



ISSN: 2306-6091

International Journal of Pharmaceuticals and Health care Research (IJPHR)

IJPHR | Vol.13 | Issue 2 | Apr - Jun -2025

www.ijphr.com

DOI : [https://doi.org/10.61096/ijphr.v13.\(SPL 1\).2025.193-202](https://doi.org/10.61096/ijphr.v13.(SPL 1).2025.193-202)

Review

A Review On *Juglans Regia*: Its Botanical Description, Phytochemistry, Traditional Uses And Its Pharmacological Activities

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	Abstract
Published on: 31 May 2025	<p>The English or Persian walnut which is <i>Juglans regia</i> L., is recognized worldwide for its important nutritional, medical and industrial uses. This review thoroughly examines the plant characters, chemical makeup, history of use, drug activities, nutritional aspects, biotechnological applications, risks and future prospects of <i>Juglans regia</i>. People in temperate regions have traditionally used walnut trees to treat infections, inflammation, diabetes and skin problems. It has been found by phytochemical research that walnuts provide a number of bioactivities from polyphenols, flavonoids, juglone, essential fatty acids, vitamins and minerals. Research has shown that these constituents give the plant useful antioxidant, anti-inflammatory, antimicrobial, antidiabetic, neuroprotective and anticancer effects. Thanks to omega-3s, dietary fiber and protein, eating walnuts can help improve the heart and brain. <i>Juglans regia</i> is important to industry and commerce for more than just the kernels people eat. People use walnut oil in both cooking and as a cosmetic and the shells are valued for their role as abrasives and fillers in manufacturing. Because it is strong and attractive, wood is used for furniture and decorative crafts. Besides use in cooking, the leaves, husks and bark of the plant are helpful in herbal medicine and to produce natural pesticides. While <i>Juglans regia</i> is helpful in many applications, its full potential cannot be reached until problems linked to standardizing its extracts, performing revealing clinical trials, managing allergic reactions and safeguarding the environment are addressed. Juglone which belongs to the naphthoquinone family, is useful for health benefits but misuse can cause toxicity. Those who are allergic to walnuts must protect themselves.</p>
Published by: DrSriram Publications	<p>Keywords: Juglans regia, Walnut, Phytochemicals, Nutritional value, Pharmacological activities</p>
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INTRODUCTION

Persian walnut or English walnut is the scientific name *Juglans regia* L. and is part of the Juglandaceae family. Across temperate areas, the tree is valued for its production of one of the most economically significant nuts. First found in the Balkans east to the Himalayas and southwest China, *Juglans regia* is now grown across Europe, North America and certain parts of Asia, thanks to its edible seeds and fine wood. Many people in traditional medicine appreciate and value the plant because of its therapeutic variety[1].

People have enjoyed eating walnuts for hundreds of years and recognize them for their great nutritional value. An edible kernel is packed with nutrients, most notably unsaturated fatty acids, protein, fiber, various vitamins and minerals and bioactive phytochemicals. The fruit of *Juglans regia* fig.1 is famous for its positive effects and this is why it is included in Mediterranean and other healthy diets[2]. Many studies suggest that eating walnuts may decrease the chance of heart disease, brain disorders, diabetes and different cancers. Because the leaves, bark, green husk and seeds have many phytochemicals, they help give the plant a broad class of pharmacological activities.

