Licium Barbarum cultivated in Italy: Chemical characterization and nutritional evaluation

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Abstract

Goji berries are the most cultivated fruit crop in Asian countries as they contain many nutrients and health-promoting bioactive compounds. These health-promoting properties have recently stimulated the interest of food and nutraceutical industries in Europe, so this crop has spread within Italy, which has become the largest European producer. Several works on the chemical composition and biological activities of Chinese goji berries are available. In this review, the chemical and the nutritional profile of goji berries from Licium barbarum spp. cultivated in Italy are reported.

Keywords: Goji berries; Licium barbarum spp; bioactive compounds; antioxidant properties; anticancer activities

Introduction

Goji berry or wolfberry is a bright orange-red berry produced by perennial plants of the genus Lycium, belonging to the Solanacee family (Aronson, 2006). Of late, Goji berries (GBs) used in traditional Chinese medicine are becoming very popular also in the Occidental world because of their properties, such as antioxidant (MA et al., 2019), anti-aging (Gao et al., 2017), anti-cancer (Ceccarini et al., 2016a; Georgiev et al., 2019), neuroprotective (Xing et al., 2016), antidiabetic (Zhao et al., 2020), immunomodulatory (Yang et al., 2013), anti-inflammatory (Chen et al., 2020), and others activities, such as hormonal profile and reproductive performance in livestock animals (Andoni et al., 2021; Brecchia et al., 2021; Agradi et al., 2022). Among Lycium (L.) species (spp), L. barbarum spp is definitely the most commercially widespread species given its high nutritional and medicinal value. The L. barbarum plant is a perennial plant that mainly grows in the Ningxia Hui Region in North-central China, the Xinjiang region in Western China, and also in Tibet and in Mongolia (Potterat, 2010). This plant is highly tolerant to adverse environmental conditions and grows in salinity regions and at different altitudes ranging from 700 to 2700 m (Kruczek et al., 2020).

In China, L. barbarum fresh leaves are much used in food dishes such as soups or used as herbal tea (Crawford, 2012) while the fruits are squeezed for their juice or used fresh or dried (Donno et al., 2015). The dried fruits and leaves have also been used for medicinal purposes, as a traditional Chinese medicine, for thousands of years (Zhu et al., 2013). According to the Traditional Chinese Pharmacopeia (TPC), Lycium spp can be used to treat various diseases including blurry vision, glaucoma, diabetes, kidney failure, cancer, cough, asthma, metabolism/energy expenditure, and aging (Amagase et al., 2009).

Many studies have shown that goji fruits have antioxidant, hypoglycemic, anticancer, and immunomodulatory effects so that supplementation of a regular diet with these berries can help to prevent many age-related
diseases (Gao et al., 2017; Ma et al., 2019; Ceccarini et al., 2016b; Menchetti et al., 2020). These health-promoting properties have also recently stimulated the interest of food and nutraceutical industries in Europe (Bae et al., 2017). This crop has spread within Italy, which has become the largest European producer (Knowles, 2016).

Several papers on the chemical composition and biological activities of Chinese GBs are available (Wang et al., 2021; Lu et al., 2021), less of Italian GBs (Lopatriello et al., 2017). This review aims to analyze the chemical and the nutritional profile of GBs from L. barbarum spp. cultivated in Italy and its application as a functional food.

**Nutritional composition of Italian GBs**

The nutritional composition of fresh GBs cultivated in Italy was investigated by Niro and Montesano (Niro et al., 2017; Montesano et al., 2018). Both research groups analyzed GBs samples from southern Italy. The nutritional composition of Italian GBs is reported in Table 1.

The results are very similar and the small differences may depend on some variables such as different methods of preparation and analysis of the samples.

