The Effects of some Compounds Found in Aronia and Goji Berries on Human Health

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REVIEW

Abstract

Berries consumption is a current concern in order to highlight the important content of their compounds on human health. Aronia berry is known as chokeberry and is native in North America and Canada. Due to the therapeutic properties, black chokeberries are very popular and appreciated fruits. The most important compounds, polyphenols and antioxidants, have many biological actions such as antioxidative, anti-inflammatory, hypotensive, antiviral, anticancer, antidiabetic and antiatherosclerotic effects Goji berry is also another important source of carotenoids and antioxidants and it has been used as a medicine in China for centuries. Goji berry is considered as a super fruit due to bioactive compounds that offer protection against cardiovascular diseases, diabetes and other comorbidities. Black chokeberry and goji berry have an antioxidant capacity ten times higher than other berries. Due to their high biological and nutritional value, these berries are being used more and more frequently in human nutrition and the extracts in the pharmaceutical industry. Therefore, the main aim of this paper was to summarize and highlight the high content of bioactive compounds and beneficial effects of aronia and goji berries upon human health.

Keywords: aronia, antioxidants, goji, health, polyphenols

INTRODUCTION

Berries are special foods used in human diet to increase resistance against sicknesses or in convalescent people’s diet, due to their complex chemical composition and high content of antioxidants, polyphenols, anthocyanins and vitamins. Berries are used as a dessert or between meals, fresh or processed as juices, jams, dehydrated or powder. They are also used in the pharmaceutical or pastry industry. Including berry consumption daily, is a way to ingest the necessary amount of vitamins and minerals that the human needs (Govers et al., 2017). For the past several years a growing amount of evidence has indicated that the consumption of fruits rich in polyphenolic compounds is correlated with a lower risk of development for oxidative stress and cardiovascular diseases (Huang et al., 2016; Denev et al., 2012). Aronia and goji berries have a rich content of polyphenols, including procyanidins, querectin, vitamins and particularly anthocyanins (Overall et al., 2017). Previous studies also suggest that the consumption of berries results in a strong shift in the gastrointestinal bacterial communities which are correlated with the decrease of the gastrointestinal oxidative stress (Overall et al., 2017). Accumulating scientific evidence on the health benefits of berries has led to an interest in the investigation of some berry shrubs species for their therapeutic potential (Cianciosia et al., 2019). Goji berry (Lycium spp.) and aronia berry (Aronia melanocarpa) are two of the most...
appreciated berries due to their bioactive compounds.

DESCRIPTION OF SPECIES AND THEIR NATURAL RANGE

*Aronia berry* (*Aronia melanocarpa*) is known as chokeberry which belongs to Rosaceae family, *Aronia* genus, native to eastern North America and Canada. It has been brought to Europe around 1900 through Germany all the way to Russia (Bahtinur et al., 2013). The genus is represented by two species: *Aronia melanocarpa* (Michx.) Ell. (black chokeberry) and *Aronia arbutifolia* (L.) Pers. (red chokeberry). Both species are considered also as ornamental landscape shrubs (Jurikova et al., 2017). At the beginning of the 20th century, chokeberry was transferred to Russian botanical gardens, from where it spread to other European countries with the same climate conditions (Mohr, 2018). The health benefits of chokeberry were appreciated quite quickly along the years. Today, the area of chokeberry cultivation has expanded considerably in Europe (Finland, Sweden, Poland, Germany, Hungary, the Czech Republic, Slovenia, Bosnia, Bulgaria), Asia (China, Japan), in the USA and Canada (Šnebergova et al., 2013; Kulling et al., 2008). Two of the most popular cultivars which were developed in Europe are 'Viking' and 'Nero', both very similar in yield performance (McKay, 2004). Other varieties grown in Europe: Aron (Denmark), Nero (Czech Republic), Galicjanka (Poland), Viking and Kurkumacki (Finland), Rubin (Russia), Hugin (Sweden), Fertödi (Hungary) and Melrom in Romania (Jurikova et al., 2017; Ristvey and Sudeep, 2011).

