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Review

Bioactive compounds and health benefits of edible *Rumex* species-A review

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Abstract: Medicinal and food plants as well as their bioactive fractions have been used by diverse human cultures since ancient times. These plants provide multiple health benefits because of the presence of a plethora of phytochemicals including phenylpropanoids, isoprenoids, alkaloids, sulphated compounds, peptides and polysaccharides that are responsible for various biological activities such as anticancer, antioxidant, antifungal, antibacterial, anti-dysenteric, anti-inflammatory, antiulcer, anti-hypertensive and anticoagulant properties. The genus *Rumex* includes edible and medicinal herbs belonging to buckwheat (Polygonaceae) family, consisting of about 200 species rich in phenylpropanoids and anthraquinones. Some *Rumex* species have exhibited health-promoting effects and have been used as traditional foods and herbal remedies, though a limited information has been documented on their specific biological properties. Therefore, this survey aimed at reviewing the *Rumex* species with documented biological activity, focusing on preclinical evidences on their efficacy and safety.

Key words: Polygonaceae; Buckwheat; Functional foods; Nutraceuticals; Traditional foods; Herbal remedies.

Introduction

Medicinal plants can be a promising alternative for many diseases and conditions (1-17). Always, these plants are also valued to flavor foods, giving the food a dual role, i.e. flavor and bioactive compounds (6, 18-23). Furthermore, medicinal plants are low cost and tend to have fewer side effects than synthetic drugs (21, 24-27).

The family Polygonaceae comprises about 50 genera and 1200 species that are worldwide distributed. Important genera include *Rheum, Rumex, Polygonum, Coccoloba, Calligonum* and *Persicaria* (28), traditionally used as herbal remedies for treating several ailments including urinary inflammation, gallstones, chronic cutaneous diseases, skin burns, hepatitis, jaundice, fever, osteomyelitis and as anticancer, diuretic and laxative agents (29-37). Knotweed (*Fallopia japonica*) has been used traditionally in Asia for treating hepatitis, inflammation, skin burns, osteomyelitis and gallstones (38). Roots of *Rumex crispus* have been applied in folk medicine to cure jaundice, fever, constipation and chronic cutaneous diseases, whereas fruits and seeds have been prescribed for treating hepatitis and cancer. Rhizome of *Polygonum sachalinense* has been used in oriental medicine as diuretic and laxative (39, 40).

As other plant families, Polygonaceae are rich in secondary metabolites, in particular phenylpropanoids and anthraquinones, possibly responsible for the healthy properties ascribed to these plant species (29).

Genus *Rumex*

About 250 species are included in the genus *Rumex*, both annual and perennial herbs worldwide distributed. Previous studies have reported anticancer, antidiarrheal, antioxidant, analgesic, anti-inflammatory, anthelminthic and antimicrobial activities of plants belonging to this genus (40), rich in bioactive phytochemicals (Figure 1).

