
86	7′-O-[β-D-glucopyranose]-N^1,N^{10}-didihydrocaffeoylspermidine	$C_{31}H_{45}N_3O_{11}$	alkaloids	Jin et al. (2015c)
87	7″-O-[β-D-glucopyranose]-N^1-dihydrocaffeoyl-N^3-caffeoyspermidine	$C_{31}H_{44}N_3O_{11}$	alkaloids	Jin et al. (2015c)
88	7′-O-[β-D-glucopyranose]-7″-O-[β-D-glucopyranose]-N^1-dihydrocaffeoyl-N^3-caffeoyspermidine	$C_{37}H_{53}N_3O_{16}$	alkaloids	Jin et al. (2015c)
89	Lyrium spermidine A	$C_{28}H_37N_3O_8$	alkaloids	Zhao et al. (2014)
90	N^1-caffeoyl-N^3-dihydrocaffeoyl spermidine	$C_{25}H_{33}N_3O_6$	alkaloids	Zhao et al. (2014)
91	N-monocinnamoyl-putrescine	$C_{13}H_{18}N_2O$	alkaloids	Zhao et al. (2014)
92	Hexadecane	$C_{16}H_{34}$	essential oil	Altintas et al. (2006)
93	Heptacosane	$C_{27}H_{56}$	essential oil	Altintas et al. (2006)
94	Ethyl hexadecanoate	$C_{18}H_{36}O_2$	essential oil	Altintas et al. (2006)
95	(*E*,*E*)-2,4-Decadienal	$C_{10}H_{16}O$	essential oil	Altintas et al. (2006)
96	(*E*)-Geranylacetone	$C_{13}H_{22}O$	essential oil	Altintas et al. (2006)
97	Hexahydrofarnesyl acetone	$C_{18}H_{36}O$	essential oil	Altintas et al. (2006)
98	Docosane	$C_{22}H_{46}$	essential oil	Altintas et al. (2006)
99	Methyl hexadecanoate	$C_{17}H_{34}O_2$	essential oil	Altintas et al. (2006)
100	Tricosane	$C_{23}H_{48}$	essential oil	Altintas et al. (2006)
101	Farnesylacetone	$C_{18}H_{30}O$	essential oil	Altintas et al. (2006)
102	Tetracosane	$C_{24}H_{50}$	essential oil	Altintas et al. (2006)
103	Methyl linoleate	$C_{19}H_{34}O_2$	essential oil	Altintas et al. (2006)
104	Ethyl linoleate	$C_{20}H_{36}O_2$	essential oil	Altintas et al. (2006)
105	Hexacosane	$C_{26}H_{54}$	essential oil	Altintas et al. (2006)
106	Phytol	$C_{20}H_{40}O$	essential oil	Altintas et al. (2006)
107	Octacosane	$C_{28}H_{58}$	essential oil	Altintas et al. (2006)
108	Nonacosane	$C_{29}H_{60}$	essential oil	Altintas et al. (2006)
109	Heneicosane	$C_{21}H_{44}$	essential oil	Altintas et al. (2006)
110	Linoleic acid	$C_{18}H_{32}O_2$	fatty acids	Chi et al. (2016)
111	Pentadecenoic acid	$C_{15}H_{28}O_2$	fatty acids	Chi et al. (2016)
112	Palmitoleic acid	$C_{16}H_{30}O_2$	fatty acids	Chi et al. (2016)
113	Oleic acid	$C_{18}H_{34}O_2$	fatty acids	Chi et al. (2016)
114	Stearic acid	$C_{18}H_{36}O_2$	fatty acids	Chi et al. (2016)
115	Arachidic acid	$C_{20}H_{40}O_2$	fatty acids	Chi et al. (2016)
116	Myristic acid	$C_{14}H_{28}O_2$	fatty acids	Chi et al. (2016)
117	tetracosanoic acid	$C_{41}H_{82}O_2$	fatty acids	Chi et al. (2016)

