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Biological properties of honeysuckle (*Lonicera caerulea* L.): a review

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The honeysuckle (*Lonicera caerulea* L.) belonging to the Caprifoliaceae family, has been used for a long time in Chinese, Japanese and Russian folk medicine. Nowadays, the fruits of honeysuckle are becoming more and more popular also in Europe – mainly in Poland, Slovenia, the Czech Republic, and Slovakia because of valuable medicinal properties and they are popularly used as an ingredient of dietary supplements and medicinal preparations. The fruits of *Lonicera caerulea* are rich in phenolics, especially anthocyanins and vitamin C. The major bioactive anthocyanin of haskap is cyanidin-3-*O*-glucoside (C3G). Consumption of high amounts of an antioxidant substance may have a positive impact on human health, particularly the prevention of cancer and inflammatory diseases. The berries of blue honeysuckle containing a significant amount of biologically active substances can be included into the group of so-called "superfruits". Consumers are constantly seeking better alternatives, healthier products of plant origin, to rule out negative aspects, and this will be an alternative to widely existing food products. In addition, the growing interest of producers in new products rich in health-promoting properties makes them more attractive to the consumer. The content and health properties of the fruit were identified to be dependent on the cultivar, genotype, and the place of harvesting. This paper reviews and highlights the limited nutritional and therapeutic information currently available on the honeysuckle.

Keywords: *Lonicera caerulea*, honeyberry, cultivars, biochemical composition, health benefits

Introduction

Species belonging to the genus *Lonicera* such as *Lonicera caerulea* var. edulis, *L. caerulea* var. *kamtschatica*, *L. caerulea* var. *altaica*, *L. caerulea* var. *byarnikovae*, and *L. caerulea* var. *emphyllocalyx*, as well as their hybrids, collectively known as *Lonicera caerulea* L., also known as blue honeysuckle, haskap, honeyberry, sweet berry honeysuckle or edible honeysuckle, are representative of such plants (Chmiel et al., 2014; Chang et al., 2018; Gawroński et al., 2020). The berries of blue honeysuckle contain a significant amount of biologically active substances. These berries can be included into the group of so-called "superfruits" (Bojarska et al., 2019). Haskap is a deciduous berry shrub, growing to 1.5–2.0 m tall. Its flowers are pale yellow, melliferous, and have a delicate, pleasant aroma

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(Grobelna et al., 2020). The berries have an elongated elliptic or cylindrical shape, are dark purple (Figure 1).

They can reach approximately 2 cm in length and 1 cm in width (Bieniek et al., 2005; Hummer et al., 2012; Yamamoto et al., 2014; Auzanneau et al., 2018; Gołba et al., 2020). The fruits have thin skin with a characteristic waxy coating. Their weight ranges from 0.3 to 2.0 g. The taste can be characterized as bitter to sour-sweet, varying among cultivars (Hummer et al., 2012; Gołba et al., 2020). Blue honeysuckle plants have been used for ages in Asia for their medicinal properties (Thompson and Chaovanalikit, 2006; Ochmian et al., 2012). Blue honeysuckle has a lot of positive features: early ripening (even two weeks before strawberry), exceptional hardiness, no specific demands for soil and climatic conditions, or low susceptibility to pests and diseases (Szot and Wieniarska, 2012). In the literature, the first mention of this plant originates from Russia in the 17th century. At present, honeyberry is cultivated across Japan, China, Russia, Central, and Eastern Europe – Poland, the Czech Republic, Slovenia, Slovakia, North America-Canada, and the USA (Svarcovaa et al., 2007; Senica et al., 2018; Becker and Szakiel, 2019; Grobelna et al., 2019). According to the available literature, the fruits of honeyberry are a valuable source of vitamins, minerals, and secondary metabolites with properties that are important for maintaining proper human health (Grobelna et al., 2020). Currently, in many countries, there are two serious problems: diseases of civilization and ageing of the population. They can be limited, among others through a proper diet, rich in fruit, especially those with both high antioxidant activity and content of polyphenols (Korczyński et al., 2015). A high total polyphenolic content and antioxidant activity are typical for blue honeysuckle berries (Rupasinghe et al., 2018; Grobelna et al., 2019) and determine the edible value and health benefits of this plant. The chemical composition of berries varies depending on genetic factors (cultivar), climate, weather conditions, as well as agronomic practices (Szot and Wieniarska, 2012). Fully ripened fruits contain between 12.4 and 20.3 % of dry matter, with a predominance of fructose and glucose (Rupasinghe et al., 2018; Grobelna et al., 2020). The noteworthy among bioactive compounds are anthocyanins (Rupasinghe et al., 2018; Grobelna et al., 2019). The most abundant anthocyanin is cyanidin-3-glucoside (79–92 %), whereas cyanidin-3,5-diglucoside, peonidin-3-glucoside, cyanidin-3-rutinoside, peonidin-3-rutinoside, and pelargonidin-3-glucoside occur in smaller amounts (Wang et al., 2016; Grobelna et al., 2020). Cyanidin-3-*O*-glucoside (C3G) comprises over 60 % of the total polyphenols. There is evidence of significant antioxidant, cardio-protective, anti-inflammatory, neuroprotective, anticancer, and anti-diabetic properties of C3G-rich haskap preparations and C3G alone both *in vitro* and *in vivo* (Wang et al.,

