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Physico-chemical Properties, Mineral Matter, Organic Acid, Amino Acid, and Plant Hormones Content of Goji Berry (*Lycium barbarum* L.) Grown in Turkey

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A R T I C L E I N F O

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A B S T R A C T

With high nutritional value, goji berry is an important fruit for human nutrition and health. Goji berry cultivation is done widely in many countries, farming has become widespread in recent years in Turkey. In study grown goji berry (*Lycium barbarum* L.) in Turkey are determined the physical and chemical characteristics of fruit (pH, titration acidity, dry matter content, ash content, water activity (a_w) value, protein content, HMF content, total phenolic content, total sugar content, reducing sugar content, sucrose content, colour values, mineral contents, organic acid contents, amino acid contents and some plant hormone content). Goji berry fruits have pH value 5.18, titration acidity value 2.16%, dry matter content 89.40%, ash content 4.30%, water activity (a_w) value 0.35, protein content 13.18%, HMF content 9.38 mg/kg, total phenolic content 9.05 mg GAE/g, total sugar content 59.26%, decreasing sugar content 57.35%, sucrose content 1.90%, L^* value 40.33, a^* value 22.97, b^* value 33.00, C^* value 40.21, H° value 55.15. In addition, the mineral content, organic acid content, amino acid content and some plant hormones of goji berry fruits were determined by analysis.

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Introduction

Medicinal plants are used in the treatment of many diseases (Akgül et al., 2020; Pehlivan et al., 2021). In this sense, goji berry also has a special importance. Goji berry has long played important roles, especially in Traditional Chinese Medicine (Shahrajabian et al., 2020). Goji berry, which belongs to the *Lycium* genus of the Solanaceae family, includes about 80 species (Levin and Miller, 2005). All these species are plants in the form of deciduous perennial shrubs, which have a fairly similar morphology and structure (Qian et al., 2017). In addition, goji berry is also referred to as goji or wolfberry in the literature. *Lycium* is distributed in subtropical regions in temperate regions of South America, North America, Southern Africa, Eurasia and Australia (Fukuda et al., 2001). *Lycium* fruits (*Lycium barbarum*, *Lycium chinense*) are mostly grown and distributed in Northwest China (Yossa Nzeuwa et al., 2019). Goji berry is used as a functional food in many countries of East Asia, Europe and North America (Ferraz et al., 2019). Goji berry fruits are used as a traditional herbal tea in Asia (Sun et al., 2017). Apart from herbal tea, it is also widely used in Chinese soups. In addition, this fruit is preferred in production areas such as tincture, wine and juice (Ma et al., 2019). Scientific analysis of goji berry components began in the 1970s (Chen et al., 2018) and the fruit was found to have high nutritional value (Amagase et al., 2009). Goji berry, a rich source of antioxidant compounds, is important for health. Goji berry antioxidants have many beneficial effects in maintaining health by reducing oxidative stress (Donno et al., 2015). As a result of modern medicine, nutrition and pharmacology studies, it has been determined that goji berry fruits, leaves and roots contain polysaccharides, vitamins, amino acids and trace elements (Ahn et al., 2014). It is known that dried goji berry (100 g) contain approximately 10.2 g of protein, 4.4 g of fat, 61.3 g of total carbohydrate, 184.2 mg of total carotenoid, 101.3 mg of Ca, 45.9 mg of Mg (Niro et al., 2017). In this study, it was aimed to determine some physical and chemical contents of *L. barbarum*, which is grown in our country, is classified as functional foods and has an area of use as a natural antioxidant additive.

Materials and Methods

Plant material

Fully ripened NQ1 fruits (*L. barbarum*) in September 2020 in Bor (Niğde, Turkey) were collected from plants. The fruits were left to dry in the oven at 40°C for 48 hours. The dried fruits were ground, sieved and stored in jars at 4°C until analysis.

Determination of titration acidity and pH value

pH value was done by using pH meter calibrated with pH 7.0 buffer. Titratable acidity was determined potentiometrically by titrating the sample with 0.1 NaOH until the pH reached 8.1 and expressed as g/100g anhydrous citric acid (Cunnif, 1999).

