Übersichtsarbeit | *Review Article*

Schweiz. Zschr. GanzheitsMedizin 2008;20(7/8):399–405. © Verlag für GanzheitsMedizin, Basel. www.ganzheitsmedizin.ch

Goji Juice: A Novel Miraculous Cure for Longevity and Well-Being? A Review of Composition, Pharmacology, Health-related Claims and Benefits

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Goji juice and other Goji-derived products are becoming increasingly popular in Europe and North America. They are sold as food supplements or "super food", mostly via the Internet. Goji is the name given since the beginning of this century to *Lycium barbarum* and a closely related species, *L. chinense*. The fruit has a long tradition of use as food and traditional medicine in Asian countries but reports on its consumption in Europe up to now have been only anecdotal. Health claims recently propagated cover almost all imaginable therapeutic indications. However, the main focus is on age-related conditions. Specifically, Goji is often praised as quasi-miraculous cure for well-being and longevity.

In order to critically assess the potential of Goji and distinguish between hype and potential health benefits, we have reviewed the current scientific knowledge of the fruit's constituents, pharmacology and toxicology. The market situation and legal issues are also briefly addressed. Since only *L. barbarum* plays a significant role in commercial products outside Asia, we have focussed on this species. In addition, selected information is given on *L. chinense* to provide a comprehensive picture of Goji fruit.

Botanical aspects and origin of Goji

Lycium barbarum L. (synonym *L. halmilifolium* Miller) (Solanaceae) is a shrub one to three meters high. The oblong, orange to dark red berries

Background: In recent years, products derived from Goji berries *(Lycium barbarum*) have become increasingly popular in Europe and North America. Numerous products are sold mostly via the internet. On the novel food market, the fruit is sometimes referred to as a "superfruit"; in particular, Goji is praised as cure for longevity and well-being. In Asia, the fruit of *L. barbarum* and the closely related species *L. chinense* have in fact a long tradition of use as a food and traditional medicine. In Europe, however, reports on its consumption up to now are anecdotal. **Objective:** To provide an overview of the current knowledge on constituents, pharmacology and toxicology of Goji and Goji-derived products. In addition, legal issues and the market situation are briefly addressed. **Method:** Systematic analysis of scientific literature on Goji fruit found in major electronic data bases. **Results:** A range of potentially beneficial pharmacological activities, particularly antioxidative and immunomodulatory properties, have been detected both *in vitro* and *in vivo*. Proteoglycans and carotenoids appear to be the pharmacologically relevant compounds. Preliminary data suggest some potential for the prevention of age-related diseases, including neurodegenerative diseases, atherosclerosis and diabetes. However, clinical data are essentially lacking. On the toxicological level, the fruit appears nontoxic but a case of possible drug interaction has been reported **Conclusions:** Goji fruit deserves further investigation to assess its real potential, in particular in the context of age-related diseases. At the same time, there is no scientific evidence to support claims made for Goji juice as a "cure-all" and quasi-miraculous potion for longevity. While the fruit can be considered safe, some caution is advised with regard to possible drug interactions as well as products of unknown or ill-defined origin.

Key words: *Lycium barbarum,* Solanaceae, Goji, novel food, constituents, health claims, safety, antioxidant, immunomodulation, anti-aging, traditional Chinese medicine

Goji-Saft, ein neuer Wundertrank für Langlebigkeit und Wohlbefinden? Eine Übersicht zu Inhaltsstoffen, Pharmakologie, Wirkversprechen und Nutzen

Hintergrund: Produkte auf der Basis von Goji Beeren *(Lycium barbarum)* wurden in letzter Zeit immer beliebter in Europa und Nord Amerika. Zahlreiche Produkte werden über Internet vertrieben. Auf dem Novel Food-Markt wird die Frucht oft als „Superfrucht" bezeichnet und insbesondere als „Wundermittel" für einen guten Gesundheitszustand und Langlebigkeit angepriesen. Die Frucht von *L. barbarum* und der nahe verwandten Spezies *L. chinense* haben in Asien eine lange Tradition als Nahrungsmittel und in der traditionellen Medizin. Dagegen sind Berichte über den bisherigen Konsum von Goji-Beeren in Europa von anekdotischer Natur. **Zielsetzung:** Es soll eine Übersicht gegeben werden über den derzeitigen Kenntnisstand betreffend Inhaltsstoffe, pharmakologische Untersuchung und toxikologische Daten. **Methoden:** Systematische Auswertung der wissenschaftlichen Literatur zur Goji-Frucht aus den gängigen elektronischen Datenbanken. **Ergebnisse:** Eine Reihe von potenziell bedeutsamen pharmakologoischen Aktivitäten einschliesslich antioxidativer und immunmodulatorischer Eigenschaften wurden in verschiedenen Modellen nachgewiesen. Massgeblich für die Aktivität scheinen Proteoglykane und Carotinoide zu sein. Vorläufige Daten deuten auf ein gewisses Potenzial zur Vorbeugung von altersbedingten Krankheiten hin, unter anderem von neurodegenerativen Erkrankungen, Atherosklerose und Diabetes. Klinische Daten fehlen aber weitestgehend. Toxikologische Untersuchungen belegen, dass die Frucht ungiftig ist. Ein Fall von möglicher Arzneimittelinteraktion wurde aber dokumentiert. **Schlussfolgerungen:** Goji verdient sicherlich weitere Untersuchungen, um die klinische Bedeutung der nachgewiesenen pharmakologischen Aktivitäten zu substantivieren, insbesondere bei altersbedingten Krankheiten. Auf der anderen Seite fehlen jegliche wissenschaftliche Belege, welche die überzogenen Ansprüche als "Wundermittel" unterstützen. Während die Frucht toxikologisch unbedenklich scheint, ist eine gewisse Vorsicht geboten im Hinblick auf mögliche medikamentöse Interaktionen und bei Produkten unbekannter oder zweifelhafter Herkunft.