derivatives account for 95% of the total anthocyanins in the fresh fruit (Zheng et al., 2011), and most of them are 3,5-diglycoside derivatives with acylated phenolic acids such as coumaric acid and caffeic acid. Petunidin 3-O-[6-O-(4-O-(trans-p-coumaroyl)-α-L-rhamnopyranosyl)-β-D-glucopyranoside]-5-O-[β-Dglucopyranoside] exhibit higher scavenging activities against 2,2′-azinobis(3-ethylbenzothiazoline-6-sulphonic acid), 1,1-diphenyl-2-picrylhydrazyl and superoxide radicals than the crude extract of anthocyanins. It is also demonstrated to have potential cytoprotective effect on hydrogen peroxide-induced intracellular reactive oxygen damage in neuronlike rat pheochromocytoma line cells by promoting cell proliferation, mitigating lipid peroxidation and regulating endogenous antioxidant enzymes (glutathione peroxidase, superoxide dismutase and catalase) (Tang et al., 2017). In addition, delphinidin-derived anthocyanins accumulate in *L. ruthenicum* fruits but not in *L. barbarum* fruits. In *L. barbarum* fruits, no anthocyanins were detected at any stage of the fruit development. Anthocyanin accumulation varies during fruit development. It accumulates during fruit ripening and sharply increases at full maturity in *L. ruthenicum* (Zeng, Wu et al., 2014). In comparison to fresh, cyaniding derivatives were only found in dried fruits of *L. ruthenicum*, and most anthocyanins in fresh

Table 2
Anthocyanins of dried or fresh fruits of *L. ruthenicum* (Tian et al., 2016).

Anthocyanins of dried fruits	Anthocyanins of fresh fruits
Pelargonidin-3-O-galactoside	Petundin-3-O-galactoside-5-O-glucoside
Pelargonidin-3-O-diglucoside	Petundin-3-O-glucoside-5-O-glucoside
Cyanidin-3-O-galactoside	Delphinidin-3-O-rutinoside(cis-p-coumaroyl)-5-O-glucoside
Cyanidin-3, 5-O-diglucoside	Delphinidin-3-O-rutinoside(trans-p-coumaroyl)-5-O-glucoside
Cyanidin -3-O-glucoside	Petunidin-3-O-rutinoside (caffeoyl)-5-O-glucoside
Pelargonidin -3-O-glucoside	Petunidin-3-O-rutinoside (cis-p-coumaroyl)-5-O-glucoside
Delphinidin -3-O-(6′-p-coumaryl)-glucoside	Petunidin-3-O-rutinoside(trans-p-coumaroyl)-5-O-glucoside
Petunidin-3-O-rutinoside(trans-p-coumaroyl) -5-O-glucoside or Petunidin-3-O-rutinoside(trans-p-coumaroyl) -5-O-glucoside	Petundin-3-O-glucoside (maloyl)-5-O-glucoside
	Petunidin-3-O-rutinoside (feruloyl)-5-O-glucoside
	Malvidin-3-O-rutinoside (cis-p-coumaroyl)-5-O-glucoside

fruits have the structure of 5-O-glucoside (Table 2) (Tian et al., 2016). In addition, anthocyanins are not stable. Cultivar, cultivation and processing could influence on anthocyanin content (Kovačević et al., 2015). Solvent concentration, pressure and temperature could influence anthocyanins extraction yield (Putnik et al., 2017). Acidic solutions (pH 1–3) provide favorable conditions for maintaining the structure of anthocyanins, and acylated anthocyanins are more stable than non-acylated anthocyanins based on photostability and thermostability tests (Hu et al., 2014).

HR-ESI-MS, NMR, Semipreparative HPLC, HPLC-DAD, HPLC-DAD-ESI-MS, and MS methods were used to detect, isolate and identify anthocyanins in *L. ruthenicum*, and HPLC with an XCharge C8SAX column is an effective method for preparing of *cis-trans* isomeric anthocyanins from *L. ruthenicum*, and the ultraviolet–visible spectra of two pairs of *cis-trans* anthocyanin isomers provide important information for the identification of the isomers (Jin, Liu, Yang et al., 2015; Jin, Liu, Guo et al., 2015; Jin, Zhao et al., 2015; Tian et al., 2016; Wu et al., 2016; Zhao et al., 2014; Zheng et al., 2011).

