The Pharma Innovation Journal 2022; 11(7): 599-612

www.ThePharmaJournal.com

The Pharma Innovation

ISSN (E): 2277-7695
ISSN (P): 2349-8242
NAAS Rating: 5.23
TPI 2022; 11(7): 599-612

www.thepharmajournal.com
Received: 16-05-2022
Accepted: 23-06-2022

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Water chestnut: Growing conditions, nutritional and phytochemical composition, novel extraction methods and health properties

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Abstract
Water chestnut (*Trapa natans*), also known as Singhara in India, is one of several free-floating plants of the *Tracheae* family that thrives in shallow water. Water chestnuts are found across Europe, Asia, and Africa. Chestnut provides a variety of nutrients and antioxidants. Water chestnuts have a high flavonoid content and are low in calories and fat-free despite containing a number of beneficial nutrients. The value of this crop has recently been increasing due to its yield and nutritional content, such as proteins, carbohydrates, fiber, and minerals. A short-duration annual crop can be incorporated into low-input cropping systems as a viable alternative crop for sustainable horticulture. Freshwater chestnuts have double the number of antioxidants as conventional chestnuts. There is a higher amount of potassium, zinc, vitamin B, and vitamin E in water chestnut kernels compared to the canned varieties. A large amount of protein is found in water chestnut kernels. A list of water chestnut health benefits is also presented.

Keywords: Water chestnut, aquatic plants, Phytochemicals, Antioxidant Potential, Health Benefits, and Novel extraction techniques

Introduction

Water chestnut, also known as Singhara in India, is an annual, floating-leaved aquatic plant found in freshwater wetlands, lakes, ponds, and slow reaches of rivers. It is grown primarily for human consumption, either as vegetables, dried to make flour to prepare flattened bread called chapatti or in the form of sweet dishes of various types depending on individual taste. Water chestnut is also known as a bull nut in English, Singhara or simkhata in Hindi, and karimbolam or vankottakkaya in Malayalam. Water chestnut is an annual aquatic plant in the *Trapa*ceae family (Jana, 2019) [23]. Every year, 2,261,589 tonnes of chestnut are produced worldwide (Jana B., 2018) [23]. China is the world's largest chestnut producer, producing 1,879,031 tonnes per year. Bolivia ranks second with an annual output of 84,813 tonnes (Lahiri, 2018). In India, fresh nut yields range between 2500-3800 kg per ha of the pond area, which could be increased to 5000kg hector by applying about 50kg of urea per ha of the pond along with weed eradication.

The nut is the fruit of the water chestnut. Each of the nut's four horns is sharp and has a spine with several barbs (Hussain N. A., 2020) [63]. On the water's surface, each plant has submerged leaves that are feather-like and oppositely paired along the stem and waxy floating leaves that are triangular and form a rosette. The petiole (leaf stem) of the floating leaves has a sac bulge that is filled with air and spongy tissue. Plant stems can grow up to 16 feet long, allowing them to thrive in deeper water. The water chestnut is an annual plant that reproduces rapidly (Lahiri, 2018). Early in the spring, the seeds germinate. Each seed can produce 10-15 rosettes, which can, in turn, produce another 15-20 seeds, or the nuts are washed by currents or waves to a new location. To other parts of the lake or river water chestnut infestation in the Nashua River (*Trapa natans*) Seeds. As a result, a single seed may produce 300 additional seeds in a single year. Water chestnuts bloom in mid-to-late July, and their nuts mature a month later. Flowering and seed production continues into the fall after the frost kills the floating rosettes. When mature nuts are dropped, they sink to the bottom and can live for up to 12 years, giving rise to new plants. The rosettes separate from their stems and float away. It thrives even on muddy coasts because it grows well and is well adapted to life on the water's edge (Jana B. , 2018). It is a very nutritious nut containing many Phosphorus, Calcium, and Magnesium. Despite its high nutritional value, it failed to capture the attention of food processors due to its seasonal availability of only 2-3 months per year.

