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Professional paper

QUALITY PROPERTIES OF SOLAR DRIED GOJI BERRIES (LYCIUM BARBARUM)

Ljubica KARAKASHOVA[1], Frosina BABANOVSKA-MILENKOVSKA[1], Jelena MLADENOVA[1], Lenche VELKOSKA-MARKOVSKA[1], Namik DURMISHI[2], Vesna BOGDANOVSKA[3]

[1*]*Faculty of Agricultural Sciences and Food - Skopje ,,Ss. Cyril and Methodius" University in Skopje, Republic of North Macedonia*
[2]*Faculty of Food Technology and Nutrition, State University of Tetovo, North Macedonia*
[3]*City General Hospital, Department of Pathology, Histopathology Laboratory, Skopje, North Macedonia*
**Corresponding Author e-mail: karakasoval@yahoo.com*

Abstract

Goji berries (Lycium barbarum) a shrub belonging to Solanaceae family, are also known as wolfberries or Chinese boxthorn. These berries are characterized by their bright orange-red ellipsoid fruits, measuring 1-2 cm in length. The versatility of goji berries lies in their suitability for consumption in both fresh and dried forms, rendering them available throughout the year.
The objective of this study was to assess the quality attributes of both fresh and dried goji berries. Specifically, the research focused on the JB2 variety of goji berries, which were subjected to drying using a solar dryer. In preparation for the drying process, the berries underwent distinct pretreatment methods, aimed at determining the optimal approach for retaining quality characteristics post-drying. The pretreatment methodologies encompassed the following: berries without pretreatment (control); immersion of berries in boiling water followed by cooling, succeeded by immersion in a 1% ascorbic acid solution for a duration of 5 minutes; immersion of frozen berries in a 1% ascorbic acid solution for 5 minutes. To determine the quality traits of both fresh and dried goji berries, a comprehensive array of chemical analyses was undertaken: total dry matter, water, total acids, ash, total sugars, vitamin C, cellulose, proteins, total oils and total polyphenols. The sensory properties were estimated by using the scoring method (max. 20).
It was estimated that goji berries, variety JB2, have good quality properties, in terms of their nutritional composition and sensorial characteristics. The application of solar drying has shown good results, both from an economic and ecological point of view, as well as in terms of preserving the chemical components of the goji berries.

Keywords: goji berries, solar dryer, pretreatment, quality properties

1. Introduction

Lycium barbarum L.is a Solanaceous defoliated shrubbery, that grows in northwest China, Tibet and other areas of Asia. The region of China, the Ningxia Province, has the most suitable growing conditions, with the longest history of production, as well as the largest areas of goji berry plantations (Zhao et al., 2020). Today, goji berries have established their presence in warm regions, including the Mediterranean and Southwest and Central Asia. About 70 species of it grows in the temperate to subtropical parts of North America, South America, South Africa, Eurasia and Australia. This plant was brought to Europe in the 18th century (Sopher, 2013; Donno et al., 2014). Since a few years ago, the production and sale of goji berries had become more relevant both in the Balkans and in the Republic of North Macedonia.

The goji berries the fruit of Lycium spp, specifically L. barbarum and L. chinense, two closely related species are also known as: wolfberry, barbary wolfberry, boxthorn, Chinese boxthorn, matrimony vine, Chinese matrimony vine etc. Goji berry plants growing to a height of 1–3 m and have delicious fruit 1–2 cm-long in the form of bright orange-red ellipsoid berries (Amagase & Farnsworth, 2011; Bertoldi et al., 2018).

The fruits of goji berries contain various active components, due to which they possess pharmacological,

biological and multifunctional medicinal properties, and are used in fresh, dried and frozen state. Goji berries ripe fruit are consumed widely as ingredient in Chinese cuisine and herbal tea, and are used to produce beer, juice, sweets, etc. In addition, they have also been used in Asian countries (China, Korea, Japan, Vietnam, Thailand and Tibet), as a traditional herbal medicine for more than 4500 years and as a functional food with the beneficial effects for human health (Amagase & Farnsworth, 2011; Donno et al., 2014; Lu et al., 2021).