The nutritional values make GBs an excellent source of macronutrients, especially carbohydrates. They are present as highly branched water-soluble L. barbarum polysaccharides and represent 5–8% of the total dry matter of the berries. Several studies indicate that the high biological activity components in GBs are polysaccharides (Amagase and Farnsworth, 2011). The mixture of L. barbarum polysaccharides exerts a retinal ganglion cell protection and reduces the oxidative stress in retinal/reperfusion injury (Li et al., 2011; Mi et al., 2012) and in high-fat diet fed mice (Ming et al., 2009) in which a decrease in total cholesterol, LDL-cholesterol, and triglycerides, and an increase in HDL-cholesterol have been observed (Luo et al., 2004). Thanks to the lipid-lowering and hypoglycaemic effects, the GBs exert a protective effect on the cardiovascular system (Ma et al., 2019). Moreover, Yang et al. demonstrated the immunomodulatory properties of L. barbarum polysaccharides that increased the phagocytosis and nitric oxide production of RAW 264.7 macrophages (Yang et al., 2015).

GBs have a low protein content (2–2.5 g/100g) and therefore they could not be considered a good source for protein. However, it has been shown that these fruits contained 17 of the 20 protein amino acids, including all eight essential amino acids (Lu et al., 2021).

**Table 1. Average nutritional composition (g/100g) of Italian fresh goji berries (mean± standard deviation).**

<table>
<thead>
<tr>
<th>Moisture</th>
<th>Fats</th>
<th>Proteins</th>
<th>Carbohydrate</th>
<th>Fiber</th>
<th>Ash</th>
</tr>
</thead>
<tbody>
<tr>
<td>Montesano et al., 2018</td>
<td>78±1.5</td>
<td>0.2±0.01</td>
<td>2.5±0.01</td>
<td>16.5±1.8</td>
<td>2.0±0.5</td>
</tr>
<tr>
<td>Niro et al., 2017</td>
<td>77.4±1.8</td>
<td>1.1±0.05</td>
<td>2.5±0.02</td>
<td>15.3±1.3</td>
<td>2.9±0.8</td>
</tr>
</tbody>
</table>

The second highly significant group of biologically active molecules present in GBs are carotenoids, the coloured components of goji fruits. The total carotenoid content of different L. barbarum fruits ranges from 0.03% to 0.5% of dried fruits with zeaxanthin dipalmitate representing more than 75% of the total carotenoids (Cenariu et al., 2021). Table 2 shows the total carotenoid and zeaxanthin dipalmitate content, expressed in milligram per 100 g of Italian dried fruits according to Bertoldi and Niro (Bertoldi et al., 2019; Niro et al., 2018).

The study of Bertoldi et al. showed that the average total carotenoid content of Asian GBs (197.8 mg/100g) was just over half of the Italian ones (355 mg/100g). These data are of particular importance as it means that Italian GBs have a biological and nutritional value higher than those of Asian origin. Instead, the data obtained by Niro showed levels of carotenoid and Zeaxanthin palmitate similar to those of Asian origin. The discrepancy between the data may depend on the different methods used for their determination or to ecological factors and cultural practices (Arena and Curvetto, 2008).

Goji antioxidative power has carotenoid content (Kulczyński and Gramza-Michalowska, 2016; Chang and So, 2008). Many studies have demonstrated a correlation between antioxidant activity of L. barbarum fruit and its antitumor (Potterat et al., 2010; Ceccarini et al., 2016a; Georgiev et al., 2019), anti-inflammatory (Amagase and Farnsworth, 2011; Chen et al., 2020), and immunomodulatory (Yang et al., 2013) activities. Cenariu et al. have indicated the cytoprotective activity of a zeaxanthin-rich extract from L. barbarum berries on tumor-derived A375 skin cell line through mitogen-activated protein kinase (MAPK) influence (Cenariu et al., 2021).