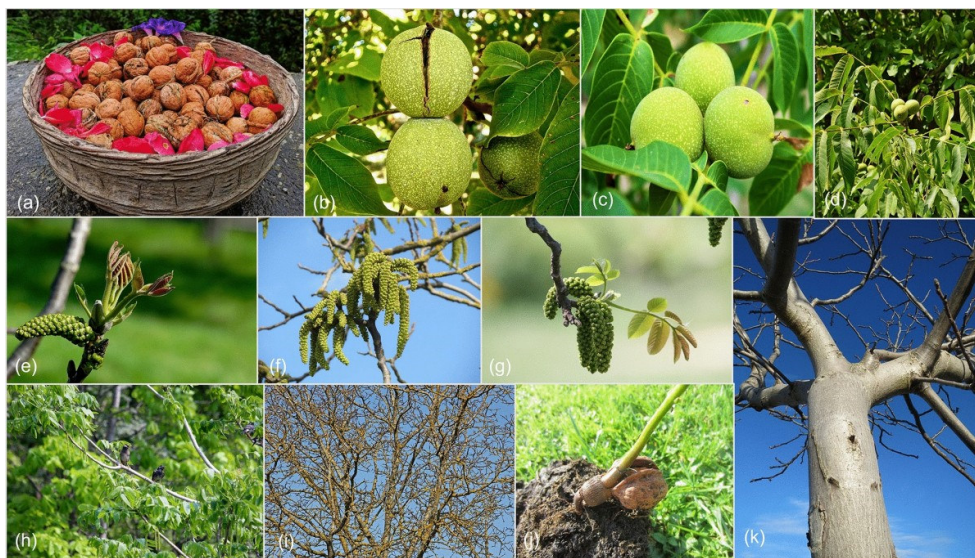


Fig 1: *Juglans regia*

In most of these well-known traditional systems such as Ayurveda, Unani and TCM, people have used different parts of walnut trees to treat many illnesses. People have used leaves and green husks to help with healing, reducing swelling and getting rid of parasites and they have extracted the oil from kernels to treat skin, hair and stomach problems. Because juglone, a unique quinone found in walnut leaves and hulls, has antimicrobial, antifungal and allelopathic activities, it has drawn special attention[3].

Juglans regia has become a major area of interest for scientists due to the progress in combined phytochemistry and pharmacology. Traditional uses of herbs have been confirmed through research and it has also been found they have antioxidant, anti-inflammatory, anticancer, antimicrobial, antidiabetic and neuroprotective properties. The majority of these bioactivities can be explained by the presence of secondary metabolites such as polyphenols, flavonoids, tannins, sterols and fatty acids in the extract. In addition, its ability to adapt, long life and uses for nuts and wood make it an important crop for farmers[4].

Although there is more research on *Juglans regia*, its full therapeutic value, including how it affects clinical use and works, is still being studied. For nutraceuticals to be accepted as evidence-based medicine, the extract should be standardized, there should be thorough toxicological tests and high-quality studies on people are necessary[5]. The purpose of this review is to look at *Juglans regia* in depth, exploring its botany, chemicals, uses in traditional medicine and relevant studies in modern pharmacology for its use as a functional food and treatment.

2. Botanical Description

The Persian or English walnut which has the scientific name *Juglans regia* L., is a large deciduous tree that belongs to the Juglandaceae family, home to around 50 species. It is the most cultivated tree in its genus,

primarily because of its healthful nuts and useful timber. The botanical features of the tree help it survive and be valuable for the economy[6].

Morphology and Habit

Juglans regia can reach heights of 25 to 35 meters and has a broad, expansive crown, as well as a solidly straight trunk. Young lilacs have grey, even bark that soon develops fissures and becomes darker as the tree ages. Its large root system, the tree can survive in many types of soil, still preferring deep, strong, sandy soil with plenty of sun. It is most comfortable in areas where it has cold winters and hot summers[7].

Leaves

The length of a *Juglans regia* leaf varies from 20 to 40 cm and is shaped like a pinnate compound. Such plants are usually made up of 5 to 9 ovate-lanceolate leaflets set alternately along their main rachis. These leaflets measure 6–12 cm and their edges are jagged with a sharp, hairless upper surface. Crushed spices are aromatic since essential oils are stored inside them. The leaves just start to show up in spring and then drop in autumn[8].

Flowers

The flowers of this tree are found separately as males and females, both growing on the same tree. Catkins that are 5–15 cm long contain the male flowers on the tree. Catkins begin to grow on last year's wood in early spring and give off a lot of pollen at that time. Female flowers are little, green and can often be found at the end of the new twigs, along with one or more other flowers. Most fruit is pollinated by the wind and for successful fertilization to take place, the nuts must develop[9].

Fruit and Seed

Juglans regia produces drupes which people generally call walnuts. Most coconuts are covered by a green, fleshy husk and, inside, they have a hard shell that contains the edible seed. Each kernel consists of two lobes and is covered with a wrinkled surface. Extra virgin olive oil is rich in oil, especially oil made up of heart-healthy unsaturated fatty acids[10].