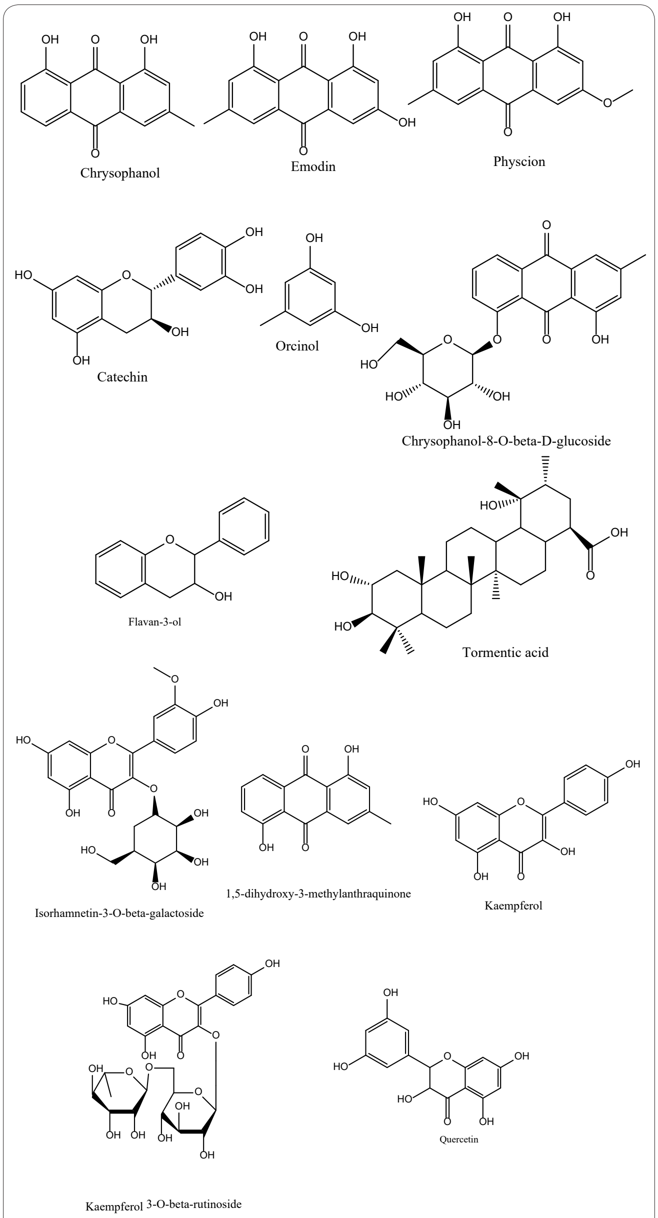

Figure 1. Chemical structures of some selected metabolites isolated from *Rumex* species.

Chemical and pharmacological profiles of genus *Rumex*

Kang et al. (41) investigated crude methanol extract obtained from roots of *R. gmelinii* and isolated 1-*O-β*-D-glucopyranosyl chrysophanol and 1-*O-β-D*-glucopyranosyl emodin. Demirezer et al. (42) reported 9 compounds from roots of *R. patientia* including chrysophanol, physcion, catechin, emodin, flavan-3-ol, 6-chlorocatechin, chrysophanol-8-*O-β-D*-glucopyranoside, emodin-8-*O-β-D*-glucopyranoside and orcinol. Among the isolated compounds, flavan-3-ol, 6-chlorocatechin and catechin exhibited antiradical scavenging activity. Kim et al. (43) reported ethyl gallate, 4(R),23-epoxy-2,3,19-trihydroxy-24-norurs-12-en-28-oic acid, 2,3,19-trihydroxy-24-norurs-4(23),12-dien-28-oic acid, tormentic acid and myrianthic acid from ethyl acetate soluble extract of the stem of *R. japonicus*. The 2,3,19-trihydroxy-24-norurs-4(23),12-dien-28-oic acid and ethyl gallate showed a significant inhibitory activity on AGEs (advanced glycation end products) formation with IC_{50} values of 87 and 14.3 µg/ml on RLAR (rat lens aldose reductase), respectively. Başkan et al. (44) isolated 1,5-dihydroxy-3-methylanthraquinone, 1,3,5 trihydroxymethylanthraquinone and 1,5-dihydroxy-3-methoxy-7-methylanthraquinone from roots of *R. crispus*.

Kim et al. (45) reported ω-hydroxyemodin, emodin, chrysophanol-8-*O-β-D*-glucoside, physcion-8-*O-β-D*-glucoside and emodin-8-*O-β-D*-glucoside. They also isolated five flavonoids: quercetin, kaempferol-3-*O-β-D*-glucoside, isoquercitrin and (+)-catechin from fruits of *R. japonicus* and evaluated their aldose reductase inhibitory potential. Wang et al. (46) isolated two oxanthrones C-glucoside, 6-methoxyl-10-hydroxyaloin A and 6-methoxyl-10-hydroxyaloin B from roots of *R. gmelinii*.

Hawas et al. (47) have isolated kaempferol 3-*O-β*-galactoside, kaempferol 3-*O-β*-glucoside, kaempferol 3-*O*-rutinoside, isorhamnetin 3-*O-β*-galactoside, isorhamnetin 3-*O-β*-glucoside, isorhamnetin 3-*O*-rutinoside from methanolic extract of *R. dentatus*. These compounds exhibited moderate antimicrobial activity, weak antioxidant and cytotoxic activities. Jo et al. (48) reported 1,8-dihydroxy-3-methoxy-6-methylanthracene-9,10-dione isolated from roots of *R. japonicus* and its antitumor activity. Ahmed et al. (49) investigated urease inhibitory potential of crude methanol extract of *R. acetosella* roots and its sub-fractions including *n*-hexane, chloroform, ethyl acetate, *n*-butanol and aqueous fraction.

Functional foods

Food habits and trends in food production and consumption have health, environmental and social impacts. Functional foods are being considered as a ‘magic food’ to alleviate some of the health care costs associated with aging. One of such example is naturally occurring fatty acids found in milk fat and adipose tissue of ruminants, whose quantity in food products can be enhanced by feeding animals a specialized diet (50, 51). “A food can be regarded as ‘functional’ if it is satisfactorily demonstrated to affect beneficially one or more target functions in the body, beyond adequate nutritional effects, in a way that is relevant to either an improved state of health and well-being and/or reduction of risk of disease” (52).

