



REVIEW ARTICLE

Nutritional, ethno-medicinal and pharmacological characteristics of Persian walnut (*Juglans regia* L.)

Saklain Mulani*, Amit Kumar, A S Sundouri, M K Sharma, Devesh Attri, Ram Wagh, Bhavesh & Rajmeet Singh

Division of Fruit Science, Faculty of Horticulture, Shalimar Campus, Sher-e-Kashmir University of Agricultural Sciences and Technology of Kashmir, Srinagar 190 025, Jammu and Kashmir, India

*Correspondence email - saklainmulani@gmail.com

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Abstract

The majority of walnut harvested in Kashmir originated from seedling-grown trees. Notably, walnuts only nut crop with substantial economic value in the region of Jammu and Kashmir. Approximately 71 % of the worlds' walnut production comes from countries situated along the historical silk route, which collectively host a significant portion of both cultivated and wild walnut orchards. Walnuts are grown commercially almost across the globe for its high demand and nutritional importance. Rich in protein and essential fatty acids, particularly Omega-3, walnuts are considered a highly nutritious nut crop and are often referred to as “Imperial Nuts” due to their remarkable health benefits. Various plant parts viz. leaves, roots, stem and fruits contain several bioactive compounds such as polyphenolic chemicals, flavonoids and alkaloids. One notable compound found in walnuts is juglone, a significant anti-cancer agent known for its therapeutic potential. . Walnuts have long been used in traditional and Ayurveda medicine for treating a variety of human health issues, including hair fall and skin illness. This systematic review compiles and synthesizes existing information regarding the nutritional composition, ethno-medicinal and traditional uses, phytochemistry and pharmacological significance of walnut.

Keywords: anti-cancer; bioactive; ethno-medicinal; juglone; pharmacological; walnut

Introduction

Nuts serve as a valuable source of nutrients that play a crucial role in promoting overall well-being. The family Juglandaceae, consists of 110 plant species. Among them, there are 21 recognized species belong to the genus *Juglans*, in which there are about 20 species that provide edible nuts. The Persian walnut (syn. English walnut) is the most widely cultivated edible nut species and possesses a somatic chromosome number (2n) of 32 (1, 2). It is known by multiple vernacular names across the world. In English it called as ‘Persian Walnut’ while in Hindi it is called as ‘Akhrot’ and ‘Doon’ in Kashmiri (3).

India ranked 11th in walnut production across the world (4), with the total cultivation area of 109.0 thousand ha and a production volume of 329.00 thousand MT. The major growing states in India are Jammu and Kashmir, Uttaranchal, Himachal Pradesh and Arunachal Pradesh. Jammu & Kashmir occupies the largest share in total area and production of walnut. Jammu and Kashmir is the leading walnut producing state (more than 90 %) with a production volume of 2.58 lakh MT from 0.84 lakh ha (5).

Walnuts are round, single-seeded drupaceous nut growing primarily in temperate regions. The nut enclosed in a green, leathery, fleshy husk, which is inedible. Once the husk is removed, the wrinkled walnut shell-comprising two halves and

an off-white interior-remains. This hard shell is encased in a thin, light brown skin and protects the edible kernel. The kernels itself is covered by a light brown seed coat that contains antioxidants, which protects it from oxidative rancidity. Walnuts are usually harvested from late August to the first week of October, depending upon the location. Maturity is determined by the cracking of the green husk, which reveals the brown nut beneath.

Historically, the walnut is considered as an emblem of intellectuality, not only because of its shell that looks like human brain but it also stands out as an exceptionally nourishing food that can be incorporated into ones' diet on a regular basis to enhance health. Every part of walnut tree viz. roots, bark, kernel, fruit, leaves, green husk and flower has several medicinal uses. Walnut is probably one of the most nutritious nuts and is often called as ‘Imperial Nut’. Various plant parts consists phytochemicals with therapeutic properties, such as flavonoids, alkaloids and polyphenolic compounds rich in calories, vitamin E and multiple essential fatty acids including omega-3, which makes it beneficial for skin, hair, heart health, type-2 diabetes, reducing obesity, fighting cancer, reducing stress and many more. However, it is important that the consumption of walnuts should be regular and in controlled quantities with proper hygiene practices.

