

Goji Berry (*Lycium barbarum*): Composition and Health Effects – a Review

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Goji berries contain many nutrients and bioactive compounds which allowed to classify them as superfruits. A short description of the fruits is presented together with cultivation requirements. The chemical composition of the berries and their health-promoting properties are described later in this literature review. Based on the available data, their potentially beneficial application in dietary prevention of diseases of affluence, such as diabetes, cardiovascular diseases and cancer, is elaborated. We also refer to the safety of Goji consumption in the context of ingredients potentially harmful for human health, allergic reactions and the interactions with other substances.

INTRODUCTION

The rapid increase in diseases of prosperity has led to more intensified research into substances contributing to their prevention and treatment. Results of many investigations showed that life style changes, such as a well-balanced diet and physical exercise, may effectively prevent the occurrence of many diseases [Amagase & Farnsworth, 2011; Amani & Gill, 2013; Batcagan-Abueg *et al.*, 2013; Gramza-Michałowska *et al.*, 2011; Gramza-Michałowska, 2014; Marrazzo *et al.*, 2014; Shashirakha *et al.*, 2015]. Based on the current analysis of food, as well as clinical and epidemiological research, scientists are searching for products characterized by better health-promoting properties. Raw materials that can be used for the production of properly engineered food are also being investigated [Ahmad *et al.*, 2015; Heş *et al.*, 2011; Kmiecik *et al.*, 2015]. Bioactive food is an emerging field in the context of health and nutrition. Many people and associations have defined its importance. However, the American Dietetic Association (ADA) has proposed the most accurate definition of the bioactive ingredients of food: “Bioactive food components are physiologically active constituents in foods or dietary supplements derived from both animal and plant sources, including those needed to meet basic human nutrition needs, that have been demonstrated to have a role in health and to be safe for human consumption” [Saldanha, 2004]. Carotenoids, flavonoids, isoflavones, phytoestrogens, sterols, stanols, vitamins and chemical elements, fiber, fatty acids, probiotics and prebiotics as well as bioactive peptides are constituents of bioac-

tive food [Guine *et al.*, 2010; Milner, 2004; Heş *et al.*, 2011; Reguła & Gramza-Michałowska, 2013; Sharma & Singh, 2010]. Research showed that bioactive compounds of food origin may fulfill many health-promoting functions in the human organism [Astrup *et al.*, 2010; Castro *et al.*, 2005; Cho *et al.*, 2013; Kris-Etherton *et al.*, 2002; Liu, 2013; Meydani & Hasan, 2010; Moller *et al.*, 2008; Morimoto *et al.*, 2012; Reguła & Gramza-Michałowska, 2010; Srinath & Katan, 2004]. They may lower cholesterol levels and blood pressure, enhance the immune system, regulate blood glucose levels and hormonal balance, help in the reduction of weight, slow down the ageing processes and counteract cancer.

ORIGIN AND DESCRIPTION OF GOJI FRUITS

Goji produces an ellipsoid orange-red berry approximately 2 cm deep with a sweet-and-tangy flavor. The Goji berry is the fruit of *L. barbarum* and *L. chinense* in the family *Solanaceae* that ranges from tomato and potato to eggplant. The author of the species name, *L. barbarum*, was Carl Linnaeus in 1753, whereas *L. chinense* was named 15 years later by Philip Miller. It is also known as Chinese wolfberry, possibly because Chinese farmers observed wolves eating these berries. *L. barbarum* and *L. chinense* are native to Asia, primarily in the central north region called Ningxia Hui Autonomous Region. In addition, commercial volumes of wolfberries grow in the Chinese regions of Xinjiang, Shaanxi, Gansu, Hebei, Inner Mongolia, and also in Japan, Korea, and Taiwan. China, the main supplier of wolfberry, yields 95,000 tones of Goji fruits, derived from 82,000 hectares. Goji berries have been an important part of traditional Chinese medicine for more than 2000 years due to their rich chemical composition and medical properties. As a food, dried wolfberries are traditionally cooked before consumption, used as herbal tea,

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TABLE 1. Composition of bioactive carotenoid fractions in goji berries (*Lycium barbarum*).