Black chokeberry (*Aronia melanocarpa*) is a multi-stemmed, deciduous bush, it can reach 2m - 2.5 m height, but in cultivation many plants reach only the half of this height range. Black chokeberry flowers have five white petals, and numerous pink stamens (Kulling et al., 2008) (Figure 1a). Strik et al. (2003) notes that black aronia berry flowers open in mid-may, late enough to avoid late spring frosts damage. Black chokeberry fruits are 1-1.5 cm diameter, glossy and black when ripe (Figure 1b). They hang down in clusters from red pedicels, with few-to-30 fruits per cluster. The fruits are pomes and each contains 1-5 seeds. They mature primarily in August, after maturation the most fruits drop (McKay, 2004). The multi-stemmed plants can form large, dense colonies over time (Brand, 2010) (Figure 1c).

![Figure 1. (a) chokeberry flower; (b) chokeberry fruits; (c) flowering chokeberry bush; (d) autumn chokeberry bush (www.climbers.lsa.umich.edu)](image-url)
Goji berry is berry is known as “wolfberry”. *Lycium* fruits are obtained from two species, *Lycium chinense* and *Lycium barbarum* (Ma et al., 2019). They belong to Solanaceae family. *Lycium* genus, is native to Ningxia Hui Autonomous Region. It is considered a super fruit in Chinese culture. The scientific name of *Lycium barbarum* was given by the swedish botanist Carl Linnaeus in 1753, whereas *L. chinense* was named 15 years later by Philip Miller (Kulczyński et al., 2016; Shah et al., 2019). Goji berries (*Lycium spp.*) is a perennial shrub that grow in separate and distinct regions distributed in temperate to subtropical parts of North America, South America, southern Africa, Eurasia and Australia (Fukuda et al., 2001).

The *Lycium* genus (Solanaceae) includes about 100 species, which are widespread in South and North America, Africa and Asia (Yao et al., 2018). The richest diversity can be found in South America, where the presence of almost 30 species of this genus has been recorded, North America and South Africa each have 20 species of goji, while Australia, the Galapagos Islands and other islands in Pacific each have only one species of *Lycium*. Ruyu and the collaborators (2017) reported that from 97 species of goji berry, 31 species are used as food or medicinal products worldwide. Red goji berry represents approximately 90% of all commercially available goji berries, and it has been planted in Northwest China for about 600 years (Bei Liu et al., 2020). Romania has the biggest cultivated areas of *L. barbarum* from the European Union. Recently, due to the increasing demand, the cultivation of *Lycium* species has become widespread among the European countries (Mocan et al., 2018). Goji berries are very popular pharmaceutical products in Asian countries such as Tibet, Thailand, Vietnam, Japan, Korea, and China. It has been broadly used among these nations for therapeutic purposes and as a functional food for over 4500 years (Shah et al., 2019). Under the Dietary Supplement Health and Education Act of 1994, goji berries can be sold in the USA and EU as an ingredient in dietary supplement or foods (Donno et al. 2014).

*Lycium spp.*, is a perennial shrub, containing stems that are arching, hermaphrodite with purple little flowers which is in flower from June to August (Figure 3a).

Figure 3. (a) goji berry flower; (b) goji berry fruit; (c) goji berry shrub; (d) fresh and dehydrated goji fruits (www.goji.md)
The fruits are 1–2 cm long, bright orange-red ellipsoid berries (Figure 3b) sweet and tangy flavor that can ripen from August to October. The fruits can be eaten raw or dehydrated (Mocan et al., 2018; Kuczyński et al., 2016) (Figure 3d). The plant can reach 2.5 m - 4 m height (Figure 3c), with simple leaves, 2-3 cm long, petiolate, entire, and alternate on young shoots while fascicled on older stems (www.climbers.lsa.umich.edu). Prefers moist, well-drained soil and can grow in nutritionally poor soil. It is tolerant to mildly acid, neutral and basic soils (Ma et al., 2019).