Schlüsselwörter: *Lycium barbarum,* Goji, Solanaceae, Novel Food, Inhaltsstoffe, Antioxidans, Immunmodulation, Anti-Aging, traditionelle chinesische Medizin

Fig. 1. *Lycium barbarum* (photo: Prof. Jingui Shen).

measure up to 2 cm and possess a bitter to sweet taste **(Fig. 1)**. Traditional vernacular names of the plant are boxthorn (German: gemeiner Bocksdorn), matrimony wine or wolfberry [1]. In recent years, the plant, and by extension, the fruit itself have been increasingly designated as Goji, a name derived from the Chinese "Gouqi". As already mentioned, Goji is also used to describe a closely related species *L. chinense* Miller. The fruits of these two Lycium species possess a highly similar anatomy and tissue structure, and differentiation based on morphological and histological analyses are very difficult. Reliable distinction requires molecular techniques such as RAPD (random amplified polymorphic DNA) analyses [2].

The original habitat of *L. barbarum* is not definitively established but is probably to be found in the Mediterranean Basin [3]. Meanwhile, the plant is widely distributed in warm regions of the world, in particular in the Mediterranean area, Southwest and Central Asia. It is also cultivated in North America and Australia as hedge plant [1]. Commercially significant cultivation of Goji is only found in China. The majority of commercially produced wolfberries comes from plantations of *L. barbarum* in the Ningxia Hui Region in north-central China and the Xinjiang Uyghur Region in Western China. In China, the production of Goji berries yielded 95'000 tons in 2004, generating US$ 120 millions of revenue [4].

Tab. 1. Indications for *Lycii fructus* in the traditional Chinese medicine [7–9]

Liver and kidney *Yin* deficiency
- Dizziness, blurry vision, diminished visual acuity
- Nocturnal emission
- Night sweating
- Infertility, impotency
- Soreness and weakness of the lower back and knees
- Prevention of premature aging, prematurely grey hair
- Fatigue, to replenish vital essence
- Wasting and thirsting disorder (diabetes)
- Blood deficiency (Anaemia)

Lung *Yin* deficiency
- Dry cough
- Cough with blood or blood streaks

Traditional use of Goji

Goji berries are a very popular ingredient in Chinese cuisine. They are consumed in soups, as porridge with rice and added to numerous meat and vegetable dishes. The fruits are harvested from August to October. In Ningxia, the main production center of Goji, the harvest is annually celebrated with a festival in August. The fruits are usually dried but they may also be consumed fresh like the young leaves which are a valued vegetable.

Lycii fructus (Gou Qi Zi) is listed in the Chinese Pharmacopeia. While only the fruit of *L. barbarum* is officinal [5], both species, *L. barbarum* and *L. chinense,* have been used for more than 2000 years in Traditional Chinese Medicine with early records tracing back to Tang Dynasty (1000–1400 AD) [6]. The berries are eaten raw, drunk as juice, wine or tea. They can also be processed to tinctures, powders and tablets. The recommend dosage of dried berries varies between 5 and 12 g [7,8]. Goji berries are used in Traditional Chinese Medicine as mild *Yin* tonic, enriching *Yin* in liver, kidneys and moistening lung *Yin*. Indications derive from its *Yin*-nourishing effect **(Table 1)**. They include blurry vision and diminished visual acuity, infertility, abdominal pain, dry cough, fatigue and headache [7–10]. The berries are also praised in folk medicine to increase longevity [11] and against prematurely gray hair [9]. Besides China, Goji berries are part of the medicinal tradition in other Asian countries including Vietnam [12], Korea and Japan.

Constituents

Polysaccharides represent quantitatively the most important group of substances in the fruit of *L. barbarum*. Quantitative data in literature diverge

considerably. A yield of 23% based on the dried fruit was obtained after optimization of extraction conditions [13]. The polysaccharide fraction consists of a complex mixture of highly branched and only partly characterized polysaccharides and proteoglycans, which is often referred to as *Lycium barbarum* polysaccharides or LBP. The glycosidic part accounts in most cases for about 90–95% of the mass and consists of arabinose, glucose, galactose, mannose, rhamnose, xylose and/or galacturonic acid [13–16].