Compound	References	
	Wang <i>et al.</i> [2010]	Inbaraj <i>et al.</i> [2008]
Carotenoid fractions	13- or 13'- <i>cis</i> - β -carotene (8.97 mg/g), all- <i>trans</i> - β -carotene (16.6 mg/g), 9- or 9'- <i>cis</i> - β -carotene (10.3 mg/g), neoxanthin (13.2 mg/g), all- <i>trans</i> - β -cryptoxanthin (53.3 mg/g), 9- or 9'- <i>cis</i> - β -cryptoxanthin (5.61 mg/g), 9- or 9'- <i>cis</i> -zeaxanthin (39.3 mg/g), 13- or 13'- <i>cis</i> -zeaxanthin (4.85 mg/g), 15- or 15'- <i>cis</i> -zeaxanthin (32.8 mg/g), all- <i>trans</i> -zeaxanthin (1326 mg/g)	all- <i>trans</i> -zeaxanthin (1.4 μ g/g), all- <i>trans</i> - β -carotene (23.7 μ g/g), zeaxanthin monopalmitate (11.3–62.8 μ g/g), β -cryptoxanthin monopalmitate (32.9–68.5 μ g/g), zeaxanthin dipalmitate (1143.7 μ g/g)

as well as in Chinese soups, or in combination with meat and vegetarian meals. Goji fruits are also used for the production of juice, wine and tincture [Gross, 2006; Amagase & Farnsworth, 2011; Benzie & Wachtel-Galor, 2011; Potterat, 2010]. Goji is a plant introduced to Europe in the 18th century [Sopher, 2013]. *L. barbarum* prefers well-drained slightly alkaline soils [Peaceful Valley Farm Supply, 2013], and sunny locations. Germination temperature is 21–23°C, whereas for *L. barbarum* this is 15–25°C and is resistant to low temperatures, first fruition however is typically observed in 3-year-old plants [Dominion Seed House, 2013; Marczyński & Piotrowski, 2013].

CHEMICAL COMPOSITION OF GOJI BERRY

Goji berries are not without reason termed a “superfruit”. Wolfberries contain many nutrients with high biological activity, such as polysaccharide complexes, carotenoids, phenylpropanoids and others, as characterized below. The polysaccharide complex is the most important and the most abundant group of compounds present in Goji fruits. They are present in the water-soluble form of highly branched *L. barbarum* Polysaccharides (LBP) with a molecular weight of 8–214 kDa, and comprise 5–8% of the total dry matter of the fruits. Their composition includes six types of monosaccharides: arabinose, rhamnose, xylose, mannose, galactose, glucose, galacturonic acid and eighteen amino acids [Amagase & Farnsworth, 2011]. Research of dos Reis *et al.* [2014] showed that goji berries fermentation yielded 87% sugars decrease within 24 h, without losses in polyphenol content, however carotenoid content was reduced by 17%. Carotenoids present in Goji are the second highly significant group of biologically-active constituents with health promoting properties. They are responsible for the characteristic orange-red color of the berries. They comprise 0.03–0.5% of the dry matter of the fruits (Table 1). Zeaxanthin is one of the most common carotenoids present in Goji (31–56% of the total carotenoid pool). It is present in the form of dipalmitin zeaxanthin. Goji is considered the best natural source of dipalmitin zeaxanthin known so far. Beta-carotene, neoxanthin, cryptoxanthin are

also present at lower concentrations [Peng *et al.*, 2005; Wang *et al.*, 2010]. Phenylpropanoids are bioactive compounds with a very high antioxidant capacity. Analysis of the antioxidant activity and phenylpropanoids in different medicinal Chinese herbs has confirmed the presence of these constituents in Goji berry at the level of 22.7 mg (gallic acid equivalent/g extract) [Guo *et al.*, 2008]. A comparison of the phenolic profile and vitamin C content of Goji berry fruit is presented in Table 2. Wang *et al.* [2010] isolated and measured the levels of individual flavonoid fractions. The most common were quercetin-3-O-rutinoside, kaempferol-3-O-rutinoside, chlorogenic acid, caffeic acids and small amounts of caffeoylquinic acid and p-coumaric acid [Zhong *et al.* 2013]. Goji berries contain 1.0–2.7% of free amino acids, with the most abundant being proline. The presence of taurine and betaine has also been confirmed [Potterat, 2010]. Additional compounds present in Goji fruits are: vitamins, such as thiamin, riboflavin, and ascorbic acid with its glucosidic precursor (2-O- β -D-glucopyranosyl). The concentration of vitamin C was found at 42 mg/100 g [Donno *et al.*, 2015]. Llorent-Martínez *et al.* [2013] confirmed the presence of many mineral elements, the most common of which were potassium (1460 mg/100 g), sodium (550 mg/100 g), phosphorus (184 mg/100 g), magnesium (90 g/100 g) and calcium (50 mg/100 g). Interestingly, the iron concentration of 5.5 mg/100 g is high in respect to Dietary Reference Intake (DRI). Goji also contains organic acids, such as citric acid, malic acid, fumaric acid and shikimic acid [Mikulic-Petkovsek *et al.*, 2012]. The most common fatty acids are: palmitic acid, linoleic acid and myristic acid. According to literature, Goji berries provide 370 kcal/100 g dried fruits [Gross, 2006].