**TRADITIONAL AND MODERN USE OF BERRIES**

*Lyccium fruits* (goji berries) have been used in traditional Chinese medicine for more than 2000 years to treat various diseases, including blurred vision, cough, asthma, diabetes, kidney failure, infertility, and nervous fatigue (Mocan et al., 2017). In traditional Chinese medicine goji berry is considered “fruit of longevity”. Is believed that consumption of goji fruits can prolong life and provide energy and health improvements (Kruczek et al., 2020). The medicinal tradition not only use goji fruits as a strengthening agent but also the roots bark as a cooling agent (Potterat, 2009). Various parts of the plants belonging to this genus, including fruits, leaves, young shoots and root bark, have been consumed as part of a traditional diet and for medicinal purposes. The beneficial effects upon human health, in the prevention of chronic diseases and comorbidities such as blood pressure, obesity, thrombosis have been demonstrated by many researchers (Bathinur et al. 2013; Yang et al., 2015; Endes et al. 2015; Denev et al. 2018). Goji berries are recommended in the treatment of many diseases such as diabetes (hypoglycemic), heart disease (hypotension, cholesterol regulation), tuberculosis, childhood pneumonia, anemia, general weakness or vision disorders caused by malnutrition (Shahrajabian et al, 2019).

*Chokeberries* have also a high content of bioactive compounds, so it can be considered a nutraceutical plant, with numerous uses. Traditional use of the black chokeberry as an antihypertensive drug in Russian medicine was supported by modern pharmacological research. The native Americans used chokeberry fruits for cold treatment and the preparation of traditional pemmican (Sharma et al., 2021).

Chokeberries became very popular for the large-scale production of juices, jams, wines, liqueurs and schnapps, the extracts from black chokeberries fruits are used to make tinctures, powders, and tablets (Gao et al., 2017), in the food industry for bakery and pastry sector (Jurendić and Ščetar, 2021). Modern use of these berries is to be consumed not only in fresh and dried forms, but also in processed products, including canned fruits, yoghurts, beverages, jams, jellies, bakery foods, chocolate, wine and others (Kulaitienė et al., 2020). Goji wines have already widely accepted by most elder people and are recognized as one of the functional wine against aging and aging-related disease (Song & Xu., 2013). Rotari and the collaborators (2015) shown that the addition of goji berries (7%) improved the quality of yoghurts, increasing the lactic acid bacteria evolution and maintained the prebiotic value during storage. The results obtained collect informations that enables the use of goji berries to increase the probiotic levels of yoghurts. Goji berry tea is a very popular hot drink that replace the regular tea. To obtain a tea with high antioxidant properties, black goji berries are the most wanted by consumers. High water temperature and long soak time can make goji berry tea with more desirable colours and also higher healthy properties than red goji berry tea (Bei Liu et al., 2020).

**Medicinal use of berries**

In recent decades, interest has grown considerably in finding natural antioxidants that can be used in food or as a medical material to replace synthetic antioxidants, which are restricted due to their harmful effect such as carcinogenicity (Ionică et al., 2012; Yahui et al., 2016). The concept of anti-aging by antioxidants found in *Lycium spp.* and *Aronia melanocarpa* has been highlighted by many evidences and has been investigated in different ways. Meanwhile, goji berries and black chokeberries have a variety of pharmacological functions, including immunoregulative, anti-apoptotic activities reducing DNA damage, which can retard biological aging. Many evidence reveals that *Lycium barbarum* plants can be considered effective anti-aging agent. The anti-aging effects are related to β-carotene and phenolic compounds. However, clinical evidences and rigorous procedures for quality control are indispensable before any recommendation of use can be made for goji products (Potterat, 2009). The carotenoids found in goji berries have been identified to be effective also in preventing chronic diseases, such as cardiovascular diseases and skin cancer (Amagase, 2014). Due to their potential pharmacological activity, the main research in goji berries has been focused on their two major components, which are polyaccharides and carotenoids (Bondia-Pons et al., 2014). Goji berry can be used as nutraceuticals or directly eaten in the diet to maintain good health. Goji berries offer skin protection against immune suppression and oxidative stress by sunlight simulated ultraviolet (SSUV) radiations (Islam et al. 2017). The research shown that goji berries contain zeaxanthin, which is a carotenoid with a very important antioxidant role found in goji berries that helps to improve ocular problems. It can represent 31-56% of total carotenoids contained in goji berries (Shahrajabian et al., 2019). Studies have shown that daily use of goji-based dietary supplements increases zeaxanthin and antioxidants that prevent macular hypopigmentation (Adams et al., 2019; Buchelli et al., 2011). The content of lipids in berries is low, but berry oils have become increasingly popular in health care because of their high content of unsaturated fatty acids and antioxidants (Brand, 2010).
Recent studies confirmed the antiproliferative properties of the EEGB in a dose and time-dependent manner negatively affecting both cancer cells’ DNA synthesis and proliferation pathways (Wawruszak et al., 2015). Level of goji berry antioxidants measured ORAC scale (ability to absorb oxygen free radicals) is very high, 30,500 units, almost 20 times more than the oranges (Dodon et al., 2015).