Wood

Juglans regia wood is known for strength, a fine appearance and dark hue, it is valued for making furniture, cabinetry, veneers and gunstocks. Because it is stable, heavy and resistant to changes in shape, it is valued as a top-quality hardwood[11].

Geographic Distribution

Persian or English walnut is the scientific name *Juglans regia* L. and it is found from the Balkans and across Central Asia down to the west of the Himalayas and southwestern China. Over a long time, it has been widely grown and cultivated in temperate parts of the world because of its importance for food and money[12].

Currently, *Juglans regia* is cultivated worldwide in locations with mild tourist areas and climates. Among the key producers in the world are China, the United States, especially California, Iran, Turkey, Ukraine, India, Chile and France, Italy and Romania in Europe. China is in the top spot for walnut production, the U.S. is second and Iran is third.

Winter Peppers do well if there are cold winters, hot summers and lots of sunlight, all with fertile and drained soil. The species lives mainly in hills and mountains at elevations between 300 and 3,000 meters. India's growing areas for tea are in Jammu and Kashmir, Himachal Pradesh and Uttarakhand[13]. Because *Juglans regia* can grow almost anywhere, it is present and useful across North America, South America, Europe and Asia.

3. Phytochemical Constituents

Juglans regia L. which is the Persian or English walnut, contains many different phytochemicals that give it its many medical benefits. Several parts of the plant such as the kernels, leaves, green husk, bark and roots hold some or all of these bioactive constituents: polyphenols, flavonoids, tannins, sterols, essential fatty acids and unique naphthoquinones. They mainly support the plant's role in neutralizing free radicals, reducing inflammation, killing microbes and helping fight cancer[14].

You can find a high concentration of phenolic compounds in *Juglans regia*, mainly in its green husk, leaves and bark. The list comprises gallic acid, ellagic acid, caffeic acid, vanillic acid and protocatechuic acid. Because of their strong antioxidant effects, phenolic compounds help reduce cell damage, prevent oxidative diseases and lower the risk of cancer and heart problems. They increase the plant's potential for fighting bacteria and slowing signs of aging[15].

Another important class of metabolites in *Juglans regia* is flavonoids which are found in especially high amounts in the leaves and husk. Quercetin, kaempferol, myricetin and rutin are recognized flavonoids in various fruits. They hold strong antioxidant and anti-inflammatory capacities and benefit heart health, decrease body-wide inflammation and help control immune responses. They might be beneficial to those with neurodegenerative diseases as well.

Juglone (5-hydroxy-1,4-naphthoquinone), a naphthoquinone, is the unique and important phytochemical found mainly in the roots, leaves and green husks of *Juglans regia*. Juglone is toxic to surrounding plants and has been proven to stop fungi, fight infections and even halt some types of cancer. This substance is thought to play a big role in walnut leaves and husk having medicinal benefits[16-18].

Most of the tannins in tea come from the leaves and green husk. Because of their astringent characteristics, polyphenols have long been used to relieve diarrhea and inflammation. The antibacterial and antioxidant properties in the plant boost its use as medicine. Moreover, beta-sitosterol and saponins are found in the nuts as well as the oil. They can lower cholesterol in the blood and also reduce inflammation and boost immunity.

PUFAs among the polyunsaturated fatty acids (PFAs) are found most in the kernel of *Juglans regia*, especially omega-3 alpha-linolenic acid, omega-6 linoleic acid and omega-9 oleic acid. By consuming healthy fats, you help protect your heart, develop your brain and defend your body against inflammation. As well, walnut kernels are rich in other nutrients, for example, gamma-tocopherol as vitamin E, thiamine as a B-complex vitamin, along with folate, as well as trace minerals such as magnesium, potassium, zinc and selenium, all which boost its nutritional and medicinal properties[19].

Besides, oils sourced from corn husk and leaves contain limonene, pinene and caryophyllene, aromatic substances that help kill insects and fight microbes. The range of phytochemicals found in *Juglans regia* reflects its potential for medical use and confirms its widespread use in both traditional systems and modern medicine.

