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Goji Bery: Important Bioactive Ingredients. A Mini-Review

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ABSTRACT

The fruits of goji berries have been considered since antiquity, and numerous modern research has proved that they are valuable to human health. Their bioactivity is attributable to a number of bioactive substances that they contain, with polysaccharides being considered the most important among them. This review is focused on bioactive compounds derived from goji berries. It is believed that these findings could be a useful tool for the goji berries producers, scientists, consumers and the food industry.

Introduction

General

Goji berry (*Lycium* sp) well known as wolfberry, boxthorn andkuko (in Japanese) orgou qi and keitze in Chinese is the common name of the fruits given by the expert in Tibetan traditional medicine and ethnobotanist Dr. Bradley Dobos. The genus *Lycium* (Solanaceae) contains about 80 representatives sprouting in distinct regions and distributed from the temperate to the subtropical regions of Eurasia, North America, South America South Africa and Australia [1]. Nowadays, the largest quantities of commercially produced goji berry fruits come from the Ningxia Hui in north-central China. Goji berry has been used as a medicine and functional food in Asia since ancient times and historical use of these fruits is important in traditional medicinal cultures such as China and Japan. According to traditional Chinese medicine the beneficial action of Goji berries, was related to their ability to contribute to the regeneration and stimulation of the liver and kidneys, improve the vision and act as a tonic to human body [2]. Thus, since the decade of 1980's numerous of research studies have been published with the aim to relate human health with the beneficial effects of goji berries fruit consumption. These studies have mainly focused on the antioxidant, anti-aging protection, neuro-protection, protection against glaucoma and diabetes, antimicrobial protection and anti-tumor properties as well as the immune-modulating effects of goji berry consumption [3-10]. Additional positive effects related to goji berry consumption are that it significantly reduces fatigue and stress and improves regularity of gastrointestinal function [11].

Important Bioactive Ingredients

According to Zhong, et al. [12] the proximate composition of dry goji berry fruits is 46% carbohydrates, 13% protein, 1.5% fat and 16% dietary fiber. Concerning vitamin and mineral content, Montesano, et al. [13], reported that 00 g of fresh goji berries contains 35 mg of vitamin C, 150.8 mg of potassium (K) and 61.4 mg of sodium (Na).

Polysaccharides: Among the biofunctional compounds described in goji berry fruit, polysaccharides are considered as one of the most important and their concentration varies from 1.02%-2.48% and 5%-8% for fresh and dried fruits, respectively [14]. Goji

berry polysaccharides are well explored for their bioactivity and considered among the most important bioactive ingredients of the fruit. They are glycosylated proteins, and most of them are water soluble. Pectic polysaccharides are major components, but glucan, xylan and arabino-galactan-proteins (AGPs) are also included. In the literature, they are designated as *L. barbarum* polysaccharides (LBP), and the range of their molecular weights is 10-2300 kDa [15,16]. LBP consist of nine monosaccharides, arabinose (Ara), galactose (Gal), glucose (Glc), fucose (Fuc), mannose (Man), rhamnose (Rha), xylose (Xyl), fructose (ribose), galacturonic acid (GalA) and glucuronic acid (GlcA), and 22 amino acids, aspartic acid, glutamic acid, hydroxyproline, serine, alanine, glycine, histidine, arginine, threonine, proline, tyrosine, valine, methionine, cystine, isoleucine, leucine, phenylalanine, tryptophan, ornithine and lysine. LBP qualitative and quantitative profile in monosaccharides as well as the position of their glycosidic linkages and their molecular weight collectively determine their pharmacological function. So far, about 30 polysaccharides in *L. barbarum* and 10 polysaccharides in *L. chinense* have been identified and characterized.

Polyphenols: Polyphenols are a complex group of more than 8000 known compounds found in many plant species and plant residuals that have become very popular in recent years due to the biological properties attributed to them [17-25]. The polyphenolic profile of *L. barbarum* consists of flavonoids and phenolic acids. According to Wang, et al. [26], the *L. barbarum* polyphenolic profile consists of phenolic acids (caffeic, coumaric, chlorogenic and caffeoylquinate) and flavonoids (quercetin diglucoside, -quercetin-3-O-rutinoside and nicotinflorin). Donno, et al. [27] carried out high pressure liquid chromatography (HPLC) analysis of polyphenolic profile of three samples of goji berry fruits originating from northern Italy plants of a variety developed after crossing *L. barbarum* and L.chinense species. The analytical results indicated that the three samples contained on average sinaminic acids, benzoic acids, flavonols, catechins, organic acids and vitamin C at levels of 461.14, 15.31, 116.27, 347.94, 4461.02 and 48.94 mg per 100 g^{-1}fresh fruit. In addition, Zhang, et al. [28], by testing eight samples of Chinese goji berry genotypes, came to the conclusion that fresh fruits derived from the four genotypes of the Ningxia region had the highest phenolic content and that quercetin-rhamno-di-hexoside (435-1065 μg g^{-1}) and quercetin-3-O-rutinoside (159-629 μg g^{-1}) appeared at higher concentrations than the flavonoid group, whereas chlorogenic acid was the predominant phenolic acid (526 μg g^{-1}).