Research has shown that goji extracts can be used as dietary supplements in the diet of performance athletes helping to reduce the side effects of oxidative stress due to excessive physical exertion (Skenderidis et al., 2018). The black goji berries (Lycium ruthenicum M.) have relatively higher antioxidant capacities, total phenolic, flavonoids, condensed tannin and anthocyanin, and it could be an important dietary source of natural nutraceuticals used for human health (Islam et al. 2017). A recent research made in Serbia, analyzed and compared the nutritional value, bioactive compounds, antioxidant and antimicrobial potentials of three varieties of L. barbarum red goji berries, yellow goji berry, and black goji berry (L. ruthenicum M.). The conclusions showed that the highest total phenolic content, including anthocyanins and the most potent antioxidant activity, was observed for the extract of black goji berry, L. ruthenicum M. (Ilić et al. 2020). The nutritional potential and health benefits of Aronia melanocarpa as a dietary food, rich in bioactive compounds has been revealed by many in vivo and in vitro evidences (Jurendić and Ščetar, 2021; Denev et al., 2018; Gajic et al., 2020). Health benefits of black chokeberries are multiple and includes antiviral, antimicrobial, anti-inflammatory, gastroprotective, cardioprotective, hepatoprotective and anti-proliferative activities against cancer cells (Jurikova et al., 2017; Kokotkiewicz et al., 2010). The results obtained by korean researcher Nhuan (2018) showed that extracts of chokeberry leaves have anticancer and antimetastatic effect, reducing the proliferation of cancer cells by up to 96.3% in liver cancer. Many in vitro and in vivo studies have demonstrated the chokeberry positive effects on inhibition of breast cancer cell proliferation, (Wawruszak et al., 2015; Tao et al., 2017), preventing leukemia and bowel cancer (Sidor et al., 2019), but also the antimutagenic and neuroprotective effects (Lee et al., 2017). Polyphenols found in chokeberry fruits reduce the risk to develop cardiovascular diseases by increasing immune defenses and reducing inflammation (Kasprzak et al., 2021; Govers et al., 2017). The anti-inflammatory effect was also demonstrated by Sidor and collaborators in 2019, to people who suffered a heart attack. The level of inflammatory markers decreased after the introduction of chokeberry extracts in the diet. The cardiovascular diseases are accompanied by chronic low-grade inflammation (Figure 4).

![Figure 4. Diseases associated with chronic low-grade inflammation](Figure 4) (Kasprzak et al. 2021)

The antimicrobial activity of chokeberries has been studied by Valcheva-Kuzmanova and Belcheva in 2005. In vitro investigations, demonstrate bacteriostatic activity of Aronia melanocarpa fruit juice against Staphylococcus aureus and Escherichia coli. Lepina et al. (2013) examined the antimicrobial activity of aqueous and ethanolic extracts from fresh, dried and frozen black chokeberry fruits. The results showed that extracts exhibited antibacterial activity against Gram-positive bacteria Bacillus cereus and Staphylococcus aureus, without any antifungal influence. The extract inhibited also the growth of Gram-negative bacterium Pseudomonas aeruginosa, but did not have an influence on Escherichia coli.

The daily consumption of aronia berry juice, powders and extracts were introduced in the human diet, which showed a change in blood pressure for people who suffered from such a disease, decrease the level of cholesterol.
and the amount of fat into the blood decreased for obese people. (Balansky et al., 2012).

Diabetes is a global pandemic which warrants urgent attention due to its rising prevalence and economic burden. Latest researches have shown that aronia berry has the potential to control type 2 diabetes (Park et al., 2013; Denev et al., 2018; Ciocoiu et al., 2017). The anti-diabetic effects were demonstrated after oral administration of a chokeberry ethanol extract to hyperglycemic rats (Valcheva et al., 2007; Gajic et al., 2020).

Chokeberries are consumed as an alternative therapy for conditions such as achlorhydria, avitaminoses, convalescence and hemorrhoids. They are also a natural source of antioxidants with an anti-aging effect (Nhuan Do and Eun-Sun, 2014). Several studies have displayed the antioxidant properties of A. melanocarpa berry juice and plant extract where oxidative stress markers were observed to have significant reductions (Banjari et al., 2017).