**Table 2. Average total carotenoid and zeaxanthin dipalmitate content (mg/100g) in Italian dried goji berries (mean± standard deviation).**

<table>
<thead>
<tr>
<th>Total carotenoids</th>
<th>Zeaxanthin dipalmitate</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bertoldi et al., 2019</td>
<td>355±49</td>
</tr>
<tr>
<td>Niro et al., 2018</td>
<td>184±4</td>
</tr>
</tbody>
</table>
Mineral composition of Italian GBs

GBs are also extremely rich in many minerals which are essential components for a balanced diet. Indeed, adequate mineral intake is essential for many human vital functions such as oxygen transport, muscle contraction, enzyme activation, blood acid–base balance, bone structure, nerve impulse conduction, heart contraction, antioxidant system activity, and immune system activation (Williams, 2005). Sodium and potassium, for example, are macro elements essential for membrane depolarization and body water balance, calcium for mineral bone structure and muscle and heart contractions, magnesium is a cofactor of more than 300 enzymes and is required for energy production and nucleic acid synthesis (Sá et al., 2019). The average values of principal macro elements in dried Italian GBs are shown in Table 3.

It was observed that potassium (K) is the main macro element of the Italian and Asian GBs. Anyway, the K concentration determined by Bertoldi in Italian GBs was about twice the average values found in Asian GBs (Endes et al., 2015). High dietary K intake (>3.5g/day) is associated with a decrease in blood pressure as documented in several clinical studies (Binia et al., 2015). Sodium (Na) concentrations were very similar in all Italian samples but about a third of that was found in the Asian GBs (Llorent-Martinez et al., 2013). Many studies suggest a direct relationship between Na intake and blood pressure values (Mente et al., 2014). Indeed, excessive Na intake (defined as >5 g Na per day (WHO, 2012)) has been shown to produce a significant increase in blood pressure and has been linked with the onset of hypertension and its cardiovascular complications (Weinberger, 1996; Strazzullo et al., 2009).

Also, phosphorus (P), magnesium (Mg), and calcium (Ca) contents were rather different in the two studies. The P value of the Bertoldi et al. study was particularly high even when compared to data obtained for Asian GBs (270 mg/100g). These discrepancies can be due to mineral variation in the soil and water source mineral quality and differences in growing conditions. Referring to Recommended Dietary Allowances (RDA) and Adequate Intake (AI), a daily portion of about 30 g of dried GBs provides on average 20% of RDA for Mg and P, 6–9% of AI for K and Na, and 1–2% of RDA for Ca (Bertoldi et al., 2019).

Regarding arsenic (As), a daily portion (30 g) of Italian GBs provides around 12 µg which is one-third less than Asian goji’s As content (18 µg/30g). Daily intake of a portion of 30 g of Italian GBs provides 5.8 µg of cadmium (Cd) which is about twice the Asian goji’s average Cd content. Thirty grams of Italian GBs also provides 0.17 µg of mercurius (Hg), a value slightly higher than that measured in Italian GBs (mean± standard deviation). The average values of the main toxic trace elements measured in Italian GBs are shown in Table 5.

Table 5. Average values (µg/100g) of the main toxic trace elements in dried Italian goji berries (mean± standard deviation).

<table>
<thead>
<tr>
<th></th>
<th>Fe</th>
<th>Zn</th>
<th>Cu</th>
<th>Mn</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bertoldi et al., 2019</td>
<td>3.9±1.8</td>
<td>3.5±1.3</td>
<td>1.3±0.8</td>
<td>1.1±0.2</td>
</tr>
<tr>
<td>Niro et al., 2018</td>
<td>3.5±1.5</td>
<td>1.5±0.6</td>
<td>0.8±0.2</td>
<td>0.5±0.2</td>
</tr>
</tbody>
</table>

Fe, Ferrum; Zn, Zincum; Cu, Cuprum, Mn, Manganesum.

A similar amount of Fe was found by the two research groups and these values were about half of that found in the Asian GBs (Bertoldi et al., 2019). Zn, Cu, and Mn contents from Bertoldi et al. samples were about two times higher than Asian berries, whereas the Zn, Cu, and Mn values from Niro et al. were similar to those of the Asian GBs (Bertoldi et al., 2019). Referring to RDA, a daily portion of about 30 g of dried GBs provides on average 10% of AI for Mn (Bertoldi et al., 2019).