Research indicates that individuals who consume nuts obtain significantly higher nutrient intakes compared to non-consumers-gaining an additional 5 g of dietary fibre, 73 mg of calcium, 260 mg of potassium, 95 mg of magnesium and 3.7 mg of vitamin E daily (6).

The agro-climatic conditions of the north western Himalayas in India are ideal for growing quality walnuts. Union Territory (UT) of Jammu and Kashmir in India holds a virtual monopoly in walnut production, contributing the bulk of Indias' export-quality yield. Walnut trade serves as a key driver of the regional economy, forming a crucial part of the UT agricultural backbone. In the Kashmir division, walnuts are grown extensively, while in the Jammu division, the districts of Ramban, Kishtwar, Doda, Rajouri and Poonch are renowned for producing superior-quality nuts. The diverse population of Jammu and Kashmir preserves a rich oral tradition, passing down valuable ethnomedicinal knowledge related to local therapeutic plant species. These wild species play an essential role in treating various ailments and maintaining community health (7).

This comprehensive review presents detailed information on the nutritional composition, ethno-medicinal significance and phytochemical and pharmacological properties of walnut.

Nutritional composition

Hundred g of walnut kernel (Table 1) provide approximately 654 kilocalories and contains 13.71 g of carbohydrates, 15.23 g of protein, 65.21 g of fat and 6.7 g of dietary fibre. They contain zero cholesterol, with only 2 mg of sodium and 441 mg of potassium. It is an excellent source of vitamins and numerous essential minerals. They provide 98 mg of calcium, 158 mg of magnesium, 346 mg of phosphorous. In terms of vitamins, they contain approximately 1.3 mg of vitamin C, 20 IU of vitamin A and 20.83 mg of vitamin E. is. Additionally, it also contains about 2.9 mg of iron and has a certain number of phytonutrients that are necessary for human nutrition and wellness (3, 8, 9, 10).

Ethno-medicinal uses

In Ayurveda, the use of herbal medicine is increasing exponentially around the world owing to its natural origins, high nutrient content and nearly non-existent adverse effects

when compared to contemporary medications. As a result, herbal medicine is gaining global popularity (11). Walnuts have long been used in traditional medicine for the treatment of multiple diseases/disabilities including cancer, diabetes, inflammation, antiradical, anti-diarrheic, prostate and cardiovascular issues. In ancient Rome, walnut were consumed as a delicacy and also used for dyeing wool and colouring hair. Walnut oil is commonly used for cooking purpose and as a base or carrier oil in medicine and aromatherapy (6). Additionally, dried walnut shells are used for polishing metals, jewellery and rifle casings. In Asia and Europe, walnuts have long been used to cure stomach problems, cancer and coughs.

A detailed investigation was conducted across major walnut-producing regions of the JKUTs' through open-ended interviews and discussions to document the traditional medicinal use of walnut. The study population included individuals aged 18-80 years from diverse backgrounds, such as local residents, herbalists, traditional healers and members of tribal communities including the Gujjars and Bakarwals. The findings revealed that tribal communities, Gujjars and Bakarwals utilised walnuts more frequently for medicinal purposes than local residents. Moreover, there was limited knowledge exchange between local residents and tribal communities regarding the ethno-medicinal uses of walnut. Among the medicinal plants surveyed, walnut emerged as the most frequently used, possessing the highest Use Value (UV-index) in local ethnobotanical traditions (12). Walnut leaves were reported to treat five different ailments, while walnut fruit was used most frequently to treat nearly ten different diseases. Nearly every part of the plant is used in some capacity, but the fruits (nuts) have been employed to their fullest potential.