NUTRITIONAL PROPERTIES AND CHEMICAL COMPOUNDS OF BERRIES

Chokeberry chemical compounds

Polyphenols
It is known that chokeberries have a high biological and nutritional value. The functional components in chokeberries include nutrients, polyphenols, low lipid content, with a total fat of 0.14% in a fresh berry. The fruits contain macroelements (K, Ca, P, Mg, and Na) and microelements (Zn, Fe, Cu, Mo, Cr, Mn, Si, Ni, B, and V) (Sidor and Michałowska, 2019). At least eight organic acids including quinic, malic, ascorbic, shikimic, citric, oxalic, succinic and isocitric acids have also been identified in their composition. The primary polyphenols include anthocyanins, proanthocyanidins, flavonols, and phenolic acids which are the most abundant and important dietary antioxidants (Jurendić and Ščetar, 2021; King and Bolling, 2020). The polyphenols are responsible for the strong antioxidant properties of chokeberries and their products (Ma et al., 2021). All these properties allow them to act against oxidative stress and to exhibit strong protective effects against cellular oxidative damage (Moskalets et al., 2021; Oprea et al., 2014). Recent studies (Table 1) revealed that chokeberry have a low content of flavonols, around 1.3% of total polyphenols, while the most abundant are glycosides including 3-O-rutinoside, 3-O-galactoside and 3-O-glucoside (Ochmian et al., 2012; Moskalets et al., 2021; Jurendić and Ščetar, 2021; Kapci et al., 2013).

Table 1. Phenolic constituents of Chokeberry

<table>
<thead>
<tr>
<th>References</th>
<th>Anthocyanins (mg/100 g fruit)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ochmian et al. (2012)</td>
<td></td>
</tr>
<tr>
<td>Cyanidin-3-O-galactoside</td>
<td>417.3 – 636.0</td>
</tr>
<tr>
<td>Cyanidin-3-O-glucoside</td>
<td>7.8 – 27.2</td>
</tr>
<tr>
<td>Cyanidin-3-O-arabinoside</td>
<td>128.0 – 299.4</td>
</tr>
<tr>
<td>Cyanidin-3-O-xylloside</td>
<td>29.0 – 38.2</td>
</tr>
<tr>
<td>Cyanidin-3-O-rutinoside</td>
<td>1.50 – 7.56</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>References</th>
<th>Phenolic acids</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ochmian et al. (2012)</td>
<td></td>
</tr>
<tr>
<td>Chlorogenic acid</td>
<td>72.0 – 96.6</td>
</tr>
<tr>
<td>Neochlorogenic acid</td>
<td>59.3 – 79.1</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>References</th>
<th>Flavanols</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ochmian et al. (2012)</td>
<td></td>
</tr>
<tr>
<td>Quercetin-3-O-galactoside</td>
<td>6.6 – 9.1</td>
</tr>
<tr>
<td>Quercetin-3-O-glucoside</td>
<td>4.4 – 11.3</td>
</tr>
<tr>
<td>Quercetin-3-O-rutinoside</td>
<td>3.9 – 6.1</td>
</tr>
<tr>
<td>Quercetin-3-O-rhamnoside</td>
<td>-</td>
</tr>
<tr>
<td>Quercetin-3-O-vicianoside</td>
<td>2.6 – 4.3</td>
</tr>
<tr>
<td>Quercetin-3-O-robinobioside</td>
<td>1.1 – 11.3</td>
</tr>
<tr>
<td>Quercetin-3-O-galactoside</td>
<td>6.6 – 9.1</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>References</th>
<th>Anthocyanins (mg /kg fruit)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Kapci et al. (2013)</td>
<td></td>
</tr>
<tr>
<td>Cyanidin-3-O-galactoside</td>
<td>2917.2</td>
</tr>
<tr>
<td>Cyanidin-3-O-glucoside</td>
<td>127.0</td>
</tr>
<tr>
<td>Cyanidin-3-O-arabinoside</td>
<td>1359.4</td>
</tr>
<tr>
<td>Cyanidin-3-O-xylloside</td>
<td>165.8</td>
</tr>
</tbody>
</table>
Vitamins

Black chokeberries contain vitamins B (B1, B2, B6, niacin, pantothenic acid), vitamin C (13–270 mg/kg), β-carotene (7.7–16.7 mg/kg), vitamin A, vitamin E, a significant amount of dietary fibers (approx. 55 g/kg according to Kulling and Rawel 2008), minerals (Šnebergrová et al., 2014), with an oxidative capacity 10 times higher than other berries. The diuretic, laxative and cathartic properties are well known by people with digestive disorders (Sidor and Michałowska, 2019).