A second major group of metabolites are the carotenoids which are at the same time responsible for the fruit's red color. The content of carotenoids increases during the ripening process. Zeaxanthin dipalmitate is the predominant constituent [17] representing 56% of the total carotenoids in the fruit of *L. barbarum* and 49% in *L. chinense* [18]. β-Cryptoxanthin monopalmitate, zeaxanthin monopalmitate, a small amount of free zeaxanthin and β-carotene are also present [19]. The fruits further contain vitamins, in particular riboflavin, thiamin and ascorbic acid, together with a glucosylated precursor of the latter [20,21]. The content of vitamin C of 42 mg/100g is comparable to that of fresh lemon fruits. Flavonoids are another important class of compounds. The content of total flavonoids is approximately 1.5g/kg of fruit [22]. Among these, rutin has been detected in hydroalcoholic extracts [22] and the aglycones myricetin, quercetin and kaempferol have been identified after hydrolysis [23]. The essential oil and fatty acids of *L. barbarum* have been analyzed by GC-MS and hexadecanoic acid, linoleic acid, β-elemene, myristic acid and ethylhexadecanoate have been identified as the main constituents [24]. The fruit contains 1–2.7% free amino acids with proline as major constituent. The non-proteinogenic amino acids taurine and γ-aminobutyric acid as well as betaine (trimethylglycine) are also contained in the fruit [25,26]. Finally, some miscellaneous compounds have been isolated including β-sitosterol and its glucoside daucosterol, scopoletin, p-coumaric acid, the dopamine derivative lyciumid A and L-monomenthyl succinate [27]. The composition of the fruit of *L. chinense* appears to be similar. As in *L. barbarum*, polysaccharides, carotenoids and flavonoids are the typical metabolites. In addition, the isolation of two cerebrosides [28] and three pyrole derivatives [29] with hepatoprotective properties is to be mentioned. The identification of a series of sterols, tocopherols, cholorogenic and neochlorogenic acids [30] has been reported.

There have been some controversies about the atropine content of the fruits. In 1989, a content of 0.95% of atropine was reported for a fruit sample collected in India [31]. This finding appears highly doubtful and does not fit with the widespread consumption of the fruits and lacking reports of apparent toxicity. Recently, a systematic investigation of Goji berries from various provenances has been undertaken with HPLC-MS [32]. Only traces of atropine, maximally 19 ppb (w/w), were detected in the analyzed samples.

Pharmacological properties

Pharmacological investigations have been mostly performed with an aqueous extract or more or less purified polysaccharide fractions. Studies focussed on antioxidative and immunomodulatory properties in the context of age-related diseases including atherosclerosis, neurodegeneration and diabetes [33]. Antioxidant properties have been detected in various *in vitro* and *in vivo* assays. The activity has been mainly attributed to the flavonoids [23] and polysaccharides (LBP) [34]. The mechanisms of action involve for both groups of compounds reducing capacity, metal ion chelation and radical scavenging activity [23]. Betain might also contribute to the antioxidant action [35]. Of particular interest is the activity of the polysaccharides, since these constituents are relatively characteristic of Goji fruit. Polysaccharides extracted from the fruit exhibited antioxidant activity in the β-carotene/linoleic assay as well as radical scavenging activity towards the superoxide anion and reducing capacity which were similar to those of the synthetic antioxidant BHT [34]. They also strongly inhibited the AAPH (2,2'-azobis (2-amidinopropane) dihydrochloride)-induced hemolysis of erythrocytes. The glycoconjugate LbGp5B inhibits LDL oxidation *in vitro* [14]. LBP showed protective effects on heat-induced damages in rat testes *in vivo* and H_2O-induced oxidative damage in mouse testicular cells *in vitro* [36]. In rabbits fed with 1.5% cholesterol over ten weeks, celiac injection of LBP reduced the increase of triglyceride, increased the ratio of HDL-cholesterol to total cholesterol and improved oxidation markers [37]. Oral administration of LBP exhibited protective effects on streptozotocin-induced oxidative stress and DNA damages in diabetic rats [38, 39]. In the same model, they markedly decreased plasma cholesterol, fasting insulin and postprandial glucose levels. Improved insulin sensitivity was associated with increased levels of the glucose transporter 4 (GLUT4) on the surface of skeletal muscle cells [40]. Hypoglycemic and hypolipidemic effects have been also observed in alloxan-induced diabetic/hyperlipidemic rabbits [41]. In a study performed with zeaxanthin dipalmitate isolated from *L. barbarum*, oral administration leads to a reduction of hepatic fibrosis induced by bile duct ligation in rats. The antifibrotic activity appears mediated at least in part by the antioxidative activity [42].

Immunomodulatory properties have attracted much attention, also with regard to cancer immunotherapy. LBP have been shown in several studies to promote splenocyte proliferation *in vitro* [14,15,43]. There are evidences that LBP act through enhanced expression of various cytokines and transcription factors. The protein polysaccharide complex LbGp4 stimulates the expression of nuclear factor κB (NfκB) and activator protein 1 (AP-1) [15]. LBP3 was shown to increase the expression of interleukin-2 (IL-2) and tumor necrosis factor-α (TNF-α) at the mRNA and protein levels in cultures of human peripheral blood mononuclear cells [44]. The immunostimulatory activity appears to account for the antitumour properties which have been detected in mice. Thus, inhibition of growth of S180 sarcoma tumors in mice was correlated with increased

macrophage phagocytosis, spleen lymphocyte proliferation, CTL activity and IL-2 mRNA expression [45]. In addition to immunostimulatory effects, propapoptotic properties may contribute to the antitumour properties. LBP inhibit cell proliferation with cell cycle arrest in the S phase and induce apoptosis of a human hepatoma cell line *in vitro* [46]. Finally, hematopoietic properties should be mentioned in the context of a potential use as adjuvant in cancer therapy. In irradiation- or chemotherapy-induced myelsosuppressed mice, LBP alleviates the decrease of red and white blood cells [47].