Phenolic compounds are plant secondary metabolites, which play an important role in defense against pathogens and pests, as well as in species dissemination. The interest in these compounds is related with their capacity to counteract oxidative stress involved in the pathogenesis of more than 100 diseases including malaria, atherosclerosis, cancer, diabetes, acquired immunodeficiency syndrome, thus promoting health benefits. Various bioactive phytochemicals from plants used as functional foods in specific disorders are summarized in Table 1. Jimoh et al. (53) studied polyphenolic content and antioxidant and antibacterial activities of the acetone, methanol, and water extracts of *Rumex ecklonianus* plant. A comparative study between wild edible plants including *Rumex* spp. and *Cirsium pumilum* showed that *Rumex* spp. contained higher amount of total phenols (102.56+3.13mg/100g) compared with *Cirsium pumilum* (93.64+0.28mg/100g)(54).

As previously introduced, *Rumex* is one of the most

Table 1. Functional foods and their health benefits.

Component	Product	Source	Health benefits	References
Flavones	Flax seed	*Linum usitatissimum*	Neutralize free-radicals and reduce risk of cancer.	
β-Glucan, vitamins, minerals and antioxidants	Oats	*Hordeum vulgare*	Reduce risk of cardiovascular disease, lower LDL and total cholesterol.	
Omega-3 fatty acids	Fish oils	Salmon	Reduce risk of cardiovascular disease and improve mental functions.	
Catechins	Tea	*Camellia sinensis*	Neutralize free radicals and reduce risk of cancer.	
Lycopene	Tomato products	*Solanum lycopersicum*	Reduces the risk of prostate cancer.	(65)
Lactic acid	Yogurt	*Lactobacillus* spp.	Improves quality of intestinal microflora.	
Pro-vitamin A	Golden rice, orange-fleshed sweet potato	*Oryza sativa, Ipomoea batatas*	Supports the immune system, strengthens vision, assists with normal organ function and reproduction.	
Xylitol	Chewing gum	Berries, oats, and mushrooms	Prevents dental caries.	
Sterols	Margarine	Plants	Improve cholesterol levels.	

important genera belonging to Polygonaceae distributed worldwide (European, Asian, African and American countries). Approximately 200 species of this genus have been reported to possess culinary as well as medicinal uses for the treatment of pain, inflammation, bleeding, tinea, tumour and constipation in Ayurveda, Siddha, Unani and Chinese healing systems (Table 2). The roots of *Rumex hastatus* are of medicinal significance for cough, headache and fever. Rumex species are rich in anthraquinones, naphthalenes, flavonoids, stilbenoids, triterpenes, carotenoids and phenolic acids (Figure 1). Previous studies revealed the presence of sterols in *R. nepalensis* and anthraquinones in *R. hastatus* (30, 55).

Economic value and relevance for functional food area

Traditional use of different *Rumex* species has taken places in different parts of the world. It has historical background along with the potential to continue contributing much in the future by supporting sustainable development of societies and economies. Interrelationship among the past, the present and the future is woven in human cultures and their habits to use plants for different purposes such as medicine, food, pharmaceuticals etc. (31). According to the traditional knowledge, these species have been used in medical practice, both in ethnoveterinary and ethnomedicine for improving of health and welfare (32-34, 56, 57). Usefulness for human diet is documented in numerous studies. For example, eleven *Rumex* species are widely used across Balkan region for preparation of traditional dishes (58). In Belarus, amongst different wild edible species there are currently in use three *Rumex* spp. for cooking, particularly in soups (59). Traditionally, in Palestinian region the leaves of *Rumex acetosa* are used as filling for a traditional pie called sambosek, or fried in olive oil and eaten (60). Up to four *Rumex* species are sold at the markets in Morocco as green leafy vegetables (61). In Mediterranean parts of Croatia, these species are usually sold at the markets as a part of wild leafy vegetable mixes. As authors have stated, the use of these mixes is much less widespread in northern parts of the country, possible due to the ecological-economical explanation - with lack of the arable land they have to eat wild products. The price of such leafy vegetable mixture is 1.6-3.2 USD per kg as reported by £uczaj et al. (62), with sold up to 4 kilograms of vegetable mixture at least once per week. Such data are promising and point to the beneficial aspect of collecting and cultivating these species. In the study conducted by Kasper-Pakosz et al. (63), it is reported that amongst different plant species being sold at the markets in Poland, *Rumex acetosa* is present as well. Further, authors have stated that most of the sold plants are also cultivated and not only harvested from native habitats. Such practice is promising from the economical point of view, conservation strategy and implementation of functional food in daily diet and eating habits. As reported by £uczaj et al. (64) many young people have oriented to the new trends in nutrition and self-medication in Europe, mostly thanks to the spreading of information via the Internet. Intensive production (cultivation) of these and other wild species is not possible if food habits will not change. In this view, economic importance and benefits of markets are influencing the process of cultural transmission of traditional uses of food plants. The main issue is scarcity of the available data from open markets in different countries that could give an insight into the offered wild herbs. Due to their medicinal properties and healthy potential, they are suitable candidate for functional food area. Rich in bioactive components, freshly eaten or cooked, wild herbs are promising vegetables for vegetarian diets and omnivores as well. Their presence on market stands in different countries, perseverance through traditional knowledge and richness in bioactive phytochemicals indicate the rising needs for functional food area, even if collecting of wild herbs is considered by some people time-consuming and season-dependent (64). Economic importance might be well correlated with increasing interest for functional food area worldwide, which further may lead to intensified production of these species and their presence at market stands.