The berries are commonly consumed in soups, as porridge with rice and added to numerous meat and vegetable dishes, eaten raw, as a juice, wine or in tea preparations, as also processed as tinctures, powders, and tablets (Potterat & Food, 2010; Pires et al., 2018). Since the beginning of the 21th century, goji products have gained traction in Europe and North America, spurred bu their attributed wellness and longevity benefits. Recent studies also suggest that L. barbarum leaves have shown a broad development and application prospects in the food industry due to the rich nutrients, biological active ingredients and trace elements (Liu et al., 2012; D'Amato et al., 2013, Pires et al., 2018).

Goji berries are a rich source of nutritional and antioxidant components. The nutritional and functional properties of wolfberry are provided by a rich variety of components, including: carbohydrates, polysaccharides, amino acids, polyphenols, mineral substances, carotenoids as coloring matters, organic acids, fatty acids, phytosterols and their derivatives (Zhao et al., 2015; Zhou et al., 2017; Cossignani et al., 2018; Zhao et al., 2020). Additionally, sugars are predominant nutritional component in berries. They are also closely related to the fruits yield and quality, and play a critical role in fruits growth, ripening and composition. It was known that the contents of all above nutritional components were varied due to the different cultivars, environment and some other factors (Lu et al., 2021).

Commercial production of Goji berries is concentrated in regions of China such as Ningxia, Xinjang, Gansu, Qinghai and Inner Mongolia, yielding an annual harvest of approximately 25,000 to 30,000 tons of dried fruits. However, the Goji berries produced in these regions exhibited different appearance and taste, which suggests that their chemical profiles should be different. Previous reports showed that polysaccharides, carotenoids, phenolic acids, flavonoids, alkaloids, amino acids, and some others build the compound library of Goji berries. Among them, polysaccharides and carotenoids have been paid more attention due to their biological actives (Lu et al., 2021).

Lycium barbarum fruit (Goji) is a powerful super food, contain more beta-carotene than any food on earth and more than 500 times the vitamin C of oranges by weight, more calcium than cauliflower, more protein than bee pollen (it's 16 % protein by weight, making it a high-protein fruit), more beta-carotene than carrots, essential fatty acids, and vitamins. Some of the scientific research findings reported about the Goji include: contains 19 amino acids (six times higher than bee pollen), 21 trace minerals, including germanium, an anti-cancer trace mineral, more protein than whole wheat, a complete spectrum of antioxidant carotenoids, 500 times the amount of vitamin C by weight than oranges, B-complex, s vitamin E, beta-sitosterol, an anti-inflammatory agent (Moffett, 2008; Pop et al., 2013).

According to the authors Pop et al., (2013) the nutritional facts information for goji berries per 100 g are: protein 1.5 g – 10.6 g, total fat 0.5 g – 3.6 g, total carbohydrate 3.1 g – 22 g, cholesterol 0.0 mg – 0.0 mg, sugars 2.4 g – 17.1 g, polysaccharides 6.9 g, water < 15 % (max.), dietary fiber 1.04 g – 7.4 g, selenium (Se) 7.02 μg – 50 μg, sodium (Na) 3.1 mg – 22 mg, potassium (K) 158.65 mg – 1130 mg, zinc (Zn) 0.3 mg – 2 mg, calcium (Ca) 15.7 mg – 112 mg, iron (Fe) 1.18 mg – 8.42 mg, vitamin C – (ascorbic acid) 2.6 mg – 18.4 mg, beta-carotene 1.05 mg – 7.45 mg, thiamin (vitamin B1) 0.02 mg – 0.16 mg, riboflavin (vitamin B2) 0.2 mg – 1.3 mg, zeaxanthin 11.6 to 28.1 mg – 82.5 to 200 mg, amino acids 1.2 mg – 8.37 mg (http://convert-to.com/634/dry-goji-berry-conversion-and-goji-nutritional-facts.html).