Another line of research has been on neuroprotective properties. Oral pretreatment with an aqueous extract of *L. barbarum* has been shown to protect rat cortical neurons against Aβ-induced toxicity. The underlying mechanism appears to involve inhibition of the Aβ-triggered c-Jun N-terminal kinase (JNK) signaling pathway [48]. Interestingly, *L. barbarum* extract also protects against reducing stress induced by dithiothreitol which indicates that the neuroprotective activity is not merely due to antioxidative properties [49]. The authors also observed reduced activity of caspases 3 and 2 and inhibition of phosphorylation of double-stranded RNA-dependent protein kinase (PKR). Neuroprotective effects have been also investigated in an ocular hypertension model of glaucoma. Rats fed with an aqueous extract of L. barbarum showed a strong reduction of the loss of retinal ganglion cells. It is noteworthy that the intraocular pressure was not altered by the treatment [51].

While there has been less investigation of the fruit of *L. chinense*, its biological properties appear to be basically similar. Noteworthy are anti-inflammatory properties on carragenan-induced paw edema and hepatoprotective activity against CCl_4-induced liver damage in rat [52].

Clinical studies

Clinical studies have been almost exclusively performed in China and have focussed on age-related conditions. Unfortunately, studies were mostly small-sized and not adequately controlled. Moreover, original data are hardly accessible. In a representative study with 42 in average 68 years old participants, consumption of 50 mg of wolfberry extract twice a day over two months decreased dizziness, fatigue, chest distress, sleep problem and anorexia [53] (cited in [6]). However, statistical significance was not assessed in the study. In another study, ingestion of 50 g/d of Goji berries in 25 elderly people for 10 days increased SOD and hemoglobin and decreased blood lipids significantly [54] (cited in [6]). Recently, in a first double-blind study performed outside China, the general effects of GoChi™, a commercial Goji juice, were investigated in young healthy adults. Different parameters were assessed by a questionnaire. Blood pressure and body weight were also monitored. The study concludes that consumption of GoChi™ for 14 days increases subjective feelings of general well-being and improves neurologic performance as well as gastrointestinal function [55]. However, the small size of the study (N=34) and the subjectivity of most parameters must be critically pointed out.

The potential effect of Goji as adjuvant in cancer therapy has been investigated in a clinical study conducted in China on 75 advanced cancer patients. A combination of IL-2/lymphokine-activated killer (LAK) therapy and *L. barbarum* polysaccharides afforded significantly higher response rates and longer remission rates than IL-2/LAK therapy alone [56].

While there are no studies demonstrating the effect of the intake of Goji itself for the prevention of age-related eye diseases, there are many lines of evidence supporting the protective role of zeaxanthin. Thus, reduced incidence of cataract and macular degeneration has been associated with the intake of leafy green vegetables which constitute a rich source of zeaxanthin and lutein [6,57,58]. A study with twelve volunteers who received free or esterified carotenoids extracted from Goji berries, suspended in a yoghourt, confirmed the absorption of zeaxanthin. Moreover, the study indicated a strongly enhanced bioavailability of zeaxynthin diplamitate, the dominating carotenoid in Goji fruit, compared with the non-esterified form [59].

Toxicology and adverse reactions

Traces of atropine detected in the fruit have no toxicological relevance and there is no risk with cultivated plants. In this context, the classification of the plant as toxic [60,61] appears unfunded. The LD50 of a water extract of Goji berries was reported as 8.32 g/kg by subcutaneous application in mice [62] and confirms the virtual absence of toxicity of the fruit. On the other hand, some caution is advised with samples of unknown origin since confusion with morphologically similar Solanaceous fruits can not be ruled out. Such confusion may in fact explain some contradictory data regarding the alkaloid content of Goji berries.

Despite the very long history of traditional use as food and herbal medicine, there are practically no reports of adverse effects due to Goji fruits. Only a few cases of allergic reactions including urticaria-like or papular rashes have been documented [8]. In Chinese medicinal books, some caution is advised to pregnant women. Also it is recommended that patients suffering from diarrhea, fever, arthritis and strong inflammatory conditions should avoid the consumption of the fruit [9,11,63]. However, no rationale is given as to substantiate this recommendation.

While the fruit appears devoid of any acute toxicity, attention should be paid to potential drug interactions, as shown by a case report documenting a possible interaction with warfarin. A 61-year old Chinese woman stabilized on warfarin developed elevated international normalized ratio (INR) after having drunk a tea of Goji berries over four days. The value returned to normal after discontinuing the tea [64]. Weak inhibition of CYP2C9 was detected *in vitro* (K_i of 3.4 mg/mL). However, the rather high value of the dissociation constant suggests that other mechanisms account for the drug interaction *in vivo*. Considering the in-

Fig. 2. Goji berries and Goji juice.

sufficient data, patients under medication should not consume Goji-derived food supplements without informing their physician.