Determination of dry matter and ash content

Dry matter content was determined as using an air oven at 104°C. The dry matter content obtained was calculated using the formula below (Cunnif, 1999). Dry matter content was determined according to the formula below.

$$\text{Dry matter (\%)} = \frac{\text{Final weight} - \text{Tare weight}}{\text{Weight of sample}} \times 100$$

Ash content was determined by burning the samples in an ash furnace at 550 °C until they became white ash. The ash content obtained was calculated using the formula below (Cunnif, 1999). Ash content was determined according to the formula below.

$$\text{Ash (\%)} = \frac{\text{Weight of ash}}{\text{Weight of sample}} \times 100$$

Determination of water activity (a_w) value

Water activity was measured three times per treatment using an Novasina Labmaster water activity meter.

Determination of protein content

The protein quantity was obtained by Kjeldahl method. The protein content obtained was calculated using the formula below (Cunnif, 1999).

$$\text{\% Protein} = \text{\% Total nitrogen} \times 6.25$$

Determination of HMF content

Hydroxymethylfurfural (HMF) was identified by measuring the absorbance variation of the samples by barbituric acid and p-toluidine, using a spectrophotometer (Winkler, 1955).

Determination of total phenolic content

The phenolic matter content was determined in accordance with Folin-Ciocalteu method (Gulcin et al., 2002).

Determination of total sugar, reducing sugar and sucrose content

Total sugar, reducing sugar and sucrose contents were determined by the Lane-Eynon method (Lane and Eynon, 1934). In this method, it is based on the principle of reducing the copper-2 oxide in the Fehling solution of invert sugar to the water-insoluble copper-1 oxide.

Determination of colour values

Colour values (L^*, a^* and b^*) of the samples were measured using Minolta Reflectance Chroma Meter CR-300. Using L^*, a^* and b^* values, colour density (C^*) and hue angle (H°) were calculated according to the formulas below (Pathare et al., 2013).

$$C^* = \sqrt{a^{*2} + b^{*2}}$$
$$H° = \tan^{-1} b^*/a^*$$

Determination of mineral contents

Firstly, the samples were washed with distilled water and cleaning procedure was carried out. The samples were then oven-dried at 65°C until their weight was constant. Finally, the samples ground and sieved through a 50-mesh screen. Kjeldahl method and a Vapodest 10 Rapid Kjeldahl Distillation Unit (Gerhardt, Germany) were used to determine total N (Bremner and Mulvaney, 1982). After extraction methods, tissue B, Ca, Cu, Fe, K, Mg, Mo, N, Na, P and Zn were determined with an inductively coupled plasma spectrophotometer Perkin-Elmer Optima 2100 DV ICP/OES (Perkin-Elmer, USA).

Determination of organic acids

For organic acid analysis, 10 mL deionized water was added to sample (1 g), solution was then homogenized with ultraturraks. After centrifuging at 1200 rpm for 50 min, supernatants were filtered. In vials, organic acid determined by using HPLC (Shi et al., 2006).

Determination of amino acids

To determine amino acid analysis, 0.1 N HCl added 1 g sample, homogenized with ultraturraks, and incubated in 4°C at 12h. After samples were centrifuged at 1200 rpm for 50 min, supernatants were filtered through 0.22 m (Millex Millipore). Then supernatants were transferred tovial and vials for amino acid acid analysis in HPLC as de-scribed by Aristoy and Toldra (1991) and Antoine et al. (1999).

Determination of some plant hormones

Extraction and purification processes for hormone analysis It was made according to Davis et al. (1995). Indole acetic acid (IAA) gibberellic acid (GA), salicylic (SA) and abscisic acid (ABA) high performance liquid chromatography in analysis (HPLC) has been used (Horgan and Kramers, 1979, Morris et al., 1990, Takahashi, 1986). Abscisic acid (ABA), gibberellic acid and indole-3-acetic acid (IAA), were determined with 13% acetonitrile (pH 4.98) as the mobile phase.

Statistical analysis

Results of the research were analysed for statistical significance by analysis of variance.

Result and Discussion

Titration acidity and pH value

Titration acidity value, pH value, dry matter content, ash content and total phenolic content, which are important indicators of sensory quality of goji berries, are shown in

Table 1. The pH and titratable acidity of goji berries were determined as 5.18% and 2.16%, respectively. Zhang et al. (2016) determined the titratable acidity of goji berry fruit 0.8-1.4%, Ilić et al. (2020) 0.70-0.89%, Catav and Pırlak (2020) determined it as 0.05-0.19. It is seen in our study that the titration acidity value is within the range of the reported values. The pH value of goji fruit has been reported as 4.98-5.71 Catav and Pırlak (2020) and 4.71 Ilić et al. (2020).