HEALTH-PROMOTING PROPERTIES OF GOJI BERRIES

Hypoglycemic properties

Many experiments have been performed in order to understand how Goji acts on the way the body handles carbohydrates. Luo *et al.* [2004] have investigated the correlation between supplementation with different polysaccharide fractions of Goji fruit and the levels of glucose in blood. The effects of *L. barbarum* preparations in alloxan-induced diabetic rabbits have been investigated by measuring a blood glucose level. Decreased blood glucose levels (≥ 3.9 mmol/L) were recognized as substantial hypoglycemic effects. Results of the experiment were unambiguous. It was found that all Goji preparations resulted in significantly decreased blood glucose levels after 10 days of treatment in the tested animals, indicating that there was a substantial hypoglycemic effect. Moreover, the hypoglycemic effect of purified polysaccharide fractions was more significant than those of water decoction and crude polysaccharide fractions, implying that *L. barbarum* polysaccharides were major bioactive components in the hypoglycemic effect. Guowen *et al.* [2010] performed a similar experiment and the results were propitious. Mice treated with *L. barbarum* extracts were characterized by significantly reduced blood glucose levels compared to the diabetic control group. Many experiments confirm diabetes is correlated with high oxidative stress. Hyperglycemia-induced oxidative stress

TABLE 2. Phenolic profile and vitamin C content of Goji berry (*Lycium barbarum*) fruit.

Chemical compound	(mg/100 g fw) Donno <i>et al.</i> [2015]	(mg/g ext) Wang <i>et al.</i> [2010]	(μ g/g pm) Mocan <i>et al.</i> [2014]	
Cinnamic acids	Caffeic acid	110.84	3.73	< 0.02
	Chlorogenic acid	113.18	12.40	5899.29
	Coumaric acid	111.32	6.06	30.29
	Ferulic acid	125.80	n.e.	< 0.02
Flavonols	Hyperoside	116.27	n.e.	n.e.
	Isoquercitrin	n.d.	n.e.	< 0.02
	Quercetin	n.d.	n.e.	5.59
	Quercetin-diglycoside	–	66.00	n.e.
	Quercitrin	n.d.	n.e.	13.00
	Rutin	n.d.	42.00	5646.66
	Kaempferol-3-O-rutinoside	–	11.30	n.d.
Benzoic acids	Ellagic acid	n.d.	n.e.	n.e.
	Gallic acid	15.31	n.e.	n.e.
Catechins	Catechin	118.76	n.e.	n.e.
	Epicatechin	229.18	n.e.	n.e.
Ellagitannins	Castalagin	n.d.	n.e.	n.e.
	Vescalagin	n.d.	n.e.	n.e.
Vitamin	Vitamin C	48.94		

fw – fresh weight; ext – extract; pm – plant material; n.d. – not detected; n.e. – not evaluated

may be implied in diabetes onset. The effect of *L. barbarum* treatment on antioxidative protective mechanisms has been investigated in streptomycin-induced diabetic rat kidneys. The antioxidative activity of superoxide dismutase, catalase and glutathione was significantly increased after Goji polysaccharide fractions treatment. Moreover, free radical scavenging activity was also elevated [Li, 2007]. Another experiment confirmed the increased activity of antioxidant enzymes in kidneys, lungs and liver of polysaccharide fractions-fed mice. Moreover, the same experiment revealed that animals on high-fat diets supplemented with polysaccharide fractions had statistically lower levels of glucose, compared to mice on high-fat diets only [Ming *et al.*, 2009].