Every component of the plant may be used alone or in combination to cure a variety of illnesses with numerous traditional applications of walnut.

Skin inflammation, scrofula, eczema and excessive hand and foot sweating are all treated with walnut plants. The leaves are used to cure sunburns, scalp dandruff, itching and are also applied topically to the body or forehead to swollen joints and to lower fever in order to treat rheumatic pain. The bark and branches are used as a brush to clean teeth and as a remedy for toothaches. The outer peel of the fruit is used to

Table 1. Nutrient constituent in walnut

Principal component	Values per 100 g	Principal component	Values per 100 g
Vitamins		Manganese	3.8 mg
Vitamin A	20 mg	Copper	1.5 mg
Vitamin K	207 mg	Zinc	3.09 mg
Vitamin E	20.83 mg	Fatty acids	
Vitamin C	1.3 mg	Unsaturated fatty acid	
Niacin	1.125 mg	Oleic acid C18:1	25.26
Folates	98 mg	Palmitoleic acid C16:1	0.77
Pantothenic acid	0.570 mg	Gadoleic acid C20:1	0.05
Pyridoxine	0.537 mg	Total MUFA	22.37
Riboflavin	0.150 mg	Linolenic acid C18:3	10.34
Thiamine	0.541 mg	Linoleic acid C18:2	57.10
Minerals		Total PUFA	4.29
Aluminium	0.58 mg	Saturated fatty acid	
Phosphorous	346 mg	Stearic acid C18:0	1.85
Calcium	98 mg	Palmitic acid C16:0	4.28
Potassium	441 mg	Arachidic acid C20:0	0.19
Magnesium	158 mg	Myristic acid C14:0	0.24
Sodium	2 mg	Total SFA	7.21
Iron	2.9 mg	PUFA/SFA	9.91

(3,8,9,10)

treat fungal infections such as athlete's foot. It also exhibits anti-plaque, teeth-whitening, anti-cariogenic, antibacterial and antifungal properties, making it a valuable agent in traditional dentistry. In recent years, researchers have shown growing interest in the bioactive compounds present in walnut bark, exploring its potential use in dental products to enhance oral hygiene (13). A detailed use of various parts enlisted in Table 2.

Anti-ageing benefits

Walnuts are rich in nutrients, particularly omega-3 fatty acids and vitamin E, which help maintain a nourished and smooth complexion. Walnuts are rich in antioxidants which counter the action of free radicals that can harm your cells and accelerate the ageing process. Walnut oil has been used since the 17th century as a remedy for wrinkles due to its high levels of essential nutrients and rich minerals. Though this oil has a greasy texture, applying it on face helps treat wrinkles and fine lines, thus making skin look younger (6, 16, 17).

Improves skin quality

Both walnuts and their oil contain abundant amounts of Vitamins B₁, B₂ and B₃ as well as vitamin B complex. The phytonutrients and fatty acids present in walnut oil improve the texture and quality of skin (6).

Treatment of psoriasis

Psoriasis is a persistent, painful skin ailment that can be alleviated by using walnut oil. By applying oil to bath or applying it topically on skin for an hour reduces the inflammation caused by psoriasis (6).

Treatment of skin infection

The anti-fungal properties of walnut oil make it great for the treatment of fungal infections like athlete's foot and candida. This oil can be applied topically on the affected areas or mixed with other herbal anti-fungal ingredients such as garlic to enhance its effectiveness (6).

Treatment of eczema

The omega-3 fatty acids in walnut oil help in treating eczema. A mixture of walnut oil and garlic juice, when applied to the affected areas, helps alleviate the symptoms (6).