Other chemical compounds

Chokeberry fruits are a rich source of dietary fiber, minerals, fat and proteins (Kulling et al., 2008) polyzacharides (sucrose, fructose, sorbitol, glucose) (Denev et al., 2018) (Table 2). Nhuan and the collaborators (2018) reported that aronia leaves contain a variety of biological active substances such as chlorogenic acid, isomers, caffeic acid and rutin. Jurendić and Ščetar (2021) reported that aronia berry extract intake regulates thermogenesis in healthy women with a cold constitution. They suggest that aronia fruits improves the maintenance of body temperature through the regulation of noradrenalin and oxidative stress level. Therefore, aronia leaves contain bioactive compounds and have biological effects resulting from the polyphenols, flavonoids, and chlorophylls (Nhuan and Sun, 2014). Other substances found in chokeberry seed oils are triterpenoids and terols with an anti-inflammatory, antiviral, healing and anticarcinogenic properties (Nestby et al., 2019).

Table 2. Chemical composition of Chokeberry

<table>
<thead>
<tr>
<th>References</th>
<th>mg/100 g fruit</th>
<th>Ochmian et al. (2012)</th>
<th>Šnebergrová et al. (2014)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dry matter %</td>
<td>15.31</td>
<td></td>
<td></td>
</tr>
<tr>
<td>pH</td>
<td>3.3–3.7</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Titratable acidity (g citric acid per 100 g)</td>
<td>0.5–0.1</td>
<td></td>
<td>6.7–11.9</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Denev et al. (2018)</th>
<th>mg/100 g fruit</th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Total sugar</td>
<td>12.21–19.70</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Glucose</td>
<td>1.53–3.02</td>
<td>36.3–57.0</td>
<td></td>
</tr>
<tr>
<td>Fructose</td>
<td>2.2–3.69</td>
<td>26.0–47.1</td>
<td></td>
</tr>
<tr>
<td>Sorbitol</td>
<td>6.55–12.99</td>
<td>46.3–85.6</td>
<td></td>
</tr>
<tr>
<td>Sucrose</td>
<td>0.06–0.41</td>
<td>0.0–0.7</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Kulling et al., 2008</th>
<th>g/kg fruit</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Fiber</td>
<td>56</td>
<td></td>
</tr>
<tr>
<td>Minerals</td>
<td>4–6</td>
<td></td>
</tr>
<tr>
<td>Fat</td>
<td>1.4</td>
<td></td>
</tr>
<tr>
<td>Proteins</td>
<td>7</td>
<td></td>
</tr>
</tbody>
</table>

Goji berry chemical compounds

Polysaccharides

Goji berry is a rich source of phenolic pigments, polysaccharides, phytosterols, phenylpropanoids, carotenoids, including beta-carotene (7 mg per 100g of dried fruit) and zeaxanthin (up to 82.4 mg per 100g of dried fruit) (Ma et al., 2019). The polysaccharide complex is the most important and the most abundant group of compounds present in goji fruits (and it can be between 5–8% of dried fruits. The most common monosaccharides that can be found in goji berries are arabinose, galactose, glucose, rhamnose, mannose and xylose (Kulczyński et al., 2016).