LIPID-LOWERING PROPERTIES IN BLOOD

The effect of polysaccharide fractions supplemented high-fat diet has been analyzed in mice in order to evaluate its impact on total cholesterol, its LDL and HDL fractions and triglyceride levels. Mice administered polysaccharide fractions supplemented high-fat diets were characterized by decreased concentrations of total cholesterol, LDL-cholesterol and triglycerides and increased HDL-cholesterol concentrations compared to mice on high-fat diets without polysaccharide fractions [Li, 2007]. Cui *et al.* [2011] obtained identical results. Pai *et al.* [2013] performed similar experiments with rats on high-fat diets. Two groups of animals were tested, a control group (normal diet) and a group on high-fat diets

supplemented with hypoglycemic drug-statin (Atorvastatin). The results are consistent with previous findings. Polysaccharide fractions supplementation caused a decrease in total cholesterol, LDL-cholesterol fraction and triglyceride concentration compared to the rats on the control high-fat diet. Moreover, the polysaccharide fractions-supplemented rats were characterized by statistically lower triglyceride and statistically higher HDL-cholesterol concentrations compared to the atorvastatin-treated rats [Pai *et al.*, 2013]. Guowen *et al.* [2010] performed an alternative analysis where the effect of the polysaccharide fractions supplementation on the diabetic mice lipid profile was evaluated. The group of animals supplemented with Goji extract had significantly lower concentrations of triglycerides and total cholesterol compared to the diabetic control group. Zhao *et al.* [2005] obtained similar results confirming the hypothesis that Goji polysaccharide fractions supplementation has a positive effect on the lipid profile of rats through decreasing total cholesterol and triglyceride concentrations. Luo *et al.* [2004] performed an experiment with alloxan-induced diabetic rabbits and found that polysaccharide fractions supplementation resulted in a hypolipemic effect and a simultaneous increase in HDL-cholesterol concentrations. Then, Cheng *et al.* [2011] investigated changes in the lipid profile of polysaccharide fractions-supplemented rats with alcohol defects of the liver and found much lower levels of triglycerides, total cholesterol and LDL-cholesterol fraction, and a simultaneously increased HDL-cholesterol concentration.