The fruits of goji berries can be consumed fresh, and are also a valuable raw material for processing into high-quality products, especially as dried fruits. Drying is one of the oldest technological procedures for conservation food and preservation of the nutritional and biological properties of fruit. With the application of drying, the use value increases, but it also enables the availability of goji berries in the markets throughout

the year.

Drying is the oldest method of food preservation. During the drying process, a large amount of water is released, it reduces water activity, the mass and volume of the fruit decreases, prolongs shelf-life and the concentration of dry matter increases, as well as the all components from its composition. During the drying of the raw material, not all the water should be removed, as this could cause a negative impact on the elasticity and ability to rehydrate (Vereš, 2004; Fratianni et al., 2018).

The most common used conventional methods for drying fruits include vacuum drying, sun drying, freeze-drying, fluidized bed drying, tray drying, hot-air drying. Most of these methods are time and energy consuming (Oliveira et al., 2015; Fratianni et al., 2018). Sun drying can be performed in ordinary atmospheric conditions in the sun or in solar dryers. One of the oldest and most economical ways is drying in the sun. In North Macedonia, there are favorable conditions for applying solar drying, because there are about 250 sunny days a year. The technology of drying fruit in solar dryers is the cheapest way of drying, because natural solar energy is used (Vasilevska-Popovska, 2009). In addition, the drying of berries is difficult due to the waxy outer peel layer, which acts as a barrier to moisture movement across the membrane. Increasing temperatures result in damages in texture, color, taste, and nutritional value. Depending on the severity and length of treatments, different losses of carotenoids are observed (Fratianni et al., 2018).

Dried fruit is a product obtained by drying whole or parts of fresh fruit, using an appropriate procedure (Official gazette No. 69/2014). Dried fruits should have an aroma and color appropriate to the variety and to have a good ability to rehydrate (increase in volume) when immersed in hot water for 10 minutes, after which it should have a taste and smell that corresponds to the fruit from which it was obtained. Also, dried fruits should not have physiological damage due to burning, to not have foreign smells and tastes and to not contain mechanical and biological impurities (Vračar, 2001). The purpose of the examination is to determining the quality (nutritional and sensory properties) of fresh and dried goji berries of the JB2 variety and to determining the impact of applied treatments on the quality of the dried product.

2. Materials and methods

In this study were used the goji berries grown in the Skopje region, in the immediate vicinity of Smilkovo Lake. The fruits were harvested in October. After a visual assessment on the field, it was determined the time of harvest. The fruits if goji berry were pretreated and dried in a solar dryer located in the vicinity of Veles.

JB2 „Figure 1“is a variety of goji berries that can be grown in the form of a bush and in the form of a tree. It is characterized by large fruits, with an expressive orange-red color. The yield of the JB2 variety is 0.31 kg per stem and 51.77 kg per 1000 m2. The fruits ripen successively and therefore the harvest takes place on several occasions, starting from June and lasting until October. In order to improve the quality of the dried product, it is necessary to prepare goji berries through the following technological operations: selection, washing, pretreatment of the berries, drying, packaging and storage.

Figure 1. JB2 variety of goji berry

After washing, the goji berries are carefully selected and any fruits that do not meet the required standards (damaged and with other mechanical impurities) are separated. The healthy, undamaged berries are then placed in dishes to drain. Then, Various pretreatments are applied to the goji berry fruits to prevent color changes and chemical composition alterations. There were three variants with following pretreatments: JB2-I-variant – control (no pretreatment); JB2-II-variant – immersing berries in hot water, cooling and immersing in 1 % ascorbic acid solution for 5 minutes; JB2-III-variant – immersion of frozen fruits in 1 % ascorbic acid solution for 5 minutes.