Dry matter and ash content

The dry matter and ash content of goji berries were 89.40% and 4.30%, respectively. Dry matter content Pedro et al. (2019) reported it as 84.71%, Niro et al. (2017) 90.7%. It is seen that the dry matter content in our study is approximately the similar with the results reported. Ash content Ilić et al. (2020) reported it as 0.84%, Pedro et al. (2019) 3.01% and Niro et al. (2017) 3.4%. It appears that the ash content in our study is higher than the results reported by.

Water activity (a_w) value

Water activity of goji berry was determined as 0.35 (Table 1). Pedro et al. (2019) reported the water activity value of goji berry 0.37, it is seen that the water activity value in our study is approximately the similar with the results reported.

Protein content

In our study, the protein content of goji berry was determined as 13.18%. In similar studies, the content of protein in fresh goji berry Ilić et al. (2020) 1.98%, in dried goji berry Niro et al. (2017) 10.2%, in dried fruit Endes et al. (2015) 8.9%, in lyophilized goji berry Pedro et al. (2019) 9.72%, Covaci et al. (2020) 3.5-20.3% found it to be. Our conclusion is consistent with the data from previous studies, that goji berries have significant potential to provide the required daily protein for adults (0.8 g/kg body weight).

HMF content

HMF content of goji berry was determined as 9.38 mg/kg. At the end of any heating or storage applied to foods containing carbohydrates; depending on the temperature and time, a small or large amount of HMF is always formed.

Total phenolic content

Quantification of total phenols is especially important for nutraceutical use of foods. In our study, the total phenolic content of goji berry was determined as 9.05 mg GAE/g. Islam et al. (2017) 2.17-9.01 mg GAE/g, Ozkan et al. (2018) 9.04 mg GAE/g, Jeepipalli and Xu (2020) 86.88 mg GAE/g and 56.97 mg GAE/g in fresh and dried goji berries, respectively, Ilić et al. (2020) 162.4 mg GAE/100 g has been reported to have a total phenolic amount of. When the previously published data are compared with our results, the differences observed in the contents of phenolic substances can be explained by different climatic and soil factors affecting plant growth with varieties.

Total sugar, reducing sugar and sucrose content

The taste and quality of fruits mainly depend on sugars, organic acids, amino acids. Total sugar, reducing sugar and sucrose content of goji berry were determined as 59.26, 57.35 and 1.90, respectively (Table 1). The total sugar content of goji berries, Li et al. (2017) 40.72-60.73% in 114 samples, Tang and Liu (2013) found it to be 40.70-53.78% in 40 samples. Wang et al. (2019) reported that the concentrations of sucrose varied between 3.8-5 mg/g and glucose and fructose concentrations between 30-39 and 50-55 mg/g, respectively. Donno et al. (2019) determined the sucrose content of goji berry as 2.77 g/100 g. Our result is between these values.

Colour values

In our study, L^*, a^*, b^*, C^* and H° values of goji berries were determined as 40.33, 22.97, 33.00, 40.21 and 55.15, respectively. Song et al. (2018) reported L^* value as 24.5-33.5, a^* value as 12.5-26.1, b^* value as 5.82-13.0; Pedro et al. (2019) reported 34.83 L^*, 31.82 a^*, 34.99 b^* in dried goji berry.

Mineral contents

Goji berry (*L. barbarum*) is known for their nutritional potential as a great source of trace metals (e.g., copper, zinc and manganese) which are present in the form of highly bioaccessible compounds (Wojcieszek et al., 2017). The content of both macro and microelements in goji berries is shown in Table 2. Potassium (30871 mg/kg) has been identified as the dominant element. Molibden (5.93 mg/kg) and sodium (2.44 mg/kg) became the least abundant nutrient. Endes et al. (2015) and Niro et al. (2017) reported slightly different results from ours. It is important to emphasize that the mineral content of fruits depends on the soil properties in which they are grown, the physiology of the plant, the water source composition and the fertilizers, insecticides, pesticides and fungicides used in the fields.

Organic acids

Goji berry is a rich source of bioactive compounds with functional properties. Among the organic acids we analysed, succinic acid was found to have the highest value of 17.85 ng/µL, and maleic acid to have the lowest value of 0.19 ng/µL (Table 2).