4. Traditional and Ethnopharmacological Uses

Persian/English walnut, scientific name *Juglans regia* L., has been appreciated in various traditional types of medicine, as well as traditional remedies in Europe and the Middle East, for several centuries. Traditionally, many parts of the plant leaves, bark, green husk, roots and kernels have been used for different health benefits. Most of its ethno pharmacological uses are caused by its antimicrobial, anti-inflammatory, astringent, laxative and nutritive properties[20].

Walnut kernels in Ayurvedic medicine are thought to strengthen the brain as well as the reproductive system. Herbalists suggest herbs for a general weakness or to address digestive issues and long-term constipation. Oil from the nuts is usually used externally to soothe joint pain, dry skin, flakes in the hair and loss of hair. Part of the cashew its leaves and bark is used for its astringent and antimicrobial qualities to address skin issues, ulcers and inflammation.

In Unani medicine, *Juglans regia* is considered warm and dry. People eat kernels believing they improve sexual desire, enhance memory and give energy. They are ingredients in remedies used for cough treatments, kidney stones and problems of the lungs. People use the green husk to get rid of worms and manage inflammation. Using fine tree bark on teeth is common because it has antibacterial properties and oral treatments for ulcers and gingivitis sometimes include it[21].

According to TCM, walnut kernels, known as "Hú Táo Rén," are thought to strengthen the kidneys, reinforce the back and knees and benefit the lungs. Such medicines can relieve problems like asthma, a persistent cough, not being able to control urination and erectile dysfunction. In TCM, walnuts are thought to improve one's vitality and energy. Walnut oil can be taken to improve how the digestive system functions and to ease bowel movements.

A tea or decoction of *Juglans regia* leaves is commonly made in European folk medicine to help with stomach problems, diarrhea and infections with parasites. People sometimes apply the leaves on the skin to control conditions such as eczema, acne and fungal infections. Green husks and bark are usually used in topical applications to speed up wound and ulcer healing. A brew of leaves has been recommended for its ability to improve blood and proteins and treat diabetes[22].

Not only is *Juglans regia* good for medicine, but it has also been used in traditional skin care and care for personal hygiene. In earlier times, people used crushed walnut shells and bark in their mouth cleansing products. Both the plant's leaves and husks are sometimes used to color and strengthen hair. Because many healthcare systems have depended on it, its current study by pharmacologists shows its traditional uses to be true. Advances in both traditional use and scientific verification of *Juglans regia* may lead to the creation of reliable herbal drugs and nutraceuticals.

5. Pharmacological Activities

The multiple pharmacological actions of *Juglans regia* L. are believed to be important reasons for its medicinal uses. Expert research has proven that a range of therapeutic compounds are present in herbal medicine. In experiments using both human cells and animals, the kernel, leaves, green husk, bark and oil from the walnut tree have shown large pharmacological effects[23].