For the drying process was used a Macedonian type of solar dryer, installed near city of Veles. This dryer features a metal construction covered with galvanized sheeting and glass. Following the pretreatments, all varieties of goji berries were evenly distributed and placed on mesh with wooden frames in the form of trays. The number and size of these trays depended on the solar dryer's capacity. The drying process was made by using heated air, which is heated by natural solar energy. The Macedonian solar dryer „Figure 2"had ventilation openings at the very bottom and at the top, which maintains natural air circulation. The temperature during the experiment ranged from 55 to 65 °C at the day, and at night from 30 to 45 °C, which had a favorable effect on the drying of goji berries.

Figure 2. The Macedonian solar dryer

Figure 3. Wooden frames as trays with goji berries

To achieve a more uniform and efficient drying process for goji berries, adjustments were made to the trays, as shown in "Figure 3," throughout the various stages of drying. The drying period using the solar dryer ranged from one to three days, directly influenced by factors such as sunlight availability, prevailing air humidity, current conditions, and the specific attributes of the material being dried. In our scenario, the drying duration for goji berries fell within the range of 36 to 48 hours.

The dried berries were appropriate cooled and packed in paper bags which aimed to stabilize and homogenize their moisture content. Subsequently, they were placed into suitable plastic packaging designed to possess optimal air porosity, enabling extended storage periods under suitable conditions. For determination of the nutritional and sensorial properties on fresh and all variants of dried berries JB2, the

following chemical parameters were determined: total dry matter by using the gravimetric method, in a drying oven at a temperature of 105 °C, to a constant mass; soluble dry matter by refractometric method; humidity by mathematical calculation; total acid by volumetric method, with 0.1 M NaOH solution and 1 % phenolphthalein solution as indicator; mineral matter (ash) by gravimetric method, burning in an Muffle furnace at a temperature of 525 ± 25 °C; sugars (glucose, fructose and sucrose) by liquid chromatography, HPLC-RI method, with aqueous extraction of sugar from berries; the dietary fiber (cellulose) gravimetrically, according to the AOAC 985.29 25 method (Prosky et al., 1985); vitamin C volumetrically, with 0.1 N-solution I2 and 1 % starch solution; proteins by the Kjeldahl method; fat content by Soxhlet method (Vračar, 2001); total polyphenols, spectrophotometrically, the absorbance was measured at 765 nm wavelength (Folin & Ciocalteu, 1927).
The sensory evaluation of the quality of both fresh and dried berries was conducted through sensory analysis, employing a points system method with a maximum score of 20 points, encompassing all sensory attributes (maximum 7 points for color, 4 points for taste, 4 points for smell, and 5 points for fruit condition and appearance) (Karakashova, Babanovska-Milenkovska, 2012). The acquired results were processed using standard statistical techniques, Microsoft Excel 2010, and the statistical software package R 3.3.3.

3. Results and discussion

According to Karakashova (2003), when it comes to the production of dried fruit, several factors play a significant role in determining quality. These include the dry matter content, the balance between sugars and acids, the color, aroma, and overall appearance of the fruits. Evaluating the quality of fruits from a technological perspective requires a comprehensive assessment of both their chemical composition and sensory attributes.
Fresh goji berries - The components from the chemical composition, their quantity and their ratio are important for the sensory, nutritional and biological properties of the product. The specificity of the chemical composition depends on the variety, climatic conditions, agrotechnical measures and the degree of the fruit maturity (Obradovič, 2011). Based on the laboratory analysis conducted, the outcomes concerning the chemical composition of fresh goji berries, specifically the JB2 variety, are presented in "Table 1"