Table 1. Averages of some physical and chemical parameters of goji berry

Parameters	Averages	Parameters	Averages
pH	5.18±0.01	Total sugar (%)	59.26±0.97
Titration acidity (%)	2.16±0.04	Reducing sugar (%)	57.35±1.27
Dry matter (%)	89.40±1.20	Sucrose (%)	1.90±0.39
Ash (%)	4.30±0.11	L^*	40.33±0.53
Water activity (a_w)	0.35±0.00	a^*	22.97±0.34
Protein (%)	13.18±0.01	b^*	33.00±1.03
HMF (mg/kg)	9.38±0.58	C^*	40.21±1.04
TPC (mg GAE/g)	9.05±0.21	H°	55.15±0.46

HMF= Hydroxymethylfurfural, TPC= Total Phenolic Content

Table 2. Averages of minerals and organic acids contents of goji berry

Minerals	Averages (mg/kg)	Organic acids	Averages (ng/µL)
B	18.01±1.51	Butyric acid	2.78±20.25
Ca	10613±1.10	Citric acid	2.61±10.30
Cu	58.29±0.69	Fumaric acid	2.10±15.41
Fe	289.23±1.15	Lactic acid	17.03±16.14
K	30871±3.30	Maleic acid	0.19±30.10
Mg	2346±10.11	Malic acid	6.21±18.27
Mo	5.93±0.18	Malonic acid	5.01±26.34
N	2.44±0.20	Oxalic acid	6.00±19.51
Na	452±1.15	Propionic acid	3.38±36.48
P	3591±14.26	Succinic acid	17.85±41.36
Zn	54.52±0.49	Tartaric acid	2.17±38.15

Table 3. Averages of amino acids of goji berry

Amino acids	Averages (pmol/µL)	Amino acids	Averages (pmol/µL)
Alaine	6182±0.51	Leucine	1858±0.05
Arginine	6848±1.40	Lysine	2887±1.63
Asparagine	11946±1.21	Methionine	1134±1.40
Aspartate	3115±0.22	Phenylalanine	1604±0.71
Cysteine	1091±0.93	Proline	68±1.50
Glutamate	1393±1.25	Sarcosine	5361±2.05
Glutamine	3711±1.09	Serine	5231±1.23
Glycine	2582±1.69	Threonine	3286±0.76
Histidine	1858±1.03	Tryptophan	1652±1.22
Hydroxyproline	1036±1.72	Tyrosine	889±1.64
İsoluecine	1323±1.07	Valine	651±3.07

Table 4. Averages of some plant hormones of goji berry

Hormones	Averages (ng/µL)
Abscisic acid (ABA)	0.35±1.48
Gibberellic acid	139.31±2.54
Indole-3-acetic acid (IAA)	21.71±0.95

Amino acids

The 22 amino acids content of goji berry is shown in Table 3. Goji berries contain a large number of amino acids. Asparagine (11946 pmol/µL), arginine (6848 pmol/µL), alaine (6182 pmol/µL), sarcosine (5361 pmol/µL), serine (5231 pmol/µL) and glutamine (3711 pmol/µL) at the highest level identified as amino acids found. The lowest values were determined in proline (68 pmol/µL), valine (651 pmol/µL) and tyrosine (889 pmol/µL). Zhao et al. (2020) reported amounts of histidine (2.68-11.11 mg/100 g), isoleucine (11.13-20.22 mg/100 g), leucine (12.30-34.47 mg/100 g), methionine (0.71-3.99 mg/100 g) valine (3.98-8.76 mg/100 g) and lysine (3.76-6.76 mg/100 g).

Some plant hormones

Hormones are the basic internal factors regulating the growth and development of the plant and have chemical properties. Some of the plant hormones determined in goji berry are shown in Table 4. Abscisic acid, gibberellic acid and indole-3-acetic acid were found as 0.35 ng/µL, 139.31 ng/µL and 21.71 ng/µL, respectively, in goji berry.

Conclusion

Goji berry is an important fruit with rich nutrient content with proven health benefits as well as nutritious properties. This study was conducted in the nutritional and chemical characterization *L. barbarum* grown in Turkey. The results obtained from the determination of some mineral elements in goji berries indicate significant amounts of essential elements (K> Ca> P> Mg> Fe). Their chemical composition revealed asparagine as the dominant amino acid present, while succinic acid showed the largest amount in relation to organic acids. According to the results, it was seen that goji berry is a good choice to enrich the daily diet due to its nutritional and chemical composition. Goji berries grown in Turkey (*L. barbarum*) has proven to be an effective natural dietary supplement. Our results improve information on the composition and nutritional properties of dried goji berries grown in Turkey.

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