Table 1: Pharmacological Activities of *Juglans regia*

Pharmacological Activity	Active Compounds	Mechanism/Effects	Study Model (In Vitro/In Vivo/Clinical)	References (Examples)
Antioxidant	Polyphenols, juglone, ellagic acid, flavonoids	Scavenges free radicals (ROS), increases SOD, CAT, and GPx activity	In vitro (DPPH assay), rodent models	Bhat et al., 2018; Pereira et al., 2007
Anti-inflammatory	Juglone, tannins, omega-3 fatty acids	Inhibits COX-2, TNF- α , IL-6, and NF- κ B pathways	Cell lines (RAW 264.7), carrageenan-induced edema in rats	Hosseinzadeh et al., 2011
Antimicrobial	Juglone, flavonoids, phenolic acids	Disrupts bacterial cell membranes (e.g., <i>S. aureus</i> , <i>E. coli</i>), antifungal effects	In vitro (agar diffusion), microbial cultures	Silva et al., 2008; Jahanbani et al., 2016
Antidiabetic	Polyphenols, fiber, magnesium	Enhances insulin sensitivity, reduces blood glucose, inhibits α -amylase/ α -glucosidase	Streptozotocin-induced diabetic rats	Hosseini et al., 2014; Asadi et al., 2018
Anticancer	Juglone, gallic acid, ellagitannins	Induces apoptosis, inhibits proliferation (e.g., breast, colon cancer cells)	In vitro (MCF-7, HT-29), xenograft models	Ahad et al., 2012; Carvalho et al., 2010
Cardioprotective	Alpha-linolenic acid (ALA), polyphenols	Lowers LDL, improves endothelial function, reduces atherosclerosis	Clinical trials, hyperlipidemic patients	Banel & Hu, 2009; Sánchez-González et al., 2014
Neuroprotective	Polyphenols, melatonin, omega-3s	Reduces oxidative stress in brain, inhibits A β aggregation (Alzheimer's potential)	In vitro (PC12 cells), rodent models	Poulose et al., 2014; Chauhan et al., 2004
Wound Healing	Tannins, juglone, flavonoids	Promotes collagen synthesis, anti-inflammatory effects	Excision wound models in rats	Akhtar et al., 2012
Hepatoprotective	Juglone, quercetin, ellagic acid	Reduces liver enzymes (ALT/AST), combats oxidative stress in liver	CCl4-induced hepatotoxicity in rats	Alkhwajah, 1997; Rahimi et al., 2015

Many researchers have studied how *Juglans regia* acts as an antioxidant. Because of its high content of phenolic acids, flavonoids, vitamin E (mostly γ -tocopherol) and polyunsaturated fatty acids, rapeseed oil is effective at scavenging free radicals. They reduce the risk of cancer, heart disease and degenerative diseases of the brain.

Preliminary research on the plant suggests it may help reduce inflammation. A recent study found that ingredients from leaves and husk can stop the development of inflammatory cytokines and prostaglandin and nitric oxide. So, it works well for treating ailments like arthritis, dermatitis and wounds that don't heal quickly[24].

It is also important to note that *Juglans regia* displays antimicrobial activity. Researchers have seen that Juglone, occurring in the walnut tree's leaves and green husk, has antimicrobial activity against many bacteria, fungi and certain parasites. Extraction from leaves and husks has been found to block the growth of *Staphylococcus aureus*, *Escherichia coli*, *Candida albicans* and *Aspergillus* species.

Juglans regia's capability to combat diabetes has been looked at in many animal models. Taking extracts of its leaves has been discovered to decrease blood sugar, help improve insulin effectiveness and keep β -cells safe. Our understanding is that these phytochemicals flavonoids and phenolic acids lower blood sugar levels and help prevent oxidative damage.

A number of studies have found that some cancerous cells can be controlled using these extracts. Many cancer cell lines such as those from breast, colon and prostate cancer, have been found to have their growth suppressed and cells killed by walnut extracts with juglone, quercetin and ellagic acid[25]. Eating *J. regia* is shown to support brain function, probably because of the omega-3s, antioxidants and polyphenols found in the

nuts. According to studies, consuming walnuts may better memory, decrease the symptoms of anxiety and depression and prevent diseases like Alzheimer's and Parkinson's. The plant contains chemicals that can guard against liver harm. Liver protection from damage by carbon tetrachloride and paracetamol has been seen in studies with walnut leaf and bark extracts. This is possible because antioxidants help and enzyme levels in the liver are controlled.

In addition, *Juglans regia* has shown that it can treat worms, reduce blood pressure, support wound healing and lower cholesterol levels. Researchers think that the unsaturated fatty acids and phytosterols found in extra virgin olive oil help to reduce cholesterol and improve lipid levels[26]. All in all, the range of applications for *Juglans regia* is good enough reason to consider the plant for medical purposes. To confirm these results and decide on safety and effectiveness, more pharmacological and clinical studies are important.

6. Nutritional Value of Walnuts

It's common to say that walnuts (*Juglans regia* L.) are a very healthy food and are called "functional" because they have a high percentage of beneficial nutrients. In many countries, people enjoy them for their delicious taste and the many good things they do for your health. Walnuts include important fatty acids, proteins, vitamins, minerals, fiber and bioactive compounds that make them valuable for any healthy diet.