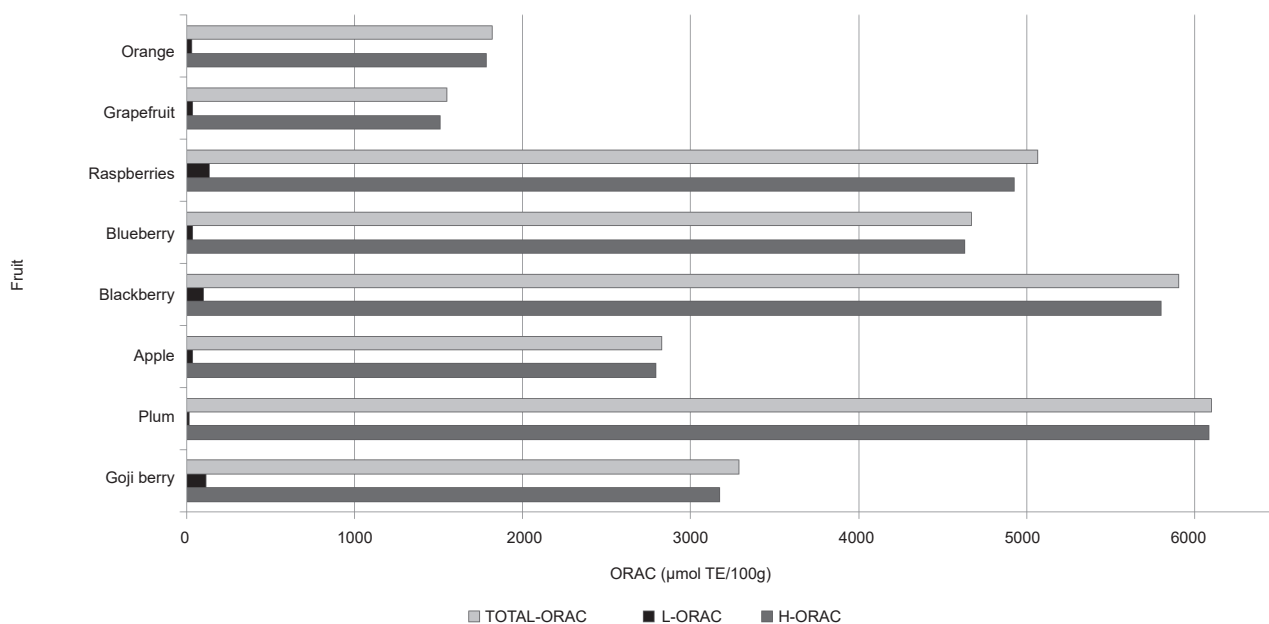


FIGURE 1. ORAC values for antioxidant activity of different fruits

ORAC – Oxygen Radical Absorbance Capacity; H-ORAC – hydrophilic for water soluble antioxidants ORAC value; L-ORAC – lipophilic for lipid soluble antioxidants ORAC value; TE – Trolox equivalents; compilation of results [USDA, 2010].

IMMUNOSTIMULATORY AND ANTICANCER ACTIVITY

Traditional Chinese medicine has utilized compounds present in Goji fruits to prevent the onset and progression of cancer. Goji also exhibits immunostimulatory activity. It has been confirmed in many tests that compounds present in Goji berries have pro-apoptotic and antiproliferative activity against cancer cells [Tang *et al.*, 2012]. Gan *et al.* [2004] confirmed that Goji polysaccharide fractions could significantly inhibit the growth of transplantable sarcoma in mice, moreover increased macrophage phagocytosis and antibody secretion by spleen cells. Furthermore, spleen lymphocyte proliferation was enhanced in comparison with the afflicted control group. It was also found that Goji polysaccharide fractions could significantly reduce lipid peroxidation in mice and inhibit proliferation of liver cancer cells [Zhang *et al.*, 2005]. Mao *et al.* [2011] also showed the anticancer properties of polysaccharide fractions. They proved the anticancer effect of *L. barbarum* polysaccharides on colon cancer cells through G0/G1 phase arrest. Zhu & Zhang [2013] also confirmed the antiproliferative activity of Goji polysaccharide fractions against HeLa cells, probably through induction of apoptosis. Zhang *et al.* [2011 a,b] also observed a similar effect. They found that the anticancer effect of Goji berry was attributed to 2-O-(beta-D-glucopyranosyl) ascorbic acid. Goji fruits are also a source of scopoletin. It has been proven that scopoletin induces inhibition of human prostate cancer cell proliferation (PC-3) [Liu *et al.*, 2000]. Amagase with coworkers [2009b] investigated the effect of Goji juice on healthy Chinese adults. Lymphocyte, interleukin-2 (IL-2) and immunoglobulin G levels in the treated group were significantly higher than those in the placebo group. Gan *et al.* [2003] observed activation of the immune system components through the administration of a *L. barbarum* polysaccharide-protein

complex that increased the expression of interleukin-2 and tumor necrosis factor-alpha at both mRNA and protein levels in human peripheral blood mononuclear cells. Glycans and glycoconjugates present in Goji exert a stimulatory effect on the expression of NF- κ B (nuclear factor kappa-light-chain-enhancer of activated B cells) and the activator protein 1 (AP-1) [Peng *et al.*, 2001]. Chen *et al.* [2008] confirmed activation NF- κ B and AP-1 through *L. barbarum* polysaccharides. They claimed that isolated fractions of LBP affected the proliferation of T cells and enhanced production of Interleukin 2 and Interferon gamma (IFN γ).

PROTECTIVE PROPERTY OF GOJI ON RETINA CELLS

A protective property of Goji extracts on retina cells has been proved in the early stage of the degeneration of the retina. It is proposed that absorbing the light zeaxanthin and luteolin present in Goji fruit displays an inhibitory effect on neuron apoptosis [Ni *et al.*, 2013]. Yu *et al.* [2013] proved that bioactive compounds present in *L. barbarum* enhance the expression of zeaxanthin and luteolin genes in diabetic mice. It is postulated that inhibited expression of these genes can cause hyperglycemia. Thus, Goji berries display neuroprotective properties on a diabetic animal's retina. The neuroprotective effect of polysaccharide fractions on the retinal ganglion cells (RGC) in rats with high intraocular pressure (IOP) also contributes to the prevention of glaucoma [Chiu *et al.*, 2010]. Tang *et al.* [2011] and Hu *et al.* [2012] also confirmed its protective influence on diabetic retinal injury. The protective property of *L. barbarum* extract on human retina neuron cells has also been demonstrated [Shen *et al.*, 2012]. It is suggested that Goji extract containing taurine may inhibit the progress of diabetic retinopathy [Song *et al.*, 2011].