Hair benefits

Walnuts are considered one of the most beneficial among all nuts for hair health, primarily due to their high content of omega-3 fatty acids, zinc, iron, B vitamins (B₁, B₆ and B₉) and protein. Omega-3 fatty acids in walnut oil form a vital part of cell structure as they stop dehydration of cells and maintain the

Table 2. Ethno-medicinal uses, preparation method and prescription of different walnut plant parts

S No.	Part used	Ethno-medicinal uses	Method of preparation	Prescription
1	Leaves	Frost bite	Two hundred gram of fresh leaves were boiled adding two litre of water and shaken completely.	Used to wash the damaged portion of the body
		Rheumatic pain	Dense paste of crushed fresh leaves is used	Paste is applied on swollen joints
		Lice killer	Fresh leaves are boiled in five litre of water for one hr.	With this water the hairs are washed
			Ten gram of fresh leaves are boiled in for one and half hour	Four tea spoon mixture is provided, twice
		Itching and acne	Six hundred gram fresh and tender leaves are added in five litre of water and boiled for	Damaged parts of the body were washed with this water
2	Kernel	Mosquito repellent	Leaves are used directly.	Within home the fresh leaves are kept.
		Against cold	5 g of fruit kernel is added mixed to cinnamon and liquorice 5 g each. the mixture is completely boiled in water and prepared in the form of tea	Consume Tea orally two to three times each day.
		Muscular pain	Oil from kernel extracted.	oil is rubbed into sore limbs in particular.
		Constipation	In 300 ml milk 5 g of fruit kernel are boiled for 10 min and some sugar is added to the	consume tea in twice a day.
		Anti-diabetic	few poppy seeds (5 gm) and Fruit kernel (40 g) are boiled with tea and salt (half litre) for	consume tea in twice a day.
		Rheumatism	Oil of kernel little warmed	warm oil is applied twice in a day
		Dandruffs	Oil is extracted from kernels	The oil can be applied twice a day to the hairs
		Improved eye sight	In 300 ml of fresh milk 5-10 g of fruit kernels are boiled.	Took at bedtime, the combination is administrated orally
		Aphrodisiac	Kernels of fruit 30 g and poppy seeds 5g are boiled with salt tea 500 ml for 10-220 min	The tea is taken twice a day
		Memory booster	The fruit kernel 5 g is boiled in mixture of milk, cream and sugar	The combination is consumed first thing in the morning
3	Fruit cover (raw)	Brain tonic	5 g of fruit kernels are boiled in half Liter of milk for 10 min and little honey or sugar is also added	Early in the morning, the mixture is given orally
		healing of wounds	The fruit epicarp is completely crushed and some quality mustard oil has been added in	The paste combination that was placed to the wound on the skin.
4	Roots	Hair fall	The ender roots are kept in bottles containing sufficient mustard oil under soil	Once a day, the oil is massaged into the hair
5	Root bark, leaves	Antiseptic	The root, bark and leaves are grounded rigorously and transform into thick paste	Skin wound is treated with a thick paste than act as an antibacterial
	Root barks, leaves and twigs	Tooth ache and tooth decay	Fresh roots, bark twigs are cut into tiny pieces and dried	Early in the morning, the little bit is chewed and used as a brush

(14,15)

physical property. As a result, walnut oil hydrates the scalp, thus preventing dry scalp which is a cause of hair loss. Dandruff is a common problem these days, which if left unattended can lead to severe hair loss. Walnuts contain alpha linolenic acid, an omega-3 fatty acid that helps condition hairs. Walnut oil moisturizes scalp region to ensure that the skin does not become flaky. Thus, topical application of this oil helps in preventing dandruff (6).

Phytoconstituents and pharmacological uses

Geographical location, weather conditions and soil type all affect the chemical makeup of phytoconstituents. Studies carried out worldwide have discovered that walnut leaves, bark and fruits possess therapeutic properties due to the existence of many bioactive compounds. An extensive body of research indicates that the whole plant is effective against a variety of illnesses in which nut extracts prevent photoaging, inflammation, oxidative damage, tumour formation and wrinkles while walnut leaves used for antidiarrheal, anthelmintic and depurative properties. Leaves are also mixed along with food grains and kept for long-term storage as they act as an effective fungicide and pesticide. Kernels benefit as a dietary food, used against diabetes, hypoxia, some skin illnesses and inflammation. Stem bark has been shown astringent, anthelmintic, depurative, bactericidal, diuretic, laxative, stimulant, detergent and insecticidal properties.

