INVASIVE KNOTWEED SPECIES AS A RICH SOURCE OF ANTIOXIDANTS

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Abstract: *Variety of food is important in terms of providing essential nutrients in the human diet. Antioxidants, which allow the organism to defend against the oxidative stress, environmental pollution and other toxic substances, play an important role in the healthy human nutrition. Three alien taxons of knotweed - Japanese (Fallopia japonica), Sakhalin (Fallopia sachalinensis) and Bohemian (Fallopia x bohemica) are abundantly spread all over Europe and represent a big ecological problem, due to their rapid expansion and flexibility, which significantly alter the biodiversity of the area. At the same time, the use of knotweed in traditional Asian medicine is extensive and in many cases successful. Resveratrol is only the most known substance in Japanese knotweed and is already widely used as a dietary supplement, in cosmetics and medicine. Determination of other antioxidants and their bioactivities (e.g. antioxidant, antimicrobial, cytotoxic) from different tissues of knotweed is therefore an interesting topic that cannot change only the attitude of modern society towards these plants, but also contribute to the creation of more effective strategy for limiting their spread. The recent scientific publications are mostly focused on Japanese knotweed, while the research of Sakhalin and the Czech knotweed is limited. Hence, the characterization of these two taxons represent the new challenge due to their altered biological and chemical activity.*

Keywords: *knotweed, invasive, antioxidants;*

1. Introduction

Variety of food is important in terms of providing essential nutrients in the human diet. The antioxidants, which allow the organism to defend against the oxidative stress, environmental pollution and other toxic substances play an important role in the healthy human nutrition . Vegetable food provides many bioactive substances that act independently and synergistically and prevent the development of chronic and oxidative stress - related diseases. Bioactive molecules present in plants are called phytochemicals, among which antioxidants prevail. In addition to plant foods the nutrition recommendations are suggesting to consume variety of food supplements based on plant extracts and with high antioxidative activity.

2. Composition Invasive knotweed species

2.1. Traditional use of knotweed

In traditional Asian medicine the use of knotweed (particularly Japanese species) is known to treat various diseases. The roots of Japanese knotweed were primarily used in traditional Chinese medicine (TCM). China Pharmacopoeia describes and claims the use of Japanese knotweed named Hu Zhang. It can be consumed either as young wild vegetable preparations from rhizomes or as a drink in the form of a medicated Itadori tea. Some closely related species, which belong to the knotweed family (*Polygonaceae*), for example buckwheat and rhubarb, also boast many positive effects on the human body and are known to contain a wide range of different antioxidants. TCM uses a Japanese knotweed for enhancing the functioning of the gall bladder, the prevention of liver disease, lung disease associated with impaired blood circulation, treatment of elevated lipid levels, tumors, inflammations, leukorrhea, ... Modern clinical and experimental studies have shown that the individual active components present in Japanese knotweed act positively on the course of many diseases. Positive effects are mainly observed in the course of cardio-vascular and nerve disease [9], [10]. There is also evidence of its antiviral, antibacterial and antifungal activity [11]. Similar activity was detected for the rhizome Sakhalin knotweed [12]. Interestingly, the alternative medicine describes Japanese knotweed as a key component in the treatment of Lyme disease [13].

In addition to the therapeutic use, the Japanese knotweed is also used in the culinary. Young shoots are consumed in a similar way as asparagus; moreover, knotweed may replace rhubarb in some dishes. Steve Brill in his book [14] describes Japanese knotweed, particularly its young shoots, harvested to a height up to 20 cm, as an excellent spring vegetable with a slightly sour taste. The book also mentions knotweed as a good source of vitamin A and vitamin C, manganese, zinc, potassium, and a number of phenolic compounds.

In Asia, Japanese knotweed rhizome juice is produced to make yellow dye staining and rice flour [15]. In India and South Asia, knotweed leaves are sometimes used as a substitute for tobacco [5]. Japanese knotweed rhizomes are also used to prepare tea named Itadori, which in Japanese language means well-being. According to the study performed by Burns et al. [16], the tea is a good dietary source of resveratrol and a suitable replacement for red wine. People, who avoid wine because of alcohol, may benefit from resveratrol by drinking Itadori tea.

Nevertheless, there are few data and research on the knotweed toxicity. There are concerns regarding consuming it by pregnant women, since substances may interfere with the functioning of uterus. Tannins, which are present in the plant, may operate carcinogenic [17] and prevent the activity of some digestive enzymes [18]. Knotweed contains oxalic acid, similarly to rhubarb (*Rheum rhabarbarum, Polygonaceae*); hence, the consumption of young shoots is preferable. The diet with a higher content of oxalic acid is not advisable for people with an increased risk for the development of arthritis, rheumatism, gout, and kidney stones. There are also indications that the consumption of knotweed in certain subjects leads to increased skin sensitivity to light, which was also observed in consumption stems of buckwheat (*Fagopyrum esculentum, Polygonaceae*) [19]. The rhizome extract nevertheless showed a low toxicity towards aquatic organisms [20].