Legal status and market situation

Goji is commonly referred to as "Himalayan Goji berry" or "Tibetan Goji berry" on the global functional food market. The variety of commercialized products is considerable **(Fig. 2)**: Besides juices, wines and beers, Goji is found in cookies, crispy bars, chocolate, müsli, sausages and soaps. Goji products have been marketed via Internet since 2002 [4]. In Switzerland, Goji products are also available in a few drugstores, "Reformhäuser" or "Bioladen". Goji products are quite expensive with 30–50 Dollars to be paid in average for a 1L bottle on the internet market. A probably decisive factor for the commercial success of Goji in Western countries has been a booklet of Dr. Earl Mindell entitled, "Goji, The Himalayan Health Secret" [65]. Dr. Mindell is a somewhat controversial Canadian-American nutritionist who has written several books on food supplements and nutrition for the public. His theories on health and nutrition have met with deep scepticism in the scientific community. In his book, he extrapolates broad recommendations of uses for Goji juice, including cancer prevention, cardiovascular health, treatment of diabetes and obesity **(Table 2)**, from traditional practices and preliminary studies performed in China. In particular, he claims quasi-miraculous effects on life expectancy for Goji identified as "the Himalayan longevity fruit". Dr. Mindell and his statements about the "extraordinary value" of Goji are abundantly cited in advertisements for Goji products, in particular by his partner company FreeLife International which distributes Gogi juice via multilevel marketing. The health benefits claimed by Dr. Mindell and to be found in the web publications of the Goji manufacturers were individually and critically reviewed in a recent book on wolfberry [66]. The authors conclude that there are no scientific evidence and peer-reviewed proofs to validate any of the claims. One of the last products launched by FreeLife International is GoChi™, a juice claimed to contain over 30% more bioactive polysaccharides. The name GoChi is a combination of *go* from Goji and the Chinese word *chi* meaning life energy. The advertising for this product draws on a recent clinical study supposed to demonstrate the product's general effects on health [55]. However, considering the highly subjective parameters, the small number of participants and the relatively short-term study, the significance of the data appears highly questionable.

Tab. 2. Goji as an expensive "cure-all": recommended uses for Goji juice and daily dose [65]

- Allergies (60–120 ml)
- Anti-aging (60–120 ml)
- Arthritis and inflammatory conditions (120 ml)
- Cancer prevention (60 ml)
- Cancer management (120–240 ml)
- Cardiovascular health (120 ml)
- Diabetes Type 2 (60 ml)
- Hypertension (90 ml)
- Immunity enhancement (60–120 ml)
- Infertility (150 ml for four months)
- Liver protection (30–60 ml)
- Obesity (60 ml, afternoon)
- Sexual dysfunction (80–120 ml)

Average price of a 1L bottle of Goji juice: 30–50 $

Goji berries and Goji products are legally sold as food or food supplements in the USA and in Europe. However, therapeutic claims are not allowed and the products should not be promoted as drugs. Thus in 2006, the FDA sent warning letters to some Goji juice distributors because their marketing claims violated the Food Drug and Cosmetic Act [67,68]. In Europe, the UK Food Standards Agency started an evaluation procedure in 2007 to establish whether Goji berries should receive the status of Novel Food which would have affected its authorization status for sale. Thus, according to the EU Novel Foods Regulation, new foods must be demonstrated to be not unsafe, their labeling to be not misleading and their nutritional quality to be not inferior to similar foods that they could replace. After reviewing the data, the agency came to the conclusion that there were sufficient records of alimentary use of Goji in the UK before 1997, and that the fruit consequently does not fall under the novel food legislation [69].

Conclusions

Goji berries have a very long tradition of use as food and traditional medicine in China and other Asian countries. Pharmacological investigations and preliminary clinical data suggest that the fruit may have beneficial properties, in particular in the prevention of age-related ailments including neurodegenerative diseases, type 2 diabetes and atherosclerosis. The polysaccharide fraction and the high content of zeaxanthin dipalmitate appear to account at least in part for the biological properties. At the same time, there is no scientific evidence supporting the health claims attributed to pricey Goji products that are distributed via Internet. While the tradition of use of this fruit over a long time without any significant report of toxicity demonstrates its safety in the context of a normal consumption, caution is advised with poorly controlled products consumed in amounts and forms which have no relation with the traditional use. In addition, adulteration may be an issue for food supplements of undefined origin. Particular caution is also recommended with patients under medication, as underlined by a case of possible interaction with warfarin.

In conclusion, while the Goji fruit may possess interesting biological properties, further studies are indispensable before any recommendation of use can be made for Goji products. Pharmacological studies should in particular address possible drug interactions. Large and controlled clinical studies are required before the real potential of Goji for prevention of chronic diseases can be definitively assessed. Finally, there is also an urgent need to establish quality standards for Goji products for assessment of safety and equivalence of commercial products.

Acknowledgments

Thanks are due to Profs. Jingui Shen and Yang Ye (Shanghai Institute of Materia Medica) for the picture of *Lycium barbarum*. Mrs. Loredana Vasquez Briceno is gratefully acknowledged for bibliographic research.