Carotenoids and related compounds

The carotenoids are the colour components of goji berries and the second highly significant group of biologically active compounds with health benefit properties. The total carotenoid content of different goji berries ranged from 0.03 to 0.5% of dried fruits (Ma et al., 2019). A total of 11 free carotenoids and 7 carotenoid esters were detected from Lycium barbarum extracts (Amagase and Farnsworth, 2011; Islam et al., 2017). Zeaxanthin is a representative carotenoid found in goji berries, in the form of dipalmitin zeaxanthin. In ripening goji berries, the content of zeaxanthin can reach around 56–77.5% of total carotenoids. (Nestby et al., 2019). Goji berries represent the natural source of dipalmitin zeaxanthin. Lycopene, beta-carotene, cryptoxanthin, and
neoxanthin are also detected in goji berry extracts (Ma et al., 2019) and they are all associated with antioxidant properties (Patsilinakos et al., 2018; Ma et al., 2019)

**Other components**

Goji berries chemical composition includes also 6% of carbohydrate, 16% of dietary fiber, 13% of protein and 1.5% of fat. Goji fruits also contains rutin, alkaloids, terpenes, cyclic peptides, cerebrosides, betaine, caffeic acid, caffeoylquinic acid, chlorogenic acid, coumaric acid, quercetin-diglucoside, kaempferol (Skenderidis and Leontopoulos, 2022; Schmid et al. 2020). Fatty acids such as oleic acid, stearic acid, palmitic acid, myristic acid, linoleic acid, arachidonic acid, and a lot of minerals with a very high antioxidant capacity can be found in goji berries (Table 3). The level of minerals and other chemical compounds in goji berries depends on environmental conditions, geographic area and methods of cultivation. It was demonstrated by many researchers such as Endes (2015)-Turkey, Pedro (2019)-Brasil, Llorent-Martínez (2013)-Spain and Skenderidis (2019)-Greece (Table 3).

**Table 3. Chemical compounds of goji berries**

<table>
<thead>
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</thead>
<tbody>
<tr>
<td>Moisture (%)</td>
<td>10.34</td>
<td>15.29</td>
<td>75.32</td>
<td>Myristic</td>
<td>0.11</td>
<td>-</td>
<td></td>
</tr>
<tr>
<td>Crude oil (%)</td>
<td>4.11</td>
<td>-</td>
<td>-</td>
<td>Palmitic</td>
<td>8.23</td>
<td>12.04</td>
<td>19.38-21.79</td>
</tr>
<tr>
<td>Crude protein (%)</td>
<td>8.90</td>
<td>9.72</td>
<td>1.98</td>
<td>Stearic</td>
<td>2.91</td>
<td>3.21</td>
<td>1.66-1.90</td>
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<tr>
<td>Fibre (%)</td>
<td>7.30</td>
<td>11.27</td>
<td>2.73</td>
<td>Oleic</td>
<td>21.69</td>
<td>19.58</td>
<td>3.69-4.78</td>
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<tr>
<td>Soluble fibres</td>
<td>-</td>
<td>2.69</td>
<td>0.90</td>
<td>Linolenic</td>
<td>60.77</td>
<td>37.06</td>
<td>42.64-43.96</td>
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<tr>
<td>Total phenol (mg GAE/100ml)</td>
<td>3.44</td>
<td>-</td>
<td>-</td>
<td>Arachidonic acid</td>
<td>1.11</td>
<td>1.49</td>
<td>1.59-3.03</td>
</tr>
<tr>
<td>Total sugar (g/100ml)</td>
<td>487</td>
<td>75.05</td>
<td>-</td>
<td>Arachidonic acid</td>
<td>-</td>
<td>3.70</td>
<td>-</td>
</tr>
<tr>
<td>Fat</td>
<td>-</td>
<td>-</td>
<td>1.15</td>
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**References**

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<td>B</td>
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<td>-</td>
<td>-</td>
<td>Mo</td>
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<td>528</td>
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<td>K</td>
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<td>2120</td>
<td>8020</td>
<td>S</td>
<td>493.58</td>
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<td>Mg</td>
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<td>446</td>
<td>Se</td>
<td>2.22</td>
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<tr>
<td>Zn</td>
<td>-</td>
<td>1.75</td>
<td>6.9</td>
<td>Mn</td>
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<td>Hg</td>
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**Antioxidant activity of berries**

The level of antioxidants found in black chokeberries and goji berries compared to other berries has shown that these berries contain ten times more antioxidants than other fruits (Boţ et al., 2015). Tolic (2017) indicate that chokeberries contain 15 times more antioxidants than blueberries. Due to the phenolic content and antioxidant activity, chokeberries can be regarded as good candidate for raw materials in production of health beneficial functional foods (Jakobek et al, 2007). To provide a example of how powerful goji berries are, especially in fresh form, receiving the daily ORAC dose from apples, one would need to eat approximately 2,294 grams of apple or more than 20 apples (Table 4). However, eating just 20 grams of goji berries will cover the daily required ORAC dose (www.greekgojiberry.com). Gao and the collaborators (2017) mention that the dosage of dried goji berries varies between 5 and 12 g /day.
Table 4. Aronia and goji berry antioxidant scale [www.greekgojiberry.com]