In addition, GBs can be a good source of microelements. The most abundant micro elements in GBs are reported in Table 4. Iron (Fe) is a very important mineral for living organisms since it participates in a wide variety of metabolic processes such as oxygen transport, electron transport, and DNA synthesis (Lieu et al., 2001). Zinc (Zn), copper (Cu), and manganese (Mn) are essential elements that principally act as cofactors of different enzymes, which participate in all the major metabolic pathways (Agget and Harries, 1979; Cox, 1999; Eirkson and Aschner, 2003).

Toxic trace elements present in Italian GBs

GBs may also contain some toxic elements that can have a negative impact on human health (Bordean et al., 2011). Bertoldi et al. also investigated Italian GBs for their toxic metal concentrations by comparing them with Asian GBs. The average values of the main toxic trace elements measured in Italian GBs are shown in Table 5.

Regarding arsenic (As), a daily portion (30 g) of Italian GBs provides around 12 µg which is one-third less than Asian goji’s As content (18 µg/30g). Daily intake of a portion of 30 g of Italian GBs provides 5.8 µg of cadmium (Cd) which is about twice the Asian goji’s average Cd content. Thirty grams of Italian GBs also provides 0.17 µg of mercurius (Hg), a value slightly higher than that found in Asian GBs (0.11 µg/30g). Finally, a daily portion of 30 g of Italian GBs provides 10.7 µg of lead (Pb), a value slightly higher than that found in Asian GBs (8.43 µg/30g).
of Italian GBs provides 25.3 µg of plumbum (Pb) that represent a significant amount of the daily dietary intake (0.02–3 µg/kg bw/day), but it is one sixth of that found in Asian berries (Bertoldi et al., 2019). Thus, concerning toxic elements, Italian GBs are better than Asian GBs.

However, caution should be used in taking large amounts of these fruits because excessive intake can overload the body with toxic mineral (Gogoasa et al., 2014).

Fatty acid and sterol composition of Italian GBs

Cossignani et al. studied fatty acid and sterol composition of GBs samples from Italy, China, and Mongolia in order to distinguish goji samples of different production areas (Cossignani et al., 2018).

Table 6 shows average lipid percentage and the average percentage values of saturated (SFA), monounsaturated (MUFA), and polyunsaturated (PUFA) fatty acids from the previously mentioned three origins.

As can be seen, the lipid percentage of Italian GBs samples was higher than that of Asian samples, in accordance with literature data (Endes et al., 2015; Rosa et al., 2017). In addition, Italian GBs samples compared to Asian ones are richer in saturated (18.9% vs 14 and 16.4 % of Chinese and Mongolian samples) and monounsaturated (31.7% vs 20.8 and 21.2 % of Chinese and Mongolian samples) fatty acids but poorer in polyunsaturated fatty acids (48.4% vs 64.2 of Chinese and Mongolian samples). Anyway, the PUFA was the most abundant fraction in all samples and the linoleic acid (C18:2 n-6) was the most abundant PUFA acid for both Italian and Asian samples, followed by α-linolenic acid (C18:3 n-3), most abundant in Italian samples with respect to Asian samples (Cossignani et al., 2018). The low percentage of lipids combined with the richness in PUFA makes GBs a new dietary source of essential fatty acids, especially linoleic acid.

Cossignani and co-workers also studied the sterol fraction of GBs from Italy, China, and Mongolia. To this end, alkaline hydrolysis was carried out on goji lipid fraction to obtain data about percentage and quantitative composition (mg/100g) of the main phytosterols identified in Italian and Asian samples (Table 7).

It can be noted that Δ5-sterols were the major components compared to Δ7-sterols and that β-Sitosterol was the most abundant sterol in Italian and Chinese samples while Δ5-Avenasterol was the most abundant sterol in Mongolian samples.