References

1. Hänsel R, Keller K, Rimpler H, Schneider G: Hagers Handbuch der Pharmazeutischen Praxis, Vol 5 Drogen E-O, Springer Verlag Berlin, Heidelberg, New York 1993.
2. Zhang KYB, Leung HW, Yeung HW, Wong RNS: Differentiation of *Lycium barbarum* from its related Lycium species using random amplified polymorphic DNA. Planta Med 2001; 67(4):379–381.
3. Genaust H: Etymologisches Wörterbuch der botanischen Pflanzennamen, 3. Auflage. Birkhäuser Verlag, Basel 1996.
4. NationMaster – Encyclopedia: Goji berries. http://www.nationmaster.com/encyclopedia/Goji-berries.
5. Pharmacopoeia of the People's Republic of China, English Edition. Chemical Industry Press, Beijing 2000.
6. Burke DS, Smidt CR, Vuong LT: *Momordica cochichinensis, Rosa roxburghii,* wolfberry, and sea buckthorn – highly nutritional fruits supported by tradition and science. Curr Top Nutrac Res 2005; 3(4):259–266.
7. Zhufan X: Practical Traditional Chinese Medicine. Foreign Language Press, Beijing 2000.
8. Bensky D, Clavey S, Stöger E: Chinese Herbal Medicine, Materia Medica Eastland Press, Inc. 3rd Edition, Seattle 2004.
9. Chen JK, Chen TT: Chinese Medical Herbology and Pharmacology. Art of Medicine Press Inc, City of Industry, CA, 2004.
10. Zhu YP: Chinese Materia Medica – Chemistry, Pharmacology and Applications. Harwood Academic Publishers, Amsterdam 1998.
11. Reid D: Handbuch der chinesischen Heilkräuter. Droemersche Verlagsanstalt Th Knaur Nachf., München 1998.
12. Bich DH, Tap N, Toan T, Hung T, Hien PV, Lo VN, Man P K, Dan NV, Nhu DT, Mai PD: Selected medicinal plants in Vietnam, Volume 2. Science and Technology Publishing House, Hanoi 1999.
13. Yin G, Dang Y: Optimization of extraction technology of the *Lycium barbarum* polysaccharides by Box-Behnken statistical design. Carbohydr Polym 2008;74:603–610.
14. Peng X, Qi C, Tian G, Zhang XX: Physicochemical properties and bioactivities of a glycoconjugate LbGp5B from *Lycium barbarum* L. Chin J Chem 2001;19(9):842–846.
15. Peng X, Huang J, Qi C, Zhang YX, Tian GY: Studies on chemistry and immuno-modulating mechanism of a glycoconjugate from *Lycium barbarum* L. Chin J Chem 2001;19: 1190–1197.
16. Peng X, Tian G: Structural characterization of the glycan part of glycoconjugate LbGp2 from *Lycium barbarum* L. Carbohydr Res 2001;331: 96–99.
17. Weller P, Breithaupt DE: Identification and quantification of zeaxanthin esters in plants using liquid chromatography-mass spectrometry. J Agric Food Chem 2003;51:7044–7049.
18. Peng Y, Ma C, Li Y, Leung KSY, Jiang ZH, Zhao Z : Quantification of zeaxanthin dipalmitate and total carotenoids in *Lycium* fruits *(Fructus Lycii).* Plant Foods Hum Nutr 2005;60:161–164.
19. Inbaraj BS, Lu H, Hung CF, Wu WB, Lin CL, Chen BH: Determination of carotenoids and their esters in fruits of *Lycium barbarum* Linnaeus by HPLC-DAD-APCI-MS. J Pharm Biomed Anal 2008;47:812–818.
20. Qi Z, Li S, Wu J, Qu R, Yang Y, Zhang, L, Yang X. (1986). Chemical constituents of *Fructus Lycii* and *Folium Lycii* – Nutrients in *Fructus Lycii* and *Folium Lycii.* Zhongyao Tongbao (Beijing, China) 1986;11(3):169–171.
21. Toyoda-Ono Y, Maeda M, Nakao M, Yoshimura M, Sugiura-Tomimori N, Fukami H: 2-O-(β-D-Glucopyranosyl)ascorbic acid, a novel ascorbic acid analogue isolated from *Lycium* fruit. J Agric Food Chem 2004;52:2092–2096.