Transparent study on the pharmacological effects and eventual toxicity of Japanese knotweed should be given more attention in the future. It would also be desirable to more accurately investigate the substances contained in the above-ground parts of the plant, and determine their positive/negative effects on the organism [10], [15].

2.2. Invasiveness of knotweed

On the other hand, alien invasive knotweed represents a big ecological problem, because of its rapid expansion and flexibility, which significantly alter the biodiversity of the area.

The ability of plants to invade an area is strongly influenced by their flexibility, regeneration capacity and resilience. A variety of substances, namely secondary metabolites, produced and secreted by plants into the surrounding area, also contribute to all of the above characteristics [21-23].

Three taxons of knotweed (Figure 1), namely Japanese knotweed (*Fallopia japonica*), Sakhalin knotweed (*Fallopia sachalinensis*) and Bohemian knotweed (*Fallopia x bohemica*), a hybrid of these two species are present in Europe. All three of them differ in the degree of invasiveness. The alien invasive knotweed is often referred to only as a source of environmental and social problems, but these plants in some parts of the world play an important role in maintaining human health and are included in the everyday human diet.

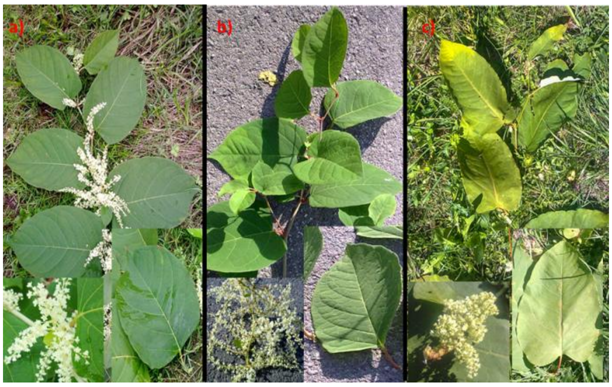

Fig. 1. *The leaves and the flowers of a) Japanese knotweed (Fallopia japonica), b) Bohemian knotweed (Fallopia x bohemica) and c) Sakhalin knotweed (Fallopia sachalinensis)*

2.3. Knotweed as a source of antioxidants

Japanese knotweed has been already extensively studied both in the ecological field, in conjunction with its invasiveness, as well as in the field of pharmaceuticals and the use of these plants for the isolation of a variety of useful

materials, especially those with antioxidant activity [5], [24]. It is also known that the useful pharmacological activity of plant foods on the human body is the result of different combinations of secondary metabolites that are present in their tissues [23], [25-27].
Knowing the fact that knotweed is a very resistant, fast-growing plant, which in most cases only causes a problem in modern society, it would be interesting to discover the wider benefits of this plant to humans [28]. Determination of particular antioxidants and the antioxidant activities of extracts prepared from different tissues of knotweed is therefore an interesting topic that can change the look of modern society on these plants, but also contribute to the creation of more effective strategy for limiting their spread. The recent scientific publications are mostly focused on Japanese knotweed, while the research of Sakhalin and the Czech knotweed is limited, even if they are widely spread across Europe.

Resveratrol, one of the main active substances in Japanese knotweed, has shown strong antioxidant activity. When used at many model organisms it affects the longevity and the aging process. Resveratrol, which is isolated from the roots of Japanese knotweed, is already widely used as a dietary supplement, in cosmetics and medicine [29-31].

Besides resveratrol, knotweed contains a large variety of secondary metabolites with antioxidant activity, such as quinones, phenolic acids, stilbenes, tannins, flavonoids and catechols [20]. The roots of Japanese knotweed are the most often considered, but also rhizomes, leaves, stems and flowers of Sakhalin and the Czech knotweed represent a potential source of natural bioactive antioxidants [32]. The main active components of knotweed are stilbenes and quinones [33].

Researchers detected in underground and aboveground parts of knotweed similar bioactive components. The main differences between the plant bodies are present in particular in quantities of individual substances. Specific differences between the three taxons and their tissues are also found. The differences can be also attributed to different geographical location of plant growth [21], [28], [34].
It was also found that the presence of mycorrhizal connections rootstock in Czech knotweed increases the amount of resveratrol and its derivatives [35]. The presence of particular fungi also affects the levels of resveratrol and its glycosides. Since glucose is transported from the plant to fungus by symbioses for the latter to cover its energy needs for nitrogen fixation, less glucose remains available for the formation of glucosides [36]. According to the current information the best source of resveratrol, however, represents the root of Japanese knotweed [33].