<table>
<thead>
<tr>
<th>Fruits</th>
<th>ORAC Score</th>
<th>Grams needed/day to reach DRI</th>
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<tr>
<td>Goji berry</td>
<td>25.300</td>
<td>20</td>
</tr>
<tr>
<td>Aronia Berry</td>
<td>16.062</td>
<td>31</td>
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<tr>
<td>Prunes</td>
<td>5.770</td>
<td>87</td>
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<tr>
<td>Raisins</td>
<td>2.830</td>
<td>177</td>
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<tr>
<td>Blueberries</td>
<td>2.400</td>
<td>208</td>
</tr>
<tr>
<td>Blackberries</td>
<td>2.036</td>
<td>246</td>
</tr>
<tr>
<td>Strawberries</td>
<td>1.540</td>
<td>325</td>
</tr>
<tr>
<td>Plums</td>
<td>949</td>
<td>527</td>
</tr>
<tr>
<td>Oranges</td>
<td>750</td>
<td>667</td>
</tr>
<tr>
<td>Cherries</td>
<td>670</td>
<td>746</td>
</tr>
<tr>
<td>Red grapes</td>
<td>739</td>
<td>677</td>
</tr>
<tr>
<td>Grapefruit</td>
<td>495</td>
<td>1.010</td>
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<tr>
<td>Apples</td>
<td>218</td>
<td>2.294</td>
</tr>
<tr>
<td>Banana</td>
<td>210</td>
<td>2.381</td>
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<tr>
<td>Pears</td>
<td>134</td>
<td>3.731</td>
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</table>

DRI- Dietary Reference Intake

ORAC is the standard test for measuring the potency of antioxidants in food. The ORAC test provides the free-radical-destroying potential of a given food. The ORAC test has been adopted by the US Department of Agriculture. The measurement is expressed in terms of a 100-gram sample. It has been suggested that humans should consume about 5000 ORAC units a day for maximum benefits. The chemical composition of chokeberry fruits differs depending on the variety, the region where it is grown, the species and the methods of extraction of chemical compounds, influencing the amount of polyphenols and antioxidants (Denev et al., 2018). Currently, there are no data in the literature about any unwanted and toxic effects of chokeberries, juice or extract (Kulling et al., 2008).

CONCLUSIONS

Aronia and goji berries can be found on the market easily and consumed at a high frequency. Zeaxanthin, lutein, phenols, antioxidants, minerals and vitamins are the most important bioactive compounds found in chokeberries and goji berries that helps in the prevention of macular degeneration, flavonoids can modulate the immune system, prevent chronic diseases, cognitive disorders, mental impairments and other neurodegenerative diseases. Aronia and goji dried berries can be used as healthy alternative to sweet snacks and may be a valuable component of the diet. These berries have multi effects including anti-inflammatory, antihypertensive, hypoglycemic, anticancer, anticoagulant and the improvement of lipid metabolism disorders. Can be used as a dietary supplement to improve human health. The consumption of these berries ameliorates postprandial glycemic response, improves profile of circulating inflammatory markers, increases antioxidative capacity of plasma and helps improving the negative diabetes effects for young people. Many studies support the health promoting benefits of these berries, especially in managing aging and degenerative diseases, cancer, heart disease, type 2 diabetes, atherosclerosis, high blood pressure, stroke, visual impairment. Aronia and goji berries provide the most beneficial effects on human health when consumed as adjuvants to treatments or therapies. The studies certify the nutritional value and health effects of these berries, which could be of a considerable interest in developing of new drugs.

Author Contributions: C.A.M. Collected the data and wrote the paper; B.E. and M.V. Contributed to conceived and designed the review article.

Funding Source: This research did not receive any specific grant from funding agencies in the public, commercial, or not-for-profit sectors.

Acknowledgments
The authors wish to acknowledge to the reviewers who helped improve the content of this article.

Conflicts of Interest
The authors declare that they do not have any conflict of interest.
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