Trapa natans fruits are sweet, astringent, cooling, diuretic, and tonic. This medicinal plant is thought to be a significant source of new chemical substances with potential therapeutic applications. (Jasmine Chaudhary, 2012) [34].

Variety

There is no specific standard water chestnut variety that has been released (Jana B., 2019) [2]. However, nuts with a variety of husk colours, such as green, red, or purple, as well as a mix of red and green, can be identified (Bhatt, 2019) [27]. Growers in West Bengal and other parts of eastern India have given various varieties of water chestnut names such as Kanpuri, Jaunpuri, Desi Large, Desi Small, and so on.

History

The plant was first introduced into Collins Lake near Scotia, New York (in the Hudson River-Mohawk River drainage area) around 1884, most likely as a food source for waterfowl. As a fugitive from the water garden. By the early 1900s, water chestnut had become established in the Hudson River. Water chestnut is scientifically known as *Trapa natans*. It is native to Europe, where it can be found in pale tropical and warm temperate climates. Naturalization has occurred in Australia and north-eastern North America. It is a European Union member. This disparity is largely due to the highly variable shape of the fruits. According to reports from the New Hampshire Department of Environmental Services in July 1998, the invasive aquatic plant water chestnut has infected) the Nashua River in Nashua (Azmir M. T., 2013). In 2015, a new population was discovered in the Connecticut River near Hinsdale. Furthermore, as the seeds become more common on temporary recreational equipment, where they become stuck in the carpeting on trailer bunks, more water chestnut infestations are expected in the future. Water chestnuts can completely cover the surface of a body of water, endangering local flora. Fishing and boating can also be difficult. Dense strands can grow to be a foot or thicker (Jasmine Chaudhary, 2012) [34].

Distribution and Evaluation

Water chestnut is native to Eurasia and can be found in pale tropical and warm temperature regions. It has become naturalized in Australia and the north-eastern region of North America. It is a member of the European Union (Huang G., 2017) [33] This disparity is largely due to the highly variable shape of the fruits. Because the fruits were used as a source of food and for their medicinal properties, the plant spread throughout. It was discovered in 1998 in southwestern Quebec, along a 5-kilometer stretch of the river du Sud, a tributary of the Richelieu River north of the US-Canada border (Jasmine Chaudhary, 2012) [34]. It can be found from the river's mouth at 73° 15'W 45° 08' N upstream about 5 miles (Huang G., 2017) [33] This appears to be a natural northward expansion from the Lake Champlain watershed, which has been present for some time in New York and Vermont. The species is also known to occur in Sodus Bay, New York, on Lake Ontario's south shore, where annual control has been practiced since the 1960s.

Distribution and Evaluation in India

Water chestnut production in India is led by Madhya Pradesh, Uttar Pradesh, Bihar, and Odisha. It can be found throughout temperate and tropical Asia and central and southern Europe. It is widely grown in India, particularly in Bihar, Madhya Pradesh, Uttar Pradesh, West Bengal, Odisha, Jharkhand, Karnataka, and Jammu and Kashmir (Huang G., 2017). The fruit of water chestnut is classified into two types based on its morphology: thorny and thornless. Bihar is home to only the red thorny fruit-type water chestnut. However, both thornless and thorn-bearing fruit plants can be found in Madhya Pradesh and Uttar Pradesh (Hoque, 2019) [3]. For the varietal development effort, water chestnut material was gathered from the Darbhanga districts of north Bihar and Madhya Pradesh of the 13 thornless germplasms collected, eight were red and five were green. Odisha, Jharkhand, and Uttar Pradesh were also chosen for their thornless germplasm (Huang J., 2017).

