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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. halimifolium* 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 pharmakologischen 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].

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.

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

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-monomethyl succinate [27]. The com-

position 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, chlorogenic 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 H₂O-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 κ B (Nf κ B) 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 anti-tumour 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, proapoptotic 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 myelosuppressed 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 A β -induced toxicity. The underlying mechanism appears to involve inhibition of the A β -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 CCl₄-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 yoghurt, confirmed the absorption of zeaxanthin. Moreover, the study indicated a strongly en-

hanced bioavailability of zeaxanthin diplamate, 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 unfounded. 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

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 \$

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 Goji juice via multi-level 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.

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.

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