Table 2. Bioactive phytochemicals, traditional uses, parts used and biological activities of *Rumex* spp. plants.

Plant species	Bioactive compounds	Medicinal/commercial uses	Parts used	Biological activities	References
Rumex alpinus	2-Acetyl-3-methylnaphthalene-1,8-diol.	Laxative, jaundice, astringent, constipation, diarrhoea, eczema.	Leaves, roots.	Antibacterial.	(66-68)
Rumex obtusifolius	Anthracene derivatives, flavonoids, procyanidins, oxalic acid.	Burns and boils, blisters, nettle stings/ wrapping up butter, sores, tumors, hepatic, eye and dermatitis, furuncles, bruises, jaundice and fever.	Leaves, roots.	Antidote, depurative, astringent, laxative, antioxidant and antibacterial, disinfectant, scar healer and as anti-arthritic and anti-anemic tonic.	(68-70)
Rumex aquaticus	Anthraquinones (emodin, chrysophanol, physcion, citreorosein, chrysophanol-8-O-glucoside), flavonoids (quercetin, quercetin-3,3′-dimethylether, isokaempferide, quercetin 3-O-arabinoside, quercetin 3-O-galactoside, quercetin 3-*O*-glucoside catechin), stilbenes (resveratrol, piceid) and 1-stearoylglycerol.	Astringent, tonic, diarrhoea, ulcers, edema, disinfestation, jaundice, antipyretic, neuroprotective. Alleviation of inflammation in the gastrointestinal tract, preventing H_2O_2-induced cytotoxicity through increasing cell viability and reducing ROS production.	Leaves, roots, seeds.	Neuroprotective. Cytoprotective effects against H_2O_2-induced oxidative stress, enhancement of the cellular antioxidant capacity.	(35, 68, 71, 72)
Rumex crispus	Rumicin, chrysarobin, β-sitosterol, hexadecanoic acid, hexadecanoic-2,3-dihydroxy propyleste, chrysophanol, physcion, emodin, chrysophanol-8-O-β-D-glucopyranoside, physcion-8-O-β-D-glucopyranoside, emodin-8-O-β-D-glucopyranoside, gallic acid, (+)-catechin, kaempferol, quercetin, kaempferol-3-O-α-L-rhamnopyranoside, quercetin-3-O-α-L-rhamnopyranoside.	Hemorrhage and dermolysis. Laxative, tonic action, rheumatism, bilious complaints, astringent in piles, bleedings of the lungs, spring eruption, scurvy, scrofula, jaundice, bowels, cancer, diphtheria. Food as soups, sauces and salads. Young leaves are used to prepare "dolma" with minced meat or roasted to prepare a meal. Suppression of RANKL-induced trabecular bone loss by preventing microstructural deterioration.	Leaves, roots, seeds.	Protection against osteoporosis, possible increase in osteoblast differentiation. Trabecular bone loss by preventing microstructural deterioration.	(36, 68, 73, 74)
Rumex hastatus	Leucodelphinidin, leucopelargonidin.	Anticancer.	Stems, leaves, roots.	Antioxidant, antimycobacterial in skin infections, gastrointestinal disturbances.	(75, 76)
Rumex patientia	Emodin-6-O-β-ᴅ-glucopyranoside, flavan-3-ol, 6-chlorocatechin, 2-acetyl-3-methyl-6-carboxy-1,8-dihydroxynaphthalene-8-O-β-D-glucopyranoside, labadoside (4,4''-binaphthalene-8,8''-O,O-di-β-D-glucopyranoside), orientaloside (2-acetyl-3-methyl-1,8- dihydroxynaphthalene-8-O-β-D-glucopyranoside), patientosides A and B.		Leaves	Antipyretic, anti-inflammatory, analgesic, cytotoxic.	(42, 76, 77)
Rumex vesicarius	Flavonoids, C-glycosides: vitexin, isovitexin, orientin, iso-orientin; anthraquinones: emodin, chrysophanol, rumicin, lapathin; oxalic acid, tannins, mucilage, mineral salts and vitamin C.	Tonic, Diuretic, antiscorbutic, appetizer, laxative, astringent, carminative, stomachic and for jaundice.	Stems, leaves, roots	Antioxidant, Antimycobacterial in skin infections, gastrointestinal disturbances.	(76, 77)