Walnuts are valuable because they are high in PUFAs and especially in ALA, a plant form of omega-3 fatty acid. Walnuts are a good source of ALA which contributes to heart health by lowering inflammation, decreasing both blood pressure and bad cholesterol and raising some good cholesterol. Apart from ALA, walnuts have linoleic acid (omega-6) and oleic acid (omega-9) which help keep the heart and brain healthy[27].

Since they provide good plant protein, walnuts are helpful for vegetarians and vegans. Around 15% of walnuts consist of protein, giving you essential amino acids used for healing broken tissue, maintaining muscle and creating enzymes.

Walnuts are also known for their generous supply of dietary fiber, both types. Psyllium fiber is beneficial for digestion, a healthy gut bacteria community and controlling blood sugar and cholesterol levels. People who regularly eat fiber-rich foods such as walnuts, may be at lower risk for type 2 diabetes, heart disease and obesity.

There is a high amount of vital vitamins and minerals in walnuts. Most nuts are full of vitamin E, mainly the gamma-tocopherol which is a potent antioxidant. They additionally have B-complex vitamins, especially folate (B9), thiamine (B1), vitamin B6 and riboflavin (B2) which help with energy and nerve system activities. Mineral-wise, walnuts contain generous amounts of magnesium, phosphorus, copper, manganese, zinc, iron and potassium. Minerals are significant for strong bones, for making enzymes function, for regulating the immune system and for making red blood cells[28].

Besides macronutrients and micronutrients, walnuts contain polyphenols, flavonoids and ellagic acid, all of which provide strong protection from free radicals and inflammation. They assist in eliminating free radicals, reducing the effects of stress and shield the body against chronic diseases like cancer, Alzheimer's and heart problems at any stage of life.

Walnuts have a high calorie level, around 654 kcal per 100 grams, mainly because of the fats, but research has suggested that eating them moderately does not lead to weight gain and helps prevent overeating and unhealthy snacking.

Overall, *Juglans regia* contains a rich variety of nutrients that are very good for health. The fact that walnuts provide healthy fats, protein, fiber, vitamins, minerals and antioxidants makes them one of the healthiest nuts available. Eating walnuts is important because it greatly supports health, protects from diseases and provides nutrients.

7. Industrial and Commercial Uses

The English or Persian walnut (*Juglans regia* L.) is valuable in the economy because it has many uses in industry and commerce. Both traditional and modern industries use different pieces of the walnut, including the nut itself, the shell, husk, leaves, bark and wood. Besides showing the plant's versatility, these uses also have a strong effect on global agricultural economics.

The food industry uses *Juglans regia* the most, as people all over the world enjoy walnut kernels as a nutritious nut. Raw walnuts and those that have been roasted, salted or added to bakery items, sweets, cereals, snack bars, yogurt or health supplements can be bought and used. Walnut oil made from the kernels is appreciated as a special edible oil since it holds lots of omega-3 fatty acids and antioxidants. It is a common ingredient in salad dressings, fancy foods and supplements. Walnut flour made from defatted walnuts is used for both gluten-free baking and high-protein dietary items[29].

In this field, walnut extracts, oil and powder are frequently used. Its emollient, moisturizing and anti-aging qualities make walnut oil important in skincare products. You can find this substance in many creams, lotions, hair oils, massage oils and lip balms. Walnut shell powder which is formed by grinding the hard shell, is

mixed into exfoliating scrubs and cleansers because it gently scrubs and cleanses the skin. The rich source of antioxidants found in leaf extracts makes them useful in herbal cosmetics for skincare and to ease inflammation. Various parts of *Juglans regia* are applied by the pharmaceutical and herbal industry in creating medicines and nutraceuticals. People rely on extracts from the plant's leaves and green husk for their antimicrobial, antifungal, antidiabetic and anti-inflammatory benefits. Herbal forms of walnut such as capsules, tinctures and teas, are advertised to control blood sugar, strengthen the liver, boost digestion and support the immune system.

Juglone which is natural to walnut roots and husks, can be used as a natural herbicide for agriculture and pest management. In organic farming, walnut husk extract serves as a safe way to keep pests away. When properly prepared, the husk becomes beneficial for improving the fertility of the soil.