ANTIOXIDANT POTENTIAL

Chemical analysis of Goji berry confirmed its high antioxidative activity. Based on the current analysis it was concluded that *L. barbarum* displays scavenging activity against free radicals (superoxide anion, hydroxyl radicals). Goji antioxidative activity is mainly attributed to carotenoid pigments, flavonoids, polysaccharide fraction and vitamin analog – C-2-O-(beta-D-glucopyranosyl) ascorbic acid [Guo *et al.*, 2008; Jiang, 2014; Li & Zhou, 2007; Lin *et al.*, 2009; Wang *et al.*, 2010; Zhang *et al.*, 2011 a,b]. One of the widely used markers of antioxidant potential is ORAC value (The Oxygen Radical Absorbance Capacity) [Gramza-Michałowska & Korczak, 2013]. ORAC of fresh berries was found to be similar to cherry or red currant [USDA, 2010]. A comparison of ORAC values for the antioxidant activity of goji berries and other fruits is presented in Figure 1. ORAC assay results for fruits represent its antioxidant value, not proportionally however for the human body, because of the bioactive compounds absorption and metabolism. The effect of *L. barbarum* extract on the oxidative stress induced in liver of rats on high-fat diets was investigated. Changes in the liver tissue levels of malondialdehyde (MDA), glutathione, as well as activity of antioxidant enzymes (superoxide dismutase, catalase and glutathione peroxidase) and oxygen radical absorbance capacity were used as biomarkers of the protective effect of *L. barbarum* used as a dietary supplement. The decreased MDA level used as a marker of lipid peroxidation was observed in animals on high-fat diets supplemented with *L. barbarum*. Furthermore, increased concentrations of glutathione and antioxidant enzyme activities were evaluated [Cui *et al.*, 2011]. The protective effect of *L. barbarum* extract on rats with alcohol-induced liver necrosis was investigated by Cheng & Kong [2011]. Results showed that animals supplemented with Goji fruits extract exhibited decreased activity of alanine aminotransferase (ALT) and aspartate transaminase (AST), biomarkers of liver damage. Moreover, a decreased MDA concentration and a significant increase in antioxidant enzyme activity SOD, CAT, GPx and increased glutathione levels characterized rats supplemented with *L. barbarum* extract. Shan *et al.* [2011] analyzed the influence of Goji fruit polysaccharides on oxidative stress induced by physical activity. The *L. barbarum* supplemented-group was characterized by a decreased MDA content and higher levels of SOD and GPX, which confirmed protection against oxidative stress caused by physical activity. Li *et al.* [2007] performed an interesting experiment on mice supplemented with polysaccharide fraction and analyzed oxidative stress caused by ageing. They observed increased activity of endogenous antioxidant systems (SOD, CAT, GSH-Px), decreased levels of lipid peroxidation markers (MDA) and increased total antioxidative capacity in the organs of animals (lungs, liver, heart, and brain) supplemented with polysaccharide fraction of Goji berries [Li *et al.*, 2007]. Then, Xiao *et al.* [2012] confirmed that this fraction exhibited liver-protective properties against the hepatotoxic oxidative stress inducer carbon tetrachloride. Reduced liver necrosis rates, increased activity of endogenous antioxidant system, and decreased lipid peroxidation expressed as MDA level were measured. Responses of humans supplemented with Goji juice exhibited similar patterns (increased

TABLE 3. Goji antioxidant capacity parameters evaluated with several methods.

References	TEAC	FRAP	DPPH	TPC
Henning <i>et al.</i> [2014]	2.7 [mmol TE/100g]	0.9 [mmol TE/100g]	1.4 [mmol TE/100g]	–
Mocan <i>et al.</i> [2014]	35.72 [μg TE/mg]	–	29.30 [μg QE/mg]	6159 [mg GAE/g]
dos Reis <i>et al.</i> [2014]	–	–	–	16.67 [mg GAE/g]
Medina [2011]	–	–	–	895 [mg GAE/100g]
Donno <i>et al.</i> [2015]	–	–	–	268.35 [mg GAE/100g]