3.2. Polysaccharides

Polysaccharides extracted from *L. ruthenicum* fruit form a dark brown powder. The polysaccharide content in this species is higher (10.3% of the dry fruit weight) than in the other three traditional Tibetan medicinal plants *Hippophae rhamnoides* L., *L. barbarum* L., and *Nitraria tangutorum* Bobr. (Ni et al., 2013). The total *L. ruthenicum* polysaccharide (LRP) content was 56.1 ± 3.1 mg/g fresh weight (FW) (Zhang et al., 2016). Chemical analysis of crude *L. ruthenicum* polysaccharide (CLRP) isolated from the fruits of *L. ruthenicum* illustrated that decolored CLRP contained 93.2% carbohydrate and contained 4.4% protein, and it was composed of 68.7% neutral sugar and 24.5% acid sugar. The polysaccharide components were glucan and rhamnogalacturonan I, according to the monosaccharide composition and the ratios of Rha/GaIUA. The monosaccharide composition of the CLRP was as follows: arabinose (40.7%), galacturonic acid (26.4%), galactose (18.9%), xylose (5.1%), rhamnose (4.9%), glucose (2.7%), and mannose (1.3%). Five glycoconjugates, LRP1, LRP2, LRP3, LRP4, and LRP5, were isolated from the purified CLRP of *L. ruthenicum*. The molecular weight of LRP1 was 56.2 KDa, and its yield was 0.003% of the crude herb. The monosaccharides of LRP1 were arabinose (45.1%), galactose (43.8%), glucose (4.2%), mannose (2.8%), rhamnose (2.7%), and xylose (1.4%). LRP1 was characterized as a branched polysaccharide rich in arabinose and galactose, with a backbone composed of (1 → 3)-linked galactose. The branches were composed of (1 → 5)-linked arabinose, (1 → 2)-linked arabinose, (1 → 6)-linked galactose, (1 → 3)-linked galactose, (1 → 4)-linked galactose, and (1 → 2,4)-linked rhamnose. Arabinose, xylose, mannose, and glucose were located at the terminal of the branches (Ni et al., 2013; Peng, Lv et al., 2012). The molecular weight of LRP3 was 75.6 KDa, and its yield was 0.008% of the crude herb. LRP3 contained 97.2% total carbohydrate and 1.7% protein. The monosaccharides of LRP3 were arabinose (56.6%), galactose (39.6%), and rhamnose (3.8%). LRP3 was characterized as a highly branched polysaccharide with a backbone composed of (1 → 3)-linked β-D-galactopyranosyl residues, many of which were substituted at the O-6 position by galactosyl or arabinosyl groups. The branches were composed of (1 → 5)-linked arabinose, (1 → 2)-linked arabinose, (1 → 6)-linked galactose, (1 → 3)-linked galactose, (1 → 4)-linked galactose, and (1 → 2,4)-linked rhamnose, and the major nonreducing termini were α-L-arabinofuranosyl residues (Peng, Song et al., 2012). The molecular weight of LRP4-A was 105 KDa, and its yield was 0.19% of the crude herb. LRP4-A contained 95.7% total carbohydrate and 1.4% protein. The monosaccharides of LRP4-A were arabinose (42.9%), galactose (48.6%), glucose (5.7%) and rhamnose (2.8%). LRP4-A was characterized as a highly branched polysaccharide with a backbone of β-(1 → 6)-linked galactose partially substituted at the O-3 position. The branches were composed of (1 → 3)-linked galactose, (1 → 3)-linked arabinose, (1 → 5)-linked arabinose, and (1 → 2,4)-linked rhamnose. Arabinose, galactose, and glucose were located at the termini of the branches (Lv et al., 2013). The molecular weight of LRP5 was 137 KDa, and its yield was 0.086% of the crude herb. LRP5 contained 97.5% and 2.3% protein. The monosaccharides of LRP4-A were arabinose (23.3%), galactose (12.3%), xylose (5.3%) and galacturonic acid (48.7%). The high level of galacturonic acid indicated that LCRP5 was pectin. For the protein part of LRP5, the amino acid composition was glycine (14.2%), glutamic acid (12.6%), aspartic acid (11.6%), serine (9.3%), proline (8.4%), alanine (7.5%), threonine (7.1%), hydroxyproline (4.7%), leucine (4.7%), valine (4.3%), isoleucine (3.8%), arginine (3.5%), lysine (3.2%), phenlalanine (3.1%), tyrosine (1.4%), and histidine (0.6%). LRP5 consisted of a (1 → 4)-linked galacturonic acid backbone occasionally interrupted by (1 → 2)-linked rhamnose. The side chains were attached to position 4 of the rhamnosyl units, including (1 → 3)-linked arabinose, (1 → 3)-linked galactose, (1 → 3,6)-linked galactose, (1 → 4)-linked galacturonic acid, (1 → 2)-linked rhamnose and (1 → 2,4)-linked rhamnose, and the termini were arabinose and rhamnose (Peng, Liu, Shi, & Li, 2014).