22. Qian J, Liu D, Huang A G: The efficiency of flavonoids in polar extracts of *Lycium chinense* Mill. fruits as free radical scavenger. Food Chem 2004;87:283–288.
23. Le K, Chiu F, Ng K: Identification and quantification of antioxidants in *Fructus lycii.* Food Chem 2007;105(1):353–363.
24. Altintas A, Kosar M, Kirimer N, Baser KH, Demirci B: Composition of the essential oils of *Lycium barbarum* and *Lycium ruthenicum* fruits. Chem Nat Comp 2006;41(1):24–25.
25. Chen S, Wang Q, Gong S, Wu J, Yu X, Lin S: Analysis of amino acid in *Fructus lycii.* Zhongguo Yaoke Daxue Xuebao 1991;22(1): 53–5. (CA 115:15369).
26. Cao Y, Zhang X, Chu Q, Fang Y, Ye J: Determination of taurine in *Lycium barbarum* L. and other foods by capillary electrophoresis with electrochemical detection. Electroanalysis 2003;15(10):898–902.
27. Hiserodt RD, Adedeji J, John TV, Dewis ML: Identification of monomenthyl succinate, monomenthyl glutarate, and dimenthyl glutarate in nature by high performance liquid chromatography-tandem mass spectrometry. J Agric Food Chem 2004;52:3536–3541.
28. Kim SY, Choi YH, Huh H, Kim J, Kim Y C, Lee H S: New antihepatotoxic cerebroside from *Lycium chinense* fruits. J Nat Prod 1997;60: 274–276.
29. Chin YW, Lim SW, Kim SH, Shin DY, Suh YG, Kim YB, Kim YC, Kim J: Hepatoprotective pyrrole derivatives of *Lycium chinense* fruits. Bioorg Med Chem Lett 2003;13:79–81.
30. Noculak-Palczewska A, Matkowski A, Gasiorowski K, Tabaka H, Oszmianski J, Lamer-Zarawska E: Chemical characterisation of methanolic-water extracts from the fruit of acclimated *Lycium chinense* Mill.. Herba Pol 2004;50(1):47–53.
31. Harsh ML: Tropane alkaloids from *Lycium barbarum* Linn., in vivo and in vitro. Current Sci 1989;58(14):817–818.
32. Adams M, Wiedenmann M, Tittel G, Bauer R: HPLC-MS trace analysis of atropine in *Lycium barbarum* berries. Phytochem Anal 2006;17: 279–283.
33. Chang RCC, So KF: Use of Anti-aging herbal medicine, *Lycium barbarum*, against aging-associated diseases. What do we know so far? Cell Mol Neurobiol 2008;28(5):643–652.
34. Li XM, Li XL, Zhou AG: Evaluation of antioxidant activity of the polysaccharides extracted from *Lycium barbarum* fruits in vitro. Europ Polymer J 2007;43:488–497.
35. Ren B, Ma Y, Sheng Y, Gao, B: Protective action of *Lycium barbarum* L. and betaine on lipid peroxidation of RBC membrane induced by hydrogen peroxide. Zhongguo Zhongyao Zazhi 1995;20(5):303–4. (CA 124:21718).
36. Luo Q, Li Z, Huang X, Yan J, Zhang S, Cai Y: *Lycium barbarum* polysaccharides: Protective effects against heat-induced damage of rat testes and H_2O_2-induced DNA damage in mouse testicular cells and beneficial effect on sexual behavior and reproductive function of hemicastrated rats. Life Sci 2006;79:613–621.
37. Ma L, Chen Q, Yang W, Xi S, Wan, X, Tang X, Yu Y, Kang J: Effect of *Lycium barbarum* polysaccharide against atherosclerosis in rabbits. Zhengzhou Daxue Xuebao, Yixueban 2005; 40(2):328–330. (CA 144:324440).
38. Wu H, Guo H, Zhao R (2006). Effect of *Lycium barbarum* polysaccharide on the improvement of antioxidant ability and DNA damage