Rumex dentatus	Helonioside A, gallic acid, isovanillic acid, p-hydroxycinnamic acid, succinic acid, *n*-butyl-β-D-fructopyranoside, quercetin, hexadecanoic acid 2,3-dihydroxy propyl ester, β-sitosterol, daucosterol, anthraquinones, flavonoids, phytosterols, phytosteryl esters, free fatty acids, chromones, anthrones, kaempferol 3-O-β-galactoside, kaempferol 3-O-β-glucoside, kaempferol 3-O-rutinoside, isorhamnetin 3-O-β-galactoside, isorhamnetin 3-O-β-glucoside, isorhamnetin 3-O-rutinoside, chlorogenic acid, myricetin, vitamin C.	Inhibition of proliferation of breast cancer cells; tooth extraction	Whole plant, leaves.	Antimicrobial, cytotoxic, antioxidant, breast cancer prevention and/or treatment.	(47, 76, 78, 79)
Rumex japonicus	Emodin, rutin, rumejaposide, epoxynaphthoquinol, chrysophanol, physcion, 8-O-β-glucopyranoside.	Hemorrhage, wounds. Decrease of the releases of pro-inflammatory cytokines and down-regulating the TLR4 and TLR2 expressions. Infections, malignant sore, constipation, tumors.	Roots, whole plant.	Antioxidant, anticancer, anti-proliferative, antimicrobial, apoptosis. Protective effect against sepsis in mice caused by lethal dose of heat killed *E. coli*.	(37, 76, 77, 80, 81)
Rumex scutatus		Fried in butter and then prepared as omelette.			(74)
Rumex abyssinicus	Rhein, chrysophanol, emodin, emodic acid, aloeemodin, alizarin, physcion, damnacanthal, catenarin, anthraquinone, plamidin C, chrysophanol-8-β-D-glucoside, emodin-8-β-D-glucoside.	Depurative, haemostatic, gonorrhea, pulmonary tuberculosis and leprosy. Cooked alone or together with other vegetables.	Shoots, leaves	Antiviral, anticancer, antibacterial, anti-inflammatory.	(82, 83)
Rumex vesicarius	8-C-Glucosyl-apigenin, 8-C-glucosyl-luteolin, 6-C-hexosyl-quercetin, 3-O-rutinosyl-quercetin, 7-O-rhamno-hexosyl-diosmetin, 7-O-rhamno-acetylhexosyl-diosmetin, catechin, epicatechin, ferulohexoside, 6-C-glucosyl-naringenin, epicatechin gallate, 6-C-glucosyl-catechin, epigallocatechin gallate.	Stomach heat, toothache, nausea, appetizer, jaundice, constipation, indigestion, dysentery.	Seeds	Diuretic, hepatoprotective, sedative, asperient.	(84, 85)
Rumex nepalensis	Rumexneposide A, physcion, chrysophanol-8-O-β-D-glucopyranoside, torachrysone, emodin-8-O-β-D-glucopyranoside, emodin-8-O-β-D-(60-O-acetyl) glucopyranoside, chrysophano, emodin, citreorosein, resveratrol, nepodin-8-O-β-D-glucopyranoside, torachrysone-8-O-β-D-glucopyranoside, chrysophanol-8-O-β-D-(60 -O-acetyl) glucopyranoside	Pain, inflammation, bleeding, tinea, tumor, constipation.			(55)

Conclusions

Medicinal plants have been used for thousands of years as food, feed and medicaments to treat and prevent various infectious and non-infectious diseases (86). Plants belonging to *Polygonaceae* family including *Rumex* species have been used in traditional medicine for treating several disorders including urinary inflammation, hepatitis, chronic cutaneous diseases, jaundice, fever, skin burns, osteomyelitis, gallstones and as diuretic, laxative and anticancer agents. Therefore, in this survey, we collected the latest literature on bioactives of *Rumex* species that exhibited pharmacological activities and can be suggested as innovative food and feed.

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Conflict of interest
The authors declare no conflict of interest.

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