3.3. Phenolic acids

Phenolics are the most abundant secondary metabolites in plants. The main phenolics in goji berries are phenolic acids and flavonoids (Szajdek & Borowska, 2008). And the most abundant phenolic compound in *L. ruthenicum* is kukoamine A (Nzeuwa et al., 2017). The total phenolic content was 26.9 ± 4.5 mg GAE/g FW and 49.06 ± 6.06 mg GAE/g dry weight (DW), and chlorogenic acid (112.5 ± 8.4 μg/g FW) was the most abundant phenolic acid (Wu et al., 2016; Zhang et al., 2016). Fourteen phenolic acids were isolated and identified in the fruits of *L. ruthenicum* (Table 1). The total phenolic content was 36.1 ± 2.8 mg GAE/g FW (Wu et al., 2016; Zhang et al., 2016).

3.4. Carotenoids

Carotenoids are biologically active compounds (Kim et al., 2002). *L. barbarum* has high levels of carotenoids than *L. ruthenicum*. And the failure of the chromoplast development in *L. ruthenicum* causes low carotenoids biosynthesis levels and continuous carotenoid degradation (Liu, Sun et al., 2014; Liu, Zeng et al., 2014). The total carotenoid content in *L. ruthenicum* was 0.084% (Peng et al., 2005) or 0.40 ± 0.05 mg GAE/g FW (Zhang et al., 2016). Zeaxanthin (0.031% or 17.01 ± 0.2 μg/g FW) is the predominant carotenoid in *L. ruthenicum* fruits (Peng et al., 2005; Zhang et al., 2016). Six carotenoids were isolated and identified in the fruits of *L. ruthenicum* (Table 1).

3.5. Alkaloids

Twenty-four alkaloids, a group of hydroxycinnamic acid amides, were isolated and identified in the fruits of *L. ruthenicum* (Table 1). It was reported that hydroxycinnamic acid amides are involved in the defense of plants against pathogens (Muroi et al., 2009).

3.6. Essential oils

A total of eighteen water-distilled essential oils were isolated and identified in the fruits of *L. ruthenicum* (Table 1). The essential oil composition was as follows: heptacosane (14.3%), ethyl linoleate (10.0%), hexacosane (7.0%), nonacosane (6.2%), ethyl hexadecanoate (5.8%), methyl linoleate (5.6%), octacosane (5.2%), farnesylacetone (4.6%), methyl hexacecanoate (4.5%), tetracosane (3.9%), phytol (3.0%), hexahydrofarnesylacetone (2.7%), tricosane (2.5%), docosane (1.5%), (E)-geranylacetone (1.1%), heneicosane (0.9%), (E,E)-2,4-decadienal (0.8%), and hexadecane (0.8%). This differs from the oil composition in *L. barbarum*. In *L. barbarum* fruits, the main oils were found to be hexadecanoic acid (47.5%), linoleic acid (9.1%), β-element (5.4%), myristic acid (4.2%), and ethyl hexadecanoate (4.0%) (Altintas et al., 2006).

3.7. Fatty acids

The fruit and seed crude oil of *L. ruthenicum* includes saturated, monounsaturated and polyunsaturated fatty acids. The identified fatty acids are shown in Table 1. Linoleic, oleic, and palmitic acid are the main components of both oils. They are the major saturated, monounsaturated, and polyunsaturated fatty acids, respectively. In addition, pentadecanoic acid exists only in the fruit oil of *L. ruthenicum* (Chi et al., 2016).