Besides its delicious fruit, *Juglans regia* is known for its valuable hardwood in furniture, cabinetry and flooring. Walnut wood is valued because it resists damage, has fine texture and a dark brown shade. It helps make beautiful furniture, excellent veneers, gunstocks, famous musical instruments and luxurious interior paneling.

Regarding use, walnut shells are treated and then used for different industrial functions. Sandblasting, polishing and cleaning parts of machinery require using biodegradable walnut shells as abrasives. Manufacturers add it to adhesives, plastics and paints as a bulking agent.

Overall, this tree is significant in food products, medicine, beauty industry, farming, woodcraft and industry. The many uses of this tree are what make it important for global economies and green business.

8. Toxicological and Safety Profile

Being widely eaten and used in medicine, the English or Persian walnut (*Juglans regia* L.) is recognized as a safe choice for humans. Still, one should always think about its toxicity and safe use before taking it as medicine.

Generally, walnuts and their products are safe when eaten in usual dietary amounts. A large number of studies prove that both humans and animals can digest and accept walnut kernel as food without side effects. The nutrients in nuts help your body and their bioactive substances are usually safe in the amounts you eat each day. In addition, studies on walnuts have found that rare side effects are related to GI discomfort for people who may be extra sensitive. Some parts of *Juglans regia* should be handled with care. Present in its green husk, leaves and bark, juglone (5-hydroxy-1,4-naphthoquinone) is known to stop plants from growing and cause poisoning. Although juglone can help against infections and cancer in small quantities, too much of it or the wrong use can result in damage. Swallowing a lot of husk or juglone substances may result in upset stomach, sickness, vomiting and, occasionally, serious problems. Because of this, these components ought to be used with care and ways to extract them should result in the correct doses for medicine.

Reactions to walnuts cause another significant safety issue. In many places, tree nut allergy is an important food allergy that can cause anywhere from mild OAS to serious anaphylaxis. Those with nut allergies need to stay away from walnuts. It is widely recognized that walnut allergy can cause reactions to other nuts and pollen, so care and labeling are important for food products that include walnuts. Walnut extracts have commonly demonstrated good safety in toxicological animal studies when taken at therapeutic doses. Results of acute and sub-chronic toxicity tests suggest that organ function is unaffected at standard doses of the product. Still, when high concentrations of certain herbal medicines are taken, they might result in slight changes in liver enzymes, so it's important to closely track the dosage. Having vitamin K in large amounts, walnuts are not recommended for individuals taking warfarin and similar drugs. As a result, those on anticoagulant therapy should only eat walnuts with advice from their doctor.

Walnuts are thought to be safe for pregnant and lactating people when eaten as part of a normal balanced diet. However, before we fully understand the risks, we should avoid eating too many walnut oil or extract products[30]. When used as food or standardized drugs, *Juglans regia* demonstrates a large safety range. We advise choosing well-defined extracts with known phytochemical content, taking them according to approved guidelines and considering anyone who might have allergies or health issues. To ensure we can safely use a medicine over time, we need more clinical toxicology research and continued monitoring of safety.

9. Challenges and Future Perspectives

Although *Juglans regia* L. has great medicinal, nutritional and industrial potential, several issues make it hard for the tree to be used and sold more widely. Resolving these difficulties helps us enjoy the plant's good qualities and use it safely in agriculture, medicine and industry.

Making sure walnut-based products meet established standards and quality is one of the main problems. Because both farming techniques and where the nuts are grown can vary, so can the phytochemical profile found in walnut extracts. Because the safety and judgment of herbal formulas can change, making results unpredictable, it's difficult to ensure each treatment works the same each time. Set procedures, good measures and reliable ways of analysis are necessary to quantify juglone, polyphenols and fatty acids for the products of *Juglans regia* to be commercialized. Many pharmacological claims about walnuts are supported by very little