Figure 1 The berries of blue honeysuckle before harvesting
Foto B. Markuszewski and O. Grygorieva

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2016; Rupasinghe et al., 2018; Grobelna et al., 2020). The other group of chemical compounds identified in the fruits of blue honeysuckle is phenolic acids, flavonoids, including flavan-3-ols, flavons, flavanols, and organic acids, iridoids (Kucharska et al., 2017; Oszmiański and Kucharska, 2018; Becker and Szakiel, 2019). Blue honeysuckle berries are characterized by a high content of vitamin C, which can reach up to 187 mg/100 g fresh weight (FW) (Jurikova et al., 2012; Caprioli et al., 2016). In addition, they also contain the mineral components, potassium is dominant, followed by phosphorus and calcium, magnesium and iron in smaller amounts, and trace amounts of manganese, copper, and zinc (Rupasinghe et al., 2018; Grobelna et al., 2019; Grobelna et al., 2020). They are characterized by a high content of organic acids, among which citric acid is the most dominant and constituted 47 % of all organic acids. Among other organic acids are malic, phytic, oxalic, quinic, and shikimic acids were also present. At the same time, oxalic, quinic, and shikimic acids were present in the lowest amounts and constituted, respectively, 5; 4, and 1 % (Grobelna et al., 2020, Wojdyło et al., 2013). Health-promoting properties of the haskap berries include protective effects against cardiovascular and neurodegenerative diseases, osteoporosis, type 2 diabetes, anaemia, as well as antimicrobial, anticarcinogenic, and anti-inflammatory activity (Park et al., 2005; Kula et al., 2013; Celli et al., 2014; Caprioli et al., 2016; Wang et al., 2016; Cory et al., 2018; Grobelna et al., 2019; Gawroński et al., 2020).

Selection of cultivars and characteristics of the cultivation

The honeyberry is a quite new orchard species that at the turn of the XXI century went to commodity production in Poland. Then Zofia‘s Łukaszewska‘s cultivars are called ‘Wojtek‘ (Figure 2), ‘Jolanta‘ and number ‘46‘ that is colloquially called ‘Zojka‘ (Figure 3), and number ‘44‘ appeared in crops. They turned out to be attractive for producers because of tasty big fruits that does not fall off. Another advantage of these species is that they bloom at the same time, which favours their good pollination. Currently, Polish, Russian and Canadian varieties are offered on the market, but they still require careful checking in the Polish climate and specific growing conditions (Podymiak, 2015). Many new varieties, Russian and Canadian breeding, have appeared in Polish nurseries. They are characterized by attractive large fruits, high fertility, and valuable pro-health properties (Bieniasz et al., 2015).

The cultivars in Poland include Wojtek, Jolanta, Atut, Duet, Brązowa, Czarna, and Warszawa (Ochmian et al., 2008; Ochmian et al., 2012; Kaczmarska et al., 2015; Becker and Szakiel, 2019; Grobelna et al., 2020). The most popular Canadian cultivars are Blue Velvet, Tundra, Aurora, Borealis, Indigo Gem, and Honeybee (Rupasinghe et al., 2012; Rupasinghe et al., 2018; Becker and Szakiel, 2019; Grobelna et al., 2020). The previous observations showed that so far the cv. Wojtek, planted with cv. Zojka as a pollinator, has proved its best in commercial plantations (Figure 4). Both cultivars bloom at a similar time and are a well-suited pair for large plantations. It is best to plant them in a proportion of 3:1, that is for 3 rows of the cv. Wojtek there should be 1 row of cv. Zojka (Podymiak, 2015). It is estimated that the cultivation area of hascap in Poland may amount to as much as 2000–2500 ha. These are both small, several-hectare plantations as well as large, specialized (Podymiak, 2020).