Table 1. Chemical composition of fresh goji berry fruits of the variety JB2

Variety	*Water (%)*	*Total dry matters (%)*	*Sucrose (%)*	*Glucose (%)*	*Fructose (%)*	*Total acids (%)*	*Soluble dry matters (%)*	*Vitamin C mg/100 g*	*Ash (%)*	*Proteins (%)*	*Fats (%)*	*Dietary fibers (%)*	*Total polyphenols (mg/100 g)*
JB2	77.25	22.22	0.57	7.74	5.24	0.53	16.00	85.68	1.71	7.37	2.57	8.67	121.00
SD	0.08	0.28	0.33	0.37	0.00	0.07	0.00	21.53	0.21	0.54	0.18	0.18	22.84
CV	0.00	0.01	0.41	0.05	0.00	0.15	0.00	0.31	0.11	0.07	0.07	0.02	0.17
$S\bar{x}$	0.05	0.20	0.23	0.27	0.00	0.05	0.00	15.23	0.15	0.39	0.13	0.13	16.15
LSD 0,05	0.12	0.36				0.03		6.43	0.39				17.58
LSD 0,01	0.19	0.56				0.05		10.02	0.61				27.38

SD - standard deviation; CV - coefficient of variation; $S\bar{x}$ - error on the mean value

According to the „Table 1“, the average chemical composition of fresh goji berries of JB2 variety is as follows: water content of 77. 25 %, total dry matter at 22.22 %, soluble dry matter making up 16 %, glucose

at 7.74 %, fructose at 5.24 %, sucrose at 0.57 %, total acids at 0.53 %, vitamin C content of 85.68 mg/100 g, ash at 1.71 %, proteins at 7.37 %, fats at 2.57 %, dietary fibers at 8.67 % and total polyphenols amounting to 121.0 mg/100 g.

The index of sweetness, or sweetness coefficient is the ratio between total sugars and total acids, components that affect the taste of fruits. For the goji berries JB2 variety, the sweetness index is 25, indicating that these fruits are perceived as having low acidity.

The evaluation of sensory properties for fresh goji berries was performed with the scoring method (max. 20). For that purpose, have been used the human senses for eyesight, smell, taste and touch, so were determined the appearance, color, taste and consistency of the goji berry. The obtained points of sensory analysis of the goji berries JB2 variety were: 5 points (max. 6) for color, 4 points (max. 4) for smell, 2 points (max. 5) for taste, 4 points (max. 5) for consistency. The total points from the sensory assessment were 15 (max. 20).

Dried goji berries **-** After drying process for all JB2 variety variants a laboratory analysis was conducted to determine their chemical composition and the outcomes are presented in the „Table 2".

From the „Table 2"it is evident that from all applied variants used for the variety JB2, the highest average value of total dry matter was determined in the variant JB2-III (86.91 %) and the lowest content was found in the variety JB2-II (85.54 %). For all applied variants, a significant statistical difference in relation to the total dry matter was determined between the variants JB2-I and JB2-III at p = 0.05 and p = 0.01.

Table 2. - Chemical composition of all variants dried goji berries variety JB2

Variety	*Water (%)*	*Total dry matters (%)*	*Glucose (%)*	*Fructose (%)*	*Total acids (%)*	*Vitamin C mg/100 g*	*Ash (%)*	*Proteins (%)*	*Fats (%)*	*Total polyphenols (mg/100 g)*
JB2-I	13.09	**86.91**	9.46	8.31	1.95	**35.65**	3.86	13.72	8.19	703.90
JB2-II	**14.34**	85.54	10.06	11.56	2.49	18,17	4.00	**15.53**	7.82	581.50
JB2-III	13.37	86.39	**12.03**	**12.82**	**2.99**	24.56	**4.16**	15.19	**11.04**	**1425.40**
x̄	13.60	86.28	10.52	10.90	2.47	26.10	4.00	14.80	9.02	903.60
SD	0.66	0.69	1.34	2.33	0.52	8.84	0.15	0.96	1.76	456.02
Cv	0.05	0.01	0.13	0.21	0.21	0.34	0.04	0.06	0.20	0.50
Sx̄	0.38	0.40	0.78	1.34	0.30	5.11	0.09	0.56	1.02	263.28
LSD 0,05	0.15	0. 71	1.39	1.59	0.46	2.06	0.24			61.20
LSD 0,01	0.22	1.05	2.04	2.34	0.68	3.04	0.35			90.10

x̄- mean value; SD - standard deviation; CV - coefficient of variation; Sx̄ - error on the mean value

In dried goji berry variant JB2-III, the highest average value was recorded for glucose content (12.03 %) and fructose content (12.82 %). Regarding the glucose and fructose content in the applied variants, a significant statistical difference was found between the variant JB2-I and JB2-III, at p = 0.05 and p = 0.01.