in NIDDM rats. Yakugaku Zasshi 2006;126(5): 365–371.

39. Li XM: Protective effect of *Lycium barbarum* polysaccharides on streptozotocin-induced oxidative stress in rats. Int J Biol Macromol 2007;40(5):461–465.
40. Zhao R, Li Q, Xiao B: Effect of *Lycium barbarum* polysaccharide on the improvement of insulin resistance in NIDDM rats. Yakugaku Zasshi 2005;125(12):981–988.
41. Luo Q, Cai Y, Yan J, Sun M, Corke H: Hypoglycemic and hypolipidemic effects and antioxidant activity of fruit extracts from *Lycium barbarum*. Life Sci 2004;76:137–149.
42. Kim HP, Lee EJ, Kim YC, Kim J, Kim HK, Park JH, Kim SY, Kim YC: Zeaxanthin dipalmitate from *Lycium chinense* fruit reduces experimentally induced hepatic fibrosis in rats. Biol Pharm Bull 2002;25(3):390–392.
43. Du G, Liu L, Fang J: Experimental study of the enhancement of murine splenic lymphocyte proliferation by *Lycium barbarum* glycopeptide. J Huazhong Univ Sci Technol 2004; 24(5):518–520.
44. Gan L, Zhang SH, Liu Q, Xu HB: A polysaccharide-protein complex from *Lycium barbarum* upregulates cytokine expression in human peripheral blood mononuclear cells. Eur J Pharmacol 2003;471:217–222.
45. Gan L, Zhang SH, Yang XL, Xu HB: Immunomodulation and antitumor activity by a polysaccharide-protein complex from *Lycium barbarum*. Int J Immunopharm 2004;4:563–569.
46. Zhang M, Chen H, Huang J, Li Z, Zhu C, Zhang S: Effect of *Lycium barbarum* polysaccharide on human hepatoma QGY7703 cells: Inhibition of proliferation and induction of apoptosis. Life Sci 2005;76(18):2115–2124.
47. Gong H, Shen P, Jin L, Xing C, Tang F:Therapeutic effects of *Lycium barbarum* polysaccharide (LBP) on irradiation or chemotherapy-induced myelosuppressive mice. Cancer Biother Radiopharm 2005;20(2):155–162.
48. Yu MS, Leung SKY, Lai SW, Che CM, Zee SY, So KF, Yuen WH, Chang RCC: Neuroprotective effects of anti-aging oriental medicine *Lycium barbarum* against beta-amyloid peptide neurotoxicity. Exp Gerontol 2005;40(8–9):7 16–27.
49. Yu MS, Ho YS, So KF, Yuen WH, Chang CC: Cytoprotective effects of *Lycium barbarum* against reducing stress on endoplasmic reticulum. Int J Mol Med 2006;17:1157–1161.
50. Yu MS, Lai Cora SW, HO YS, Zee SY, So KF, Yuen WH, Chang RCC: Characterization of the effects of anti-aging medicine Fructus Lycii on beta amyloid peptide neurotoxicity. Int J Mol Med 2007;20(2):261–268.
51. Chan HC, Chang RCC, Ip, AKC, Chiu, K, Yuen WH, Zee SY, So, KF: Neuroprotective effects of *Lycium barbarum* L. on protecting retinal ganglion cells in an ocular hypertension model of glaucoma. Exper Neurol 2007;203:269–273.
52. Lin CC, Chuang SC, Lin JM, Yang JJ: Evaluation of the antiinflammatory hepatoprotective and antioxidant activities of *Lycium chinense* from Taiwan. Phytomedicine 1997;4(3):213–220.
53. Li DY, Yuan XL, Xia HF, MaL, Guo ZY, Shen YY, Rong QZ: Preliminary clinical observations for effects of Ning Xia wolfberry extract on old peoples. Chin Trad Herb Drugs 1989;20: 26–28.
54 Li W, Dai SZ, Ma W, Gao L: Effects of oral administration of wolfberry on blood superoxide dismutase (SOD), haemoglobin (Hb) and lipid peroxide (LPO) levels in old people. Chin Trad Herb Drugs 1991;22:251–268.
55. Amagase H, Nance DM: A randomized, double-blind, placebo-controlled, clinical study of the general effects of a standardized *Lycium barbarum* (Goji) juice, GoChi™. J Alternative Compl Med 2008;14(4):403–412.
56. Cao GW, Yang WG, Du P: Observation of the effects of LAK/IL-2 therapy combining with *Lycium barbarum* polysaccharides in the treatment of 75 cancer patients. Zhonghua Zhong Liu Za Zhi (Chin J Oncol) 1994;16(6):428–431.
57. Brown L, Rimm EB, Seddon JM, Giovannucci EL, Chasan-Taber L, Spiegelman D, Willett WC, Hankinson SE: A prospective study of carotenoid intake and risk of cataract extraction in US men. Am J Clin Nutr 1999;70(4): 517–524.
58. Seddon JM., Ajani UA, Sperduto RD, Hiller R, Blair N, Burton TC, Farber MD, Gragoudas E S, Haller J, Miller DT, Yanmuzi LA, Willett W: Dietary carotenoids, vitamins A, C, and E , and advanced age-related macular degeneration. J Am Med Assoc 1994;272(18):1413–20.
59. Breithaupt DE, Weller P, Wolters M, Hahn A: Comparison of plasma responses in human subjects after the ingestion of 3R,3R'-zeaxanthin dipalmitate from wolfberry (*Lycium barbarum*) and non-esterified 3R,3R'-zeaxanthin using chiral high-performance liquid chromatography. Brit J Nutr 2004;91:707–713.
60. Schönfelder I, Schönfelder P: Der neue Kosmos Heilpflanzenführer. Kosmos-Verlag, Stuttgart 2001.
61. Roth L, Daunderer M, Kormann K: Giftpflanzen – Pflanzengifte, 3. Auflage, ecomed Verlagsgesellschaft, Landsberg, München 1988.
62. Chang HM, But PPH, Yao SC, Wang L, Yeung SCS: Pharmacology and applications of Chinese materia medica, Volume 2. World Scientific, New Jersey, London, Singapore, Hong Kong 2001.
63. Tierra M: Westliche Heilkräuter in TCM und Ayurveda. Urban & Fischer Verlag, München, Jena 2001.
64. Lam AY, Elmer GW, Mohutsky M A: Possible interaction between warfarin and *Lycium barbarum* L. Ann Pharmacother 2001;35:1199–1201.
65. Mindell E, Handel R: Goji: The Himalayan Health Secret. Momentum Media, Lake Dallas, Texas, United States 2003.
66. Gross PM, Zhang X. Zhang R: Wolfberry: Nature's Bounty of Nutrition & Health. Booksurge Publishing, Charleston, South Carolina, United States 2006.
67. Food and Drug Administration, letter of notice Ref. No. CL-06-HFS-810-214. 8. May 2006. http://www.fda.gov/cder/warn/cyber/2006/CL214e.pdf
68. Food and Drug Administration, letter of notice Ref. No. CL-06-HFS-810-226. 7. August 2006. http://www.fda.gov/Cder/warn/cyber/2006/CL226e.pdf
69. Food Standards Agency, Responses on Goji berries reviewed. 15 June 2007.
    http://www.food.gov.uk/multimedia/pdfs/gojiberriesrep.pdf

Disclosure Statement

The authors declare that no financial or other conflict of interest exists in relation to the content of this article.

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