Figure 2 The fruits of cultivar Wojtek
Foto A. Bieniek

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Figure 3 The fruits of cultivar Zojka
Foto A. Bieniek

Blue honeysuckle starts bearing fruits in the second year after planting, and the full yield (3–5 kg) can be harvested in 8–15 years after planting (Grobelna et al., 2020). Honeyberry is long-lived and can bear fruit for up to 30 years. Shrubs that are 20- to 25-year-old can die out or yield less, but treatments such as pruning and removing older stems and branches can help the plant grow afresh (Becker and Szakiel, 2019; Grobelna et al., 2020). The soil and climatic conditions for hascap growing are relatively minimal. It tolerates a wide range of soil pH and the most favourable pH range is 5.5–8.0 (Pluta, 2015; Grobelna et al., 2020). The shrubs can grow in sandy and clay soils as well as in peaty and slightly acid soils (Dawson, 2017). Soil and foliar

Figure 4 The plantation of *Lonicera caerulea* located in the north-eastern part of Poland
Foto B. Markuszewski

Figure 5 The fruits of cultivars Wojtek and Zojka after mechanical harvesting
Foto A. Bieniek

fertilization can improve the size and quality of crops (Szot and Lipa, 2012). Moreover, the quality of the fruit can be modified by the climatic conditions prevailing in a given growing season (Szot and Wieniarska, 2012). *Lonicera caerulea* demonstrates very high frost resistance, shrubs can withstand temperatures down to -40 °C and flowers down to -8 °C (Ochmian et al., 2008; Pluta, 2015; Grobelna et al., 2020). The berries of honeysuckle ripen at the end of May are one of the first dessert fruits on the market. It is very rarely pest-attacked and therefore does not require special protection against fungal diseases and other pathogens. They can be cultivated using the organic method (Szot and Wieniarska, 2012; Celli et al., 2014; Pluta, 2015). New varieties are adapted to mechanical harvesting (Figure 5). Fruits can be sold fresh or developed by the processing and pharmaceutical industries (Pluta, 2015). The selection of a cultivar is also very important for health reasons as the amount of bioactive ingredients varies between cultivars (Rop et al., 2011). Szot and Wieniarska (2012) observed that the fruits of the cv. Duet in relation to cv. Atut is characterized by a higher weight and sugar content, but on the other hand, they have a lower dry matter, anthocyanin, vitamin C, and acidity content.

Health properties of honeysuckle

Blue honeysuckle belongs to fruit species with unique biological and chemical properties. They are a valuable source of vitamins, minerals, and secondary metabolites with properties that are important for maintaining proper human health (Grobelna et al., 2020). For a long time berries have been harvested from wild plants in the regions of Russia, Chine, and Japan (Gawroński and Kaczmarska, 2018). This plant was even called the "elixir of life" by the indigenous Ainu family living on the island of Hokkaido (Celli et al., 2014). The raw material was used to treat fever, headaches, and urinary tract diseases (Kaczmarska et al., 2015). In Tibetan medicine, honeyberry bark was used to obtain an analgesic preparation for chronic arthritis and headaches. In the Far East, anti-rheumatic baths were prepared from young buds, and a decoction of shoots was administered to stimulate the appetite (Skwarcow and Kuklina, 2002; Bieniek et al, 2005). It has been shown that the infusion of arachnid flowers is very helpful in the treatment of the bladder (Kawecki et al., 2007). Decoction of fruit and leaves can be used to treat eye diseases, angina, and periodontal disease (Isaczkin et al., 2003; Bieniek et al., 2005). Additionally, such a decoction inhibited ocular inflammation, in particular uveitis (Jin et al., 2006).