4. Pharmacology

L. ruthenicum is a species used for medicine and food. It is used for the treatment of heart disease, abnormal menstruation, menopause, urethral and ureteral stones, tinea and furuncle, and gingival bleeding (Dierma & Mao, 2012; Liu, 1999; Yutuo, 1987). These traditional uses are based on experience, without an understanding of biological mechanism. A series of modern pharmacological studies have been carried out to elucidate the correlation between bioactive components and pharmacological action.

Fruit of *L. ruthenicum* contain anthocyanins, which are a type of flavonoids. Two thirds of daily intake of polyphenolics comes from flavonoids. Polyphenols could have anti-thrombotic effects and could reduce cardiovascular disease by preventing oxidative stress (Loffredo, Perri, Nocella, & Violi, 2017; Santhakumar, Bulmer, & Singh, 2014). The polyphenols in *L. ruthenicum* fruit have antioxidant activity, and there is a positive correlation between total polyphenols and DPPH, and ABTS (Zheng et al., 2011). The structures of anthocyanins also influence their antioxidant activity. Hydroxylation and anthocyanins increase their antioxidant activity (Hu et al., 2014). In addition, *L. ruthenicum* fruit extracts could inhabit reactive oxygen species in cells and may have the ability to scavenge free radicals based on a Caco-2 cell model with microscopic fluorometric imaging (Wu et al., 2016). The extracts also protect LLC-PK 1 cells, which are derived from pig kidney, against 2,2′-azobis (2-amidinopropane) dihydrochloride-induced oxidative damage by reducing reactive oxygen species, decreasing lipid peroxidation, increasing the levels of endogenous intercellular glutathione, and up-regulating antioxidant enzymes (Song, Gao, & Xu, 2014). Regarding the capacity for scavenging free radicals by DPPH, *L. ruthenicum* fruit extracts with n-butanol or 70% ethanol show a strong ability to scavenge free radicals, stronger than *L. barbarum* fruit extracts (Kosar, Altintas, Kirimer, & Baser, 2003). Anthocyanins extracted from *L. ruthenicum* may cure diabetic cardiomyopathy by alleviating oxidative stress, myocardial fibrosis, cardiac dysfunction, and cell apoptosis (Xue, Liu, Zhu, Niu, & Jing, 2014).

Polysaccharides are other bioactive compounds found in *L. ruthenicum* fruit. Water extracted polysaccharides have anti-fatigue activities according to a forced swim test. The mechanism is thought to involve the modification of several enzyme activities to prevent lipid oxidation, and this result in protection of the corpuscular membrane (Ni et al., 2013). LRGP3 has immuno-enhancement effects compared with a cyclophosphamide-treated group, the LTGP3-treated group showed accelerated spleen and thymus recovery, enhanced proliferation responses of the T cells and B cells, and increased peritoneal macrophage phagocytosis. It could also restore the levels of interleukin-2, interleukin-6, and tumor necrosis factor-α in the serum of cyclophosphamide-treated (Gong et al., 2015). The inflammatory reaction of LRGP3 induced by lipopolysaccharide was investigated. The results showed that LRGP3 inhibits the TLR4/NF-$_{K}$B signaling pathway to alleviate lipopolysaccharide-induced inflammation (Peng et al., 2014). Additionally, polysaccharides of *L. ruthenicum* fruit have antioxidant activities that were investigated by DPPH, hydrogen peroxide, and superoxide anion free radicals (Liu et al., 2013).

In addition, *L. ruthenicum* extract has an anti-radiation effect, as determined by testing for radiation injury in mice (Duan et al., 2015), and it has an anti-aging effect that was revealed by subcutaneously injecting mice with D-galactose (Tian et al., 2015). The extract could also suppress lipid accumulation in C57BL/6 mice that were fed a high-fat diet, and it could alleviate high-fat-induced non-alcoholic fatty liver disease by enhancing the anti-phosphory-lated (p) adenosine monophosphate- activated protein kinase pathway (Lin, Zhang, Wang, & Wang, 2015).

5. Perspectives

L. ruthenicum similar to *L. barbarum* and *L. chinese*, originated in America. However, the relationships between the three species mainly found in China are not known. What's more, the appearance have great difference in *L. ruthenicum* and other species in genera *Lycium*, and anthocyanins only exist in *L. ruthenicum* fruit, which may indicate a far relationship between *L. ruthenicum* and others. It also has dispute that *L. ruthenicum* is included in genera *Lycium*. So it needs some other molecular techniques, like SSR, chloroplast genome, single nucleotide polymorphism, gene clone, et al., to reveal the relationship among genera *Lycium*, and to search the genes existing in *L. ruthenicum* regulate of the synthesis of anthocyanins.