The highest value for the content of total acids for the solar dried berries variants was obtained for JB2-III variant (2.99 %). From the statistical processing of the obtained results for the content of total acids, it was determined that the average values of all variants do not statistically significantly differ from each other at p = 0.05 and p = 0.01.

The Vitamin C has the highest average presence of 35.65 mg/100 g in the variant JB2-I. Regarding the content of vitamin C, it was found that there are significant statistical differences between the all three applied variants (p = 0.05).

In the dried goji berry variant JB2-III, the mineral matters are mostly represented (4.16 %). It was determined that the average values of the mineral matters content, do not have statistically significantly differ from each other at p = 0.05 and p = 0.01.
The highest average value for the protein content of 15.53 % was found in the dried berries of the variant JB2-II and in the dried goji berries variant JB2-III was determined the highest average value for the fats (11.04 %). It was determined that in terms of protein and oil content, all dried goji berries variants do not statistically significantly differ from each other, at p = 0.05 and p = 0.01.
For the content of total polyphenols was obtained the highest average content of 1 425.4 mg/100 g in the dried goji berries variant JB2-III. Statistically significant differences in terms of total polyphenols were determined between all three variants.
The results of the sensory evaluation of the three dried goji berry variants of the JB2 variety are presented in the „Table 3“. According to the obtained results of the sensory evaluation „Table 3“, the variant JB2-I was characterized by the highest score points for color 4.5 (max.7), smell 4.0 (max. 4) and texture 4.0 (max. 5). On the other hand, the variant JB2-III had the highest score points for smell 4.0 (max. 4), taste 3.0 (max. 4) and texture 4.0 (max. 5). The average score points from all three variants were: color 3.5 (max.7), smell 3.6 (max. 4), taste 2.3 (max. 4) and texture 3.8 (max. 5). Out of the maximum 20 score points, the variant JB2-II was evaluated with lowest score points 10.5 and the variant JB2-III was evaluated with highest score points 15.0, while the average value of score points for all variants was 13.3.

Table 3. - the sensory evaluation of three variants of dried goji berries JB2

Variant	Color (max.7)	Smell (max.4)	Taste (max4)	Texture (max.5)	Total points (max.20)
JB2-I	**4.5**	**4.0**	2.0	**4.0**	14.5
JB2-II	2.0	3.0	2.0	3.5	10.5
JB2-III	4.0	**4.0**	**3.0**	**4.0**	**15.0**
$\bar{x}$	**3.5**	**3.6**	**2.3**	**3.8**	**13.3**

$\bar{x}$- mean value

4. Conclusion

Based on the obtained results for both the chemical composition and sensory properties, it can be deduced that the examined fresh goji berries of the JB2 variety possess favorable technological attributes. After applying different pretreatments and the process of solar drying, in the dried goji berries retain most of the nutrients from the fresh berries. The pretreatment what was applied in dried berries JB2-III variant proved to be the best, for which we obtained the highest values of the chemical composition for glucose, fructose, total acids, mineral substances, oils, total polyphenols and the highest total score points from the sensory evaluation.
The Republic of North Macedonia has excellent climatic and soil conditions for the cultivation of the goji berry fruit crop, but there are also excellent conditions for the application of solar energy and solar dryers in the drying of various types of fruit. By the process of solar drying, the dried goji berries as a product are rich in nutrients, vitamins, minerals, polyphenols, which have strong antioxidant activity, so it is recommended to be used in nutrition.
The application of solar drying of goji berries has proven to be useful, firstly because mostly all the nutrients of the fresh fruit were preserved, but also, the use of solar energy it turned out that is economically viable and do not have harmful effects to the environment.

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