Walnut is a rich source of neuroprotective components including long-chain omega-3 fatty acids and gamma-tocopherol (vitamin E). Additionally, the earlier research has demonstrated its use in managing symptoms of Alzheimer's disease and dementia (18, 19). Researchers have already investigated the phenolic and tannin content of walnut leaves and established its pharmacological effect. A comprehensive description of the active constituent in walnut is shown in (Table 3 and Fig. 1).

Walnut oil primarily consists of triacylglycerols, including both polyunsaturated and monounsaturated fatty acids (MUFAs), with oleic and linoleic acids as dominant components. A total of fifty phenolic compounds have been isolated from different walnut plant parts, including the pellicle

and flower. These phenolic compounds include tannins, phenolic acids, flavonoids and coumarin derivatives. The composition of phenolics varies distinctly among different parts of the walnut plant. For example, walnut pellicles contain 32 phenolic compounds, while walnut flowers contain 29. Notable phenolic compounds identified in Chinese walnuts include gallic acid, ellagic acid, caffeic acid, sinapic acid and ferulic acid. Similarly, studies on black walnut cultivars have reported the presence of three hydroxybenzoic acids: syringic acid, vanillic acid and p-hydroxybenzoic acid (20). The higher phenol content had a role in the higher level of antioxidant effectiveness (21). Additionally, walnuts act as memory enhancers by boosting serotonin levels in the brain, thereby improving learning capacity and cognitive performance.

Studies have also reported the presence of essential amino acids in various walnut cultivars, including isoleucine, histidine, leucine, lysine, methionine, phenylalanine, threonine, tryptophan and valine. In addition, non-essential amino acids such as glutamic acid, arginine, glycine, proline, serine, tyrosine, cystine and aspartic acid have also been identified (22).

Omega-3-fatty acid

The high content of Omega-3-fatty acid in walnuts offers numerous potential health benefits. These include cardiovascular protection, improved cognitive function and anti-inflammatory properties beneficial for managing conditions like rheumatoid arthritis, asthma and inflammatory skin conditions like psoriasis and eczema (40). Omega-3, which promotes general brain function and can aid with anxiety and mental disorders, can offer a treatment against depression (41).

Cancer fighting properties

Juglone, a naphthoquinone compound, is produced by walnut trees in reaction to fungal infections that cause scabs. In the cases of gastric, ovarian, prostate and breast cancers juglone has cytotoxic effects on tumour cells. The impact is amplified by suppression of the tumour cell-proliferating enzymes caspase 3, caspase 9 and cyclic D1 protein. In leukaemia, cervical cancer and lung cancer, juglone blocks the mitochondria-dependent pathway. Hence may be considered