Carotenoids: Carotenoids possess remarkable bioactive properties. The high percentage of carotenoids of goji berry fruits as well as their carotenoid profile make then an ideal source of these nutrients. According to Ma, et al. [29] goji berry carotenoid content depends on the season and territory of cultivation, and it is found to be higher in summer fruits than in fruit harvested in later seasons. Peng, et al. [30] observed that the total carotenoid content of different varieties of goji berry fruits ranges between 0.03% and 0.5% w/w. Among carotenoids, zeaxanthin and its esters are the most important carotenoids of *L. barbarum* [31,32]. The content of zeaxanthinates in goji berry fruit at the maturation stage can reach 77.5% of total carotenoids [33]. In particular, zeaxanthin dipalmitate is the predominant carotenoid in goji berries and along with zeaxanthin has been the focus of many researchers concerning their protective role against macular atrophic degeneration (AMD) [30,34,35]. Furthermore, zeaxanthin and its esters have been reported to exhibit anti-hepatotoxic activity comparable to that of silybin [36]. Zeaxanthin and other carotenoids such as β-carotene are also powerful antioxidants with proven positive health effects against oxidative stress-induced diseases. Concerning the carotenoid qualitative and quantitative profile in goji berries, Li, et al. [31], by using HPLC-DAD analysis, isolated and identified 10 carotenoids in total, including zeaxanthin, β-cryptoxanthin and their esters. In addition, Inbaraj, et al. [37], using HPLC-MS/GC flame ionization detector (GC-FID), isolated, identified and quantified 11 free carotenoids and 7 carotenoid esters, in particular zeaxanthin dipalmitate (1143.7 μg/g), monopalmitate β-cryptoxanthin isomers (32.9–68.5 μg/g), isoxanthinmonopalmitate isomers (11.3–62,8 μg/g), trans-β-carotene (23.7 μg/g) and all-trans-zeaxanthin (1.4 μg/g).

Fatty Acids: The beneficial properties of fatty acids, which are constituents of phospholipids- glycolipids in biological membranes in the human body, are related to the fact that they are involved in important metabolic processes. Fatty acids are also precursor molecules for the biosynthesis of essential steroid hormones and carry intracellular messages [38-41]. A number of studies, represented in provide data about the qualitative and quantitative fatty acid profile of Goji berries [8,42-47]. The results of these studies suggest that linoleic, oleic, palmitic, α-linolenic, stearic and arachidic acids are the primary fatty acids found in higher concentrations in goji berry fruits. On the contrary, Li, et al. [46] found that the concentration of the previously mentioned fatty acids was very low in oil derived from *L. barbarum* seeds.

Other Bioactive Ingredients: In addition to the major components mentioned previously, goji berry fruit also contains alkaloids, terpenes, cyclic peptides, cerebrosides, betaine, phytosterols and a number of important volatile compounds [48] presenting biological activity. Cerebrosides have been identified in *L. chinense* and, according to a study completed by Kim, et al. [49] they demonstrated hepato-protective activity against galactosamine-induced hepatotoxicity in a rat model. Other goji berry compounds with hepato-protective effects are the pyrrole derivatives and betaine [50]. On a dry basis, the betaine content of

goji berry *L. chinense* leaves was reported to be 1.5% and 0.9%-1.4% throughout the *L. barbarum* plant [51,52]. Lyciumin, a cyclic octapeptide (phenylpropanoids) found also in the roots of *L. chinense*, and it has been reported as a potential antihypertensive agent due to its inhibitory effects on the angiotensin-converting enzyme [53]. In addition, the 2-O-(β-D-glucopyranosyl) ascorbic acid (AA-2βG), which is a precursor of vitamin C, was isolated from Goji berries. The content of this pro-vitamin C compound was reported to be about 0.5% w/w on a dry basis for *L. barbarum* fruit, and relevant studies have shown that it increases the level of ascorbic acid in rat blood and additionally contributes to the antioxidant and anti-aging properties of goji berries [54].

Conclusion

The beneficial effects of goji berry fruits on human health include antioxidant and anti-aging activity; immunomodulatory and anti-cancer activities; antidiabetic, anti-hypertensive and hepatoprotective activity; protective effects on vision and finally prebiotic activity. Thus, the use of goji berries and their extracts in the production of high added value food and nutraceuticals that promote human health seems to be a quite promising research topic, involving innovative cutting-edge technologies that allowing full preservation of fruit bioactivity in the finished products.

Conflict of Interest

Not applicable.

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