β-Sitosterol, the predominant component in Italian samples (53.7%), is known to lower blood cholesterol levels in humans and also for its strong free radical scavenging activity (Lin et al., 2014). In addition to these properties, phytosterols possess anti-inflammatory, anti-cancer, and anti-atherogenicity activities (Berger et al., 2004).

The nutritional quality of the lipid and sterol fractions of the Italian GBs was confirmed through the determination
of the atherogenicity (AI), thrombogenicity (TI) indexes, and hypocholesterolemic (HI) index since the low values of these indexes (0.1% AI, 0.2% TI, and 10% HI, respectively) showed a good amount of anti-atherogenic lipids in the examined samples (Ulbricht and Southgate, 1991; Fernandez et al., 2007).

**Total tocopherols and ascorbic acid amounts in Italian GBs**

Niro’s research group also determined the average total tocopherols (vit E) and ascorbic acid (Vit C) amounts in fresh and dried Italian GBs samples as reported in Table 8.

<table>
<thead>
<tr>
<th></th>
<th>Fresh</th>
<th>Dried</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total tocopherols</td>
<td>2.4±0.04</td>
<td>9.7±0.20</td>
</tr>
<tr>
<td>Ascorbic acid</td>
<td>40±2.2</td>
<td>38±0.8</td>
</tr>
</tbody>
</table>

Taking into account the RDA for vit E, which is 12 mg/day (Regulation EU1169/2011) and RDA for vit C which is 80 mg/day (Regulation EU1169/2011), a portion of dried GBs (30 g) provides about 20% of the RDA for vit E and 16% of the RDA for vit C. Donno et al. (2015) reported an amount slightly higher (42 mg/100 g) of vit C in Italian dried GBs from northern Italy.

**Health benefits of Italian GBs**

Antioxidant properties together with anticancer activity of Italian GBs were investigated.

This berry has been described as a “super-fruit” thanks to its concentrated levels of beneficial substances and anti-oxidant powers. The antioxidant properties of Italian *L. barbarum* fruits (cultivated in Umbria) have been evaluated by determining the total phenolic content (TPC) and the Oxygen Radical Absorbance Capacity index (ORAC) (Ceccarini et al., 2016b). The TPC value, expressed as milligram of gallic acid equivalents (mg GAE) per 100 g of dry weight (DW) resulted in 1278.247 ± 29.60 mg GAE/100g DW. These results showed that Italian GBs have a TPC higher than the Asian one (712.01 ±29.12gGAE/100g), whereas the ORAC value, expressed as micromoles of Trolox Equivalent per 100 g of DW (µmol TE/100g DW), was slightly lower than the Asian one (22507.03±1402.02 µmol TE/100 g DW vs 26502±3807 µmol TE/100g DW). These data showed that GBs cultivated in Italy have high antioxidant properties.

Moreover, Italian fruits (cultivated in Umbria) have also been tested for their apoptotic and antiproliferative effects on human hepatocellular carcinoma (HepG2) cell line (Ceccarini et al., 2016b). To this end, a panel of 96 genes involved in oxidative stress, proliferation, and apoptosis was investigated in HepG2 cells using a quantitative real-time PCR-array analysis. Downregulation of genes involved in tumor migration and invasion together with upregulation of tumor suppressor genes suggests that Umbrian GBs play an anticancer role in vitro and could play a role against hepatocellular carcinoma (Ceccarini et al., 2016b).

**Conclusions**

Despite the limited literature data concerning the chemical and nutritional characterization of GBs cultivated in Italy, it is possible to conclude that these fruits are an important source of bioactive compounds. In addition, Italian GBs showed some nutritional differences with those of Asian origin. In particular, Italian GBs show a higher content of carotenoids and potassium in comparison to the Asian one. Finally, Italian GBs contain fewer toxic elements in comparison to the Chinese GBs. It is possible to conclude that GBs, but in particular those of Italian origin, are loaded with important nutrients and antioxidants that can support the diet for a better quality of life.

**References**


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