TEAC – Trolox Equivalent Antioxidant Capacity; FRAP – Ferric Reducing Antioxidant Potential; DPPH – 2,2'-diphenyl-1-picrylhydrazyl; TPC – Total Polyphenol Content; QE – Quercetin equivalents; TE – Trolox equivalents; GAE – Gallic Acid Equivalents

activity of antioxidant enzymes SOD and GSH-Px, and decreased lipid peroxidation) [Amagase *et al.*, 2009a; Bucheli *et al.* 2011]. Wu *et al.* [2004] confirmed the scavenging activity against superoxide anions and inhibition of lipid peroxidation. Huang *et al.* [2001] also proved the antioxidative properties of *L. barbarum*. They showed that glycoconjugates present in Goji berries inhibit peroxidation of LDL-cholesterol fraction. Goji berries antioxidant capacity parameters evaluated with several methods were presented in Table 3.

SAFETY ISSUES

Wolfberries have attracted rapidly growing attention for their documented nutrient value, which has led to a profusion of consumer products. Goji products can be bought in health food stores in Europe and North America, and are advertised as natural mood boosters with anti-ageing properties. The reported health-promoting biological effects of *L. barbarum* indeed justify the term “superfruit”. While Goji berries have many health benefits, there are some side effects that consumers need to be aware of (the presence of toxic substances, risk of allergies and interactions with other medications).

The controversially high content of atropine (0.95%), a toxic alkaloid naturally present in Goji fruit, was tested in berries from India in 1989. However, published case reports do not describe people who have experienced atropine poisoning [Harsh, 1989]. Adams *et al.* [2006] carefully tested atropine levels by means of HPLC-PAD and TLC methods. They were not able to detect atropine. Using HPLC-MS, a small amount of atropine was found, with a maximum content of 19 ppb, well below a toxic level.

Allergic reactions to Goji berries rarely occur and only a few cases have been described. Monzón Ballarín *et al.* [2011] described the first two cases of patients who experienced allergic symptoms after Goji berry consumption. First woman developed anaphylaxis after eating Goji berries, accompanied by acute generalized urticaria on the hands, palms and lips, edema, dyspnea, and acute rhinitis; and second who reported generalized urticaria, severe pruritus and skin lesions (hives),

angioedema, and dysphagia after Goji berry consumption. The skin prick tests were positive for Goji berry. Additional tests confirmed an allergy to Goji berries in both cases. Lipid transfer proteins (LTPs) seem to be involved in allergic sensitization to *L. barbarum* berries, and results have demonstrated a high degree of cross-reactivity between Goji berry and peach and tomato [Carnes *et al.*, 2013; Larramendi *et al.*, 2012].

Three published case reports have described patients who experienced interactions between Goji berry and warfarin, an anticoagulant drug. An elevated International Normalized Ratio (INR) was observed in patients after drinking Goji tea and juice, previously stabilized on anticoagulation therapy, also increased bleeding from rectum and nose was observed [Lam *et al.*, 2001; Leung *et al.*, 2008; Rivera *et al.*, 2012]. Possible interactions between Goji and prescription medications are still unknown, thus the risks of wolfberries should be taken into consideration in individuals who take medications with a narrow therapeutic index.

CONCLUSIONS

Goji berry is well-known in traditional Chinese medicine and has been utilized as an important element of a health-promoting diet for hundreds of years. Recently, there has been rapidly growing attention surrounding wolfberries in the Western world. Health food stores provide a rich variety of Goji products, such as dried fruits, tea, beer, juice, sweets, musli and supplements [Potterat, 2010]. *L. barbarum* is a plant that could be cultivated in Europe. The main aim of this review was to gather and present state of the art data regarding the health-promoting properties of Goji fruits. Goji berry is a source of many bioactive compounds, characterized by high antioxidant potential. Goji fruits with a wide spectrum of biological effects have numerous implied health effects. Wolfberry may be an effective supplement in prophylaxis of diseases of affluence, such as diabetes, cardiovascular diseases and cancer. Goji is a safe food supplement, free from toxins; however, it can cause allergies; thus, the risks should be taken into consideration in individuals with food allergies, due to the high degree of cross-reactivity between wolfberry and peach and tomato. On the grounds of harmful herb-drug interactions that enhance drug performance, an anticoagulation therapy (warfarin) is a contra-indication to use Goji berry and any product containing wolfberry. The majority of published studies have used animal models in experiments. The results have been very optimistic and promising. However, additional research must be done with a greater number of experiments involving a larger number of animals, as well as experiments involving human subjects.

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