As mentioned above, the knotweed rhizomes are a reach source of stilbenes, while the aboveground parts contain more flavonols [37]. The leaves, stems and inflorescences contain many flavanols, especially catechins and epicatechins. Considering catechins, the most abundant are the derivatives of caffeic acid [38]. In the aboveground parts of the plant quinones and stilbenes are also present, but in lower concentrations than in the rhizomes [39]. Sakhalin knotweed contains up to 70-fold lower concentration of stilbene compared to rhizomes of Japanese knotweed [38]. It was found that piceid, gicosilated form of resveratrol, is presents in different tissues in the quantity 10-times higher than the free resveratrol [33], [40], [41]. The rhizomes contain the highest concentration of stilbenes in autumn, when it is also their biggest weight in the aboveground parts of the plants compared to the spring. The content of stilbenes in the aboveground part of knotweed is much lower than in their rhizomes [33].

Given the qualitative and quantitative content of the antioxidants the Czech knotweed is more closely resembled to Japanese knotweed than to the Sakhalin one [34]. The content of stilbenes, such as piceatanol and astringin, can surpass the values in Japanese knotweed [32]. Japanese knotweed rhizome can be characterized by the presence of stilbenes and certain anthraquinones, whereas the rhizome of Sakhalin knotweed on the content of anthraquinones [42] and phenylpropanoid glycosides [21].

Young shoots contain similar components as the roots, but they are present in lower concentrations [37]. Sakhalin knotweed leaf extract could in future be used to control various plant diseases, as it has also fungicidal activity, which the researchers attributed to its high content of catechins [43].
It has to be also stressed that due to the large amounts of biomass that knotweed produce, their distribution, invasiveness, content of stilbenes and other secondary metabolites they can represent an excellent source for the extraction of antioxidants. One hectare can produce between

20 and 30 tons of plant biomass, which contains more than 80 kg stilbenes [21], [33].

Different parts of the herb can be used in a wide variety of purposes. Different parts of Japanese knotweed contain varying amounts of resveratrol, piceid, emodine and physcion, whereby it has been shown that the roots of the maximum content of these components, while the amounts of the stem and leaf-represented in small quantities [44]. Same authors have also monitored the effect of harvest time on the amount of resveratrol, piceid, emodin and physcion in the roots. Results showed that resveratrol is present in higher quantities in October, piceid in August, while the amount of emodine maintains fairly constant throughout the year.

2.4. Knotweed as an antimicrobial agent

In addition to the described antioxidant properties the knotweed is also attributed the possible antimicrobial effects. However, once more the most studied are the effects of extracts of roots of Japanese knotweed, while the extracts of other tissues and the other two knotweed taxons are limited [11]. Marinas et al. [45] in their study, carried out with different tissues of Japanese knotweed, found that leaf extracts containing quercetin, rutin and epicatechin, possessed the significant antimicrobial activity. It was also shown that epicatechin and its derivatives prevent the growth of Gram-positive bacteria, whereas its antifungal activity is much lower.

Conclusions

Since different tissues of all three taxons of knotweed contain many functional components, it is expected that these plants will be in the future used for the development of new functional foods and isolation of novel food and pharmaceutical ingredients.

So far, research in the study of secondary metabolites have mostly focused on Japanese knotweed and its rhizome, due to the high content of stilbene resveratrol and its derivatives. In the future, it would be important to accurately analyze the components also of the aboveground parts of these invasive plants and special attention has to be paid to Sakhalin and the Czech knotweed. In this way, we can obtain important information on the causes of the spread of knotweed species in a new environment and find useful components of these invasive plants, which would be useful in the food industry, the pharmaceutical industry and agriculture.

Although currently knotweed represents a burning issue for botanists and biologists, it is an excellent starting point for nutritionists in the food industry. So far, it is not used much, but it has a big potential. Due to the increasing role of resveratrol in nutraceuticals, therapeutics and cosmetics, it is expected that demand will grow in the future. This brings new market opportunities for the agriculture sector [44].

Following the pattern of the eastern cultures knotweed could also be used in cooking, in the preparation of salads, soups and some other dishes. Scientists are trying to make these plants and their benefits as close as possible to the people, for them to also see them from the positive side. On the one hand, these plants are found at almost every stream and there is enough for everyone. On the other hand, it can also be planted and thus establish it as a new market niche. However, we have to be careful to control their spread due to extreme invasiveness of these plants.

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