Phytochemistry studies focus on the separation of chemical components. There have been few reports on quality control. One of the most important reasons for this is that *L. ruthenicum* fruit components are instable, especially the anthocyanins. Light and heat treatment significantly affect stability of anthocyanins from Isabel grape residue (Bastos, De Oliveira, Melo, & De Lima, 2017) and anthocyanins in black currant juice (Mäkilä et al., 2016). Black bean anthocyanins are stable at pH 2.5 and low-temperature 4 °C (Mojica, Berhow, & Gonzalez, 2017). Improving anthocyanin stability and realization anthocyanin quantification will lay the foundation for the quality evaluation of *L.*

ruthenicum. Gum arabic and anthocyanin-loaded chitosan nanoparticles could enhance the stability of anthocyanins in beverage systems (Bo et al., 2016; Chung, Rojanasasithara, Mutilangi, & Mcclements, 2016). Can these methods be used to increase the stability of anthocyanins in *L. ruthenicum*? Spectrophotometric analysis can achieve total anthocyanin content; fourier transform ion cyclotron resonance mass spectrometry and LC/MS combine HPLC could identify anthocyanin components and complete quantitative analysis (Nankar et al., 2016), which may be used for quantitative analysis of anthocyanins in *L. ruthenicum*. Besides, fingerprint is another choice for the quality control of *L. ruthenicum*.

Pharmacology studies are focused on the polyphenolic bioactivities of antioxidants. And the total dietary intake of polyphenol is much higher than that of all other known dietary antioxidants (Scalbert & Williamson, 2000). Antioxidants could be used to treat certain chronic diseases such as depression and diabetes. Thus, *L. ruthenicum* could possibly be developed into tonic products, both as medicinal and food. In addition, cyanidin 3-glucoside and peonidin 3-glucoside isolated from *Oryza sativa* L. indica could inhibit tumor cell growth and induce apoptosis in vitro, and suppress tumor growth in vivo. (Chen et al., 2005). No studies showed that the anthocyanins from *L. ruthenicum* could antitumor and anticancer. And Polysaccharides and other active components bioactivities study are less.

Network pharmacology, integrating network biology and pharmacology, provides a system level approach to understand the pathogenesis of disease, and can be used for identification new targets and indication prediction (Li, Yuan, Pan, Wang, & Chen, 2017; Rask-Andersen, Almén, & Schiöth, 2011; Tang & Tero, 2014). It is rapidly developing during the past few years (Hopkins, 2008; Poornima, Kumar, Zhao, Blunder, & Efferth, 2016). Pharmacological network has been used to reveal potential active ingredients contribute to the hepatoprotective effects of Danshen on acute/chronic alcoholic liver disease and non-alcoholic fatty liver disease and the action mechanism (Hong et al., 2017). The study on the mechanism of action for herbal medicines, like Jia Wei Xian Ji Tang, Wu-to Decoction, Yanghe Decoction, et al., reveals that network pharmacology – based study can explore the mechanisms of herbal medicine from a holistic perspective (Fang et al., 2016; Guo et al., 2017; Tao, Chen, Jing, Ji, & Ren, 2017; Xu et al., 2017; Zeng & Yang, 2017). To our knowledge, there is no study on *L. ruthenicum* based network pharmacology. Maybe this strategy could further explore the potential active ingredients and pharmacology mechanisms of *L. ruthenicum*.

6. Conclusions

L. ruthenicum fruits are used as both medicine and food. They are different from “gouqizi” (the fruits of *L. barbarum* and *L. chinese*) because they contain bioactive anthocyanins. However, there have been relatively few studies on *L. ruthenicum*. The quality control of *L. ruthenicum* is still a blank. The potential active ingredients and pharmacology mechanisms need to further explore. *L. ruthenicum* could possibly be developed into tonic products, as medicinal and food. However, before that, there remains a lot of research need to do.

Conflict of interest

The authors declare no conflict of interest.

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