Table 3. Phytoconstituents of walnuts with pharmacological activities

Plant parts	Phytochemical compound	Pharmacological activity	References
Seeds	Glutelin, albumin, globulins and prolamins	Wound healing, Anticancer	30,31,32
Green husk of fruit	Tannins, citric acid, Glucose, malic acid, calcium oxalate, phosphate, polyphenols and Juglone	Liver and kidney protective	28,29
Walnut oil	Monoacylglycerol, diacylglycerol, triacylglycerol, Poly unsaturated fatty acids, oleic and linoleic acid	Antinociceptive and anti-inflammatory activity	3,33,34
Flowers	Gallic acid, quercetin, polyphenols, coumarin, flavonoids, fat, sterols, protein, minerals and vitamins	Antidepressant, antihypoxic, anti-inflammatory	3,39
Fruit	Tocopherols, Fatty acids, total phenolic, phytosterols and tannins	Anti-microbial effects, anti-oxidant activity, thyroid hormone enhancing activity	37,38
Stem	Ascorbic acid, sitosterol, phenols, quercetin-3-larabioside, naphthoquinones and flavonoids.	Antifungal activity	3,26,22
Leaves	Flavonoids-Quercetin, Phenolic acids, tannins, essential fatty acids, ascorbic acid, caffeic acid, para-coumaric acid, juglone; arabinoside, xyloside, Alkaloid; Saponin galactoside and rhamnoside; Naphthoquinones	Anti-oxidant activity, lipid-lowering effect, anti-hypertensive effect, anti-microbial effects, gastro-protective activity, hypercholesterolaemic activity Anti-diabetic effect, anti-cancer effect, hepato-protective activity, Anti-ageing activity	3,23,24,25,26,27
Bark	Polyphenols	Antimicrobial activity, antimycobacterial activity, antioxidant activity, antifungal activity, platelet aggregation, bleeding time, plasma coagulation	3,35,36

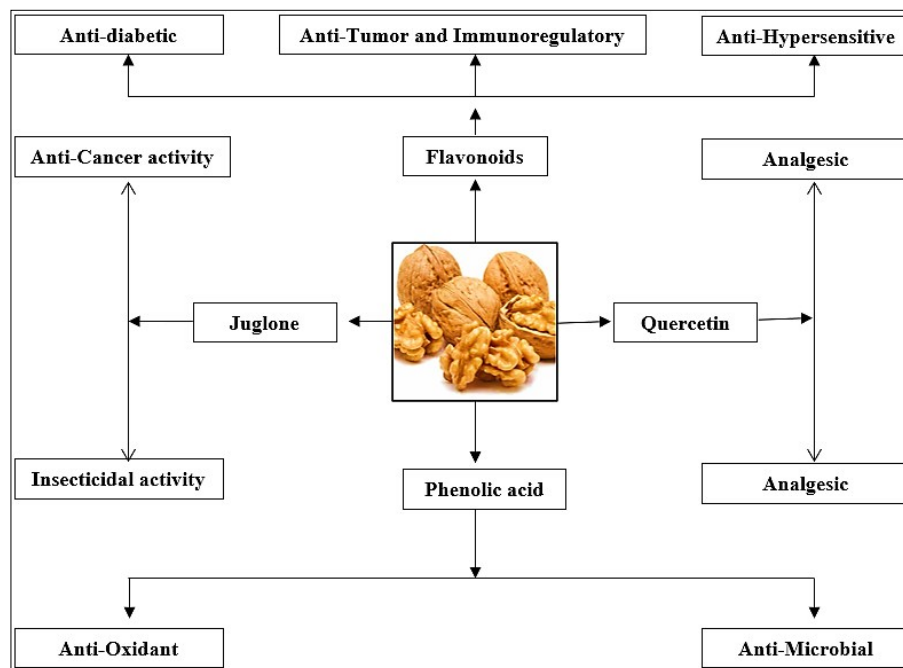


Fig. 1. Prominent phytoconstituents.

in cancer treatment. Consumption of handful of walnuts a day reduces breast cancer risk by 50 %. Research conducted at Marshall University School of Medicine in West Virginia discovered that eating around 28 walnuts a day can lower the risk of breast cancer (42).

Juglone, derived from the green husk of walnuts, also inhibits the migration of endometrial cancer cells and induces autophagy. These effects represent novel approaches in cancer treatment, such as the inhibition of cell migration, autophagy induction and triggering endoplasmic reticulum stress. Juglone is a potent inhibitor of prolyl isomerase Pin1, an enzyme overexpressed in many cancers, leading to apoptosis and preventing the proliferation of cancer cells (43).

Furthermore, methanolic extracts of walnut leaves, bark and green husk demonstrate significant anticancer activity through anti-proliferative mechanisms involving reactive oxygen species (ROS) generation and activation of mitochondrial apoptosis pathways (44).