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Honeyberry is widely used in the treatment of viral and bacterial infections. The raw material can inhibit the growth of pathogenic bacteria strains such as *Candida parapsilosis*, *Staphylococcus epidermidis*, *Enterococcus faecalis*, *Streptococcus mutans* and food-borne bacteria: *Listeria monocytogenes*, *Escherichia coli*, and *Campylobacter jejuni* (Palíková et al., 2008; Raudsepp et al., 2013). This property is particularly important due to the ability of the haskap berry to counteract diseases of the oral cavity and gastrointestinal tract. In addition, due to their detoxifying properties, fruits are used in poisoning with heavy metals, medications, and in the treatment of cardiovascular diseases. It also exhibits soothing properties in case of food allergic ailments (Li and Li, 2005). Fruit juice can treat ulcers and impetigo (Kawecki et al., 2007; Szot et al., 2014).

It was found that extracts from blue honeysuckle berries have anticancer properties. This anticancer property is related to the induction of antioxidant defence enzymes, inhibition of cancer cell proliferation, and factors causing metastases (Rupasinghe et al., 2018; Zhou et al., 2018). Iridoids have been recently identified in fruits of blue honeysuckle (Kucharska et al., 2016). Iridoids rarely occur in fruits, except for cornelian cherry, cranberry, lingonberry, and bilberry (Heffels et al., 2017; Kucharska et al., 2017). Recent studies have shown that longanic acid is the most abundant iridoid in blue honeysuckle berries (Kucharska et al., 2017). However, iridoids such as loganin, sweroside, secologanin, secoxyloganin, pentosides of loganin, and pentosyl-sweroside have also been identified (Kucharska and Fecka, 2016; Kucharska et al., 2017; Oszmiański and Kucharska, 2018; Grobelna et al., 2020). Loganin helped to alleviate *diabetes mellitus* by improving liver function and reducing nephropathy (Tundis et al., 2008; Park et al., 2011). Iridoids are biologically active compounds with anti-inflammatory, neuroprotective, hepatoprotective, hypotensive, and antibiotic properties (Heffels et al., 2017; Kucharska et al., 2017; Oszmiański and Kucharska, 2018). Prevalent antioxidants are able to reduce reactive oxygen species, counteracting ageing processes (Duthie, 2007; Gołba et al., 2020). Research shows that blueberry extract protects DNA from damage, preventing carcinogenesis (Duthie, 2007). Fruits reduce the negative effects of oxidative stress, caused by UV radiation, inhibiting the formation of free radicals. Kamchatka berry is also linked to its anti-inflammatory potential. Long-term exposure to inflammation may consequently lead to arteriosclerosis, neurodegenerative diseases, diabetes, and even cancer. It has been shown that the effect of using blueberries is comparable to that of diclofenac, a popularly used anti-inflammatory drug substance (Rupasinghe et al., 2018). The research has also shown the positive impact of honeysuckle berries on inhibiting melanogenesis, resulting in a whitening effect (Jurikova et al., 2012; Celli et al., 2014). The fruits of honeysuckle also have strong antidiabetic properties. In Podsędek et al. (2014) studies, the hascap berries showed the strongest α-glucosidase inhibitory activity among fruits such as blackcurrant, highbush blueberry, bilberry, red gooseberry, and sweet cherry. According to Johnson et al. (2011), inhibition of α-glucosidase and β-fructosidase allows delaying disaccharide digestion, which is important for postprandial hyperglycemia control in patients with diabetes. In addition, it has been shown that the plant has a positive effect on hyperthyroidism by reducing the level of thyroid stimulating hormone in the body (Park et al., 2016). The berries of honeysuckle also play an important role in fighting urinary tract symptoms and digestive problems (Kontiokari et al., 2003; Del Rio et al., 2010).

Conclusion

The main advantage of *Lonicera caerulea* is high content of bioactive compounds and, therefore, it can be used as a very good component of functional food, dietary supplements, and even herbal medicinal products. It is worth mentioning that not only fruits have a beneficial effect on health. Flowers have been proven to fight colds; bark has a diuretic effect and leaves help with throat infections. According to conducted studies, regular consumption of berries could reduce cancer and insulin resistance. The climatic and soil requirements of *Lonicera caerulea* enable its cultivation in the European countries, so the area under cultivation continues to increase. Therefore, to fully utilize these fruit, it is important to look for new ways to process them.

Conflicts of interest

The authors declare no conflict of interest.

Ethical statement

This article does not contain any studies that would require an ethical statement.

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