clinical proof. Although promising results have been found in both animal and laboratory studies about its effects as an antioxidant and on inflammation, cancer and brain health, there aren't many human trials. Larger studies including various groups and standard walnut extracts are needed to check the claims and find out how walnuts should be dosed. The problems of sustainability and concern for the environment are particularly severe when growing and harvesting at a large scale. Because walnut trees need particular environmental conditions and a lot of water, they are not usually grown in very dry areas. If wild walnut populations are taken for medicine, largely for their leaves and husks, this could cause threats to both diversity and the balance of their ecosystems. New ways of cultivating walnuts, modern agroforestry forms and programs to conserve forests are needed so that walnuts remain available in the long run and the environment is not harmed. Both the processing and the method used after harvest are important factors affecting the quality and shelf life of walnut products. Not drying or storing food correctly or improper packaging, can cause the food to become rancid, lose its essential nutrients or become contaminated by microbes. By using advancements such as cold storage, vacuum packaging and natural antioxidants, walnuts can better keep their important nutrients and benefits while being transferred to households. Care should be taken because walnuts may cause allergic reactions and harm to health. Cytotoxicity due to juglone and common nut allergies mean formulators and label writers must carefully take these dangers into account. Concentrating on detoxifying the by-products of walnut cultivation and developing varieties that are not likely to cause allergies would allow walnut to be used by people with sensitivities.

Juglans regia is expected to bring exciting results in different areas in the future. Thanks to progress in biotechnology and plant breeding, different types of walnut trees might be created with healthier bioactive compounds, stronger resistance to diseases and greater adaptability to weather changes. Using nanotechnology, it might become possible to create medicines from walnuts to help drugs be delivered effectively with fewer side effects.

People asking for more natural and functional food items creates a chance for new walnut-based supplements and nutraceuticals. Adding walnuts to preventive health measures could help bring down cases of cardiovascular disorders, diabetes and neurodegeneration. Using walnut shells, husks and pulps for biofuels, bioplastics and pesticides fits well with the sustainable goals and circular economy principles in use around the world. By doing this, we can turn waste into profit and help reduce agricultural waste at the same time. In short, resolving these challenges with diverse science, new inventions and sustainable methods can make *Juglans regia* reach its highest potential. As a result, we can create good, safe and healthful nuts products that help the environment and humans as time progresses.

CONCLUSION

An important plant, *Juglans regia* L. or the English or Persian walnut, has many useful roles in medicine, food, industry and commercial activities. This review points out how *Juglans regia* can be used in many ways and has attracted both long-term and current scientific interest globally. Because walnuts are high in polyphenols, flavonoids, essential fatty acids, vitamins and minerals, they are valued in many traditional and recent uses.

Because *Juglans regia* has both botanical and geographic diversity, it can adapt to different weather conditions and is now grown in several parts of the world. Its high omega-3 and antioxidants, walnuts are valuable for cardiovascular health and for improving brain function and they are good for your general health too. There is new research showing that the plant's many traditional uses are validated by its effects on antioxidants, inflammation, microbes, diabetes, the brain and cancer.

Industrially and commercially, *Juglans regia* is still very important. Both walnut flesh, derived from the kernel and walnut-derived oils are widely used in food, skin care items, drugs, farming and woodworking. Walnuts are valuable to industry not only because of the nuts but also because of the by-products which more and more people see as useful, including for natural cleaning, pest control and making eco-friendly plastic.

Even with these benefits, it is still difficult to use *Juglans regia* in many ways and commercially. Differences in what plants contain, little clinical research supporting all old claims, some allergic risks and caring for the environment all require careful consideration. Standardization, monitoring quality and testing safety help ensure any products made from walnuts work well and are safe. There is a lot of potential ahead for research and application with *Juglans regia*. Better walnut-derived products are expected as a result of recent progress in biotechnology, pharmacology and food science. Studying more of its bioactive compounds could result in new drugs and foods that help address recently discovered health problems. By treating walnut by-products as important materials, we can achieve both sustainable development and more economic growth.

Simply put, *Juglans regia* is a resource with potential for health, nutrition and as part of the economy. Combining old and new methods will help us find new ways of using hemp and make its use safe, effective and sustainable. As more people learn about natural and functional products, walnuts are set to become more

important for global health and industry. As a result, combining studies from various fields with eco-friendly methods will offer the best benefits of *Juglans regia* to people now and in years ahead.

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