Anti-diabetes

Walnuts are rich in polyunsaturated and monosaturated fatty acids, which are essential in reducing the type 2 diabetes by regulating insulin activity. Presence of polyphenols showed a strong inhibition against different enzymes like amylase, sucrose, maltase and glycosidase (45). The polyphenolic compounds like tellimagradin I, tellimagradin II and casuarictin showed antidiabetic activity. Consuming walnuts helps people maintain a better fatty acid profile and avoid gaining weight. Walnuts contain elevated levels of peroxisome proliferator-activated receptor alpha (PPAR- α), a nuclear receptor that regulates lipid metabolism and inhibits fat synthesis and storage, thereby reducing diabetes risk. A study published in *Diabetes Care* concluded that consuming 20 ounces of walnuts daily improves type 2 diabetes by increasing the body's availability of essential polyunsaturated fatty acids and enhancing endothelial function (46).

Other uses

Due to the high economic value of walnut wood, its cutting is currently restricted in northern India. Walnut wood is favoured for manufacturing gunstocks, furniture (beds, chairs, tables), mirror frames and artisanal items. It is also used in crafting musical instruments such as the tabla, guitar, piano, flute, sitar and the *baglama*, a folk instrument. Owing to its soft texture and ease of carving, walnut wood is extensively used in fine woodworking.

In the Kashmir Valley and surrounding north-western Himalayan regions, walnuts hold cultural and religious significance. They are integral to Hindu rituals, sacred festivals and marriages, where they are often buried ceremonially for the prosperity of future generations. Walnuts are also exchanged as gifts during festive occasions such as New Year celebrations.

Walnut kernels are used to prepare *chutney*, a traditional accompaniment in the Kashmiri non-vegetarian feast known as *Wazwan*. In Himachal Pradesh's Kullu region, crushed walnut kernels are blended with wheat flour to make *Sidoo*, a local delicacy similar to vegetarian *momos*. Villagers mix walnut leaves with henna for use as a burn ointment and to clean carpets. The leaves are also used in therapeutic baths to treat fungal infections. During winter, native Kashmiris consume roots of aged walnut plants as a health food. Additionally, the leaves, bark and roots are used as natural toothbrushes. When dried and crushed, these parts serve as natural dyes for hair, hands, palms, rugs, Kashmiri carpets and even lips.

According to local folklore, it is believed that nothing can grow beneath a walnut tree and that sleeping under one can cause headaches, dizziness and vomiting. This is attributed to the speculative release of heavier-than-air gases like hydrogen cyanide from the leaves, though there is no scientific evidence supporting this claim (47).

Conclusion

This systematic review has gathered substantial information on the pharmacological properties and bioactive constituents of walnut, with a primary focus on their ethno-medicinal applications known by the local people in walnut-growing regions. Walnut is one of the significant medicinal plants, possessing significant therapeutic potential. Rich in phytochemicals, fat-soluble bioactive compounds nutrient and non-nutrient antioxidants, walnuts are not only a great option for basic nutritional needs but also for their physiological benefits on human hosts. This makes them a great choice for food additives and heart-healthy snacks.

Walnut is a very effective and safe medicinal plant with a wide spectrum of ethno-pharmacological properties. Beyond their medicinal value, walnut products-wood, leaves and nuts, walnuts have a lengthy history in popular culture, traditions and sports in most of the regions where they are grown. Research on bioavailability and *in vivo* efficacy continues to reveal the mechanism behind the bioactive compounds with the biological effects they produce. This review underscores the importance of incorporating walnuts into a regular, nutritious diet. Despite of this, existing evidence supports the bioactive properties of walnut polyphenols, which should be explored more thoroughly in future.

Authors' contributions

SM and AK participated in the preliminary collection of information, reviewed and drafted the initial version of the manuscript. AS, MS, DA, RW, B and RS participated in formatting article. All authors together approved and finalized the final manuscript.

Compliance with ethical standards

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