Physiology of Water Chestnut

Plant: The water chestnut is an annual aquatic plant with a submerged stem; stems can grow to be 12-15 feet long (Li M., 2015). The plant's roots are extremely fine and serve to anchor the plant in the mud The plant's spongy cord-like stems can grow up to 16 feet long (although typical lengths tend to be in the six-to-eight-foot range) A network of branching roots connects the stems to the water's surface

Leaves: A rosette of floating leaves with saw-tooth borders above the water's surface; triangular in shape and connected to an inflated petiole that gives the leafy area considerable buoyancy; additional, feather-like leaves can be seen down the submerged stem (Jasmine Chaudhary, 2012) [34].

Flowers: Flowers are four-petaled and white; form in June; are insect-pollinated, not much raised above, and broad with a short conical, often spinous beak in the center through which the radicle is protruded, with two spines at two angles, the second pair of spines often wanting fruit is a nut with four 1/2-inch, barbed spines, The stony These cotyledons are massive and teeming with food (Li M., 2015).

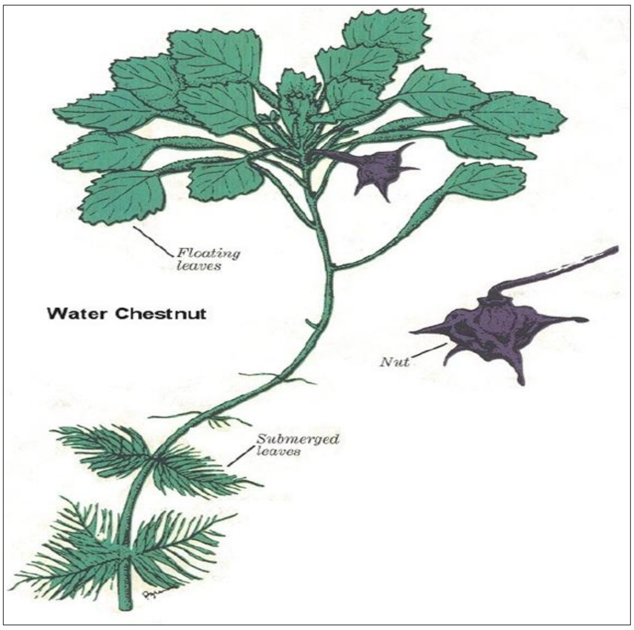

Fig 1: Water Chestnut Plant.

Although seeds can live for up to 12 years, most germinate within the first two years.

Spreads: The rosette and fruits detach from the stem and drift away on currents or by attaching to birds and other floating things.

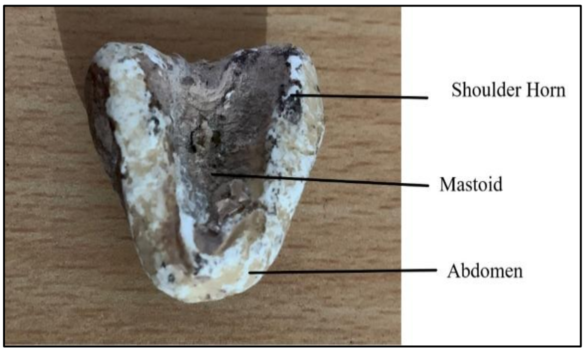

Fig 2: Water chestnut Seed

Physical, Ecological and Economic Impacts

Water chestnut has become a major problem throughout much of its range, particularly along the Hudson and Potomac Rivers and Lake Champlain (Mukesh Babu, 2013) [35].

Fig 3: Water chestnut infestation on Lake Champlain

The plant has the ability to form nearly impenetrable floating vegetation mats. These mats endanger boaters and other water-based recreationists. By significantly limiting light penetration into the water, dense mats can inhibit or prevent the growth of native aquatic plants beneath the canopy. Reduced plant development, combined with the decomposition of water chestnut plants that die back every year, can reduce dissolved oxygen levels in the water, harm other aquatic creatures, and potentially lead to fish kills (Mukesh Babu, 2013) [35].

Fig 4: Major River infestation on Indian Lakes

Trapa's rapid and abundant growth has the potential to outcompete native aquatic vegetation. (Charles R, 2006). Another effect of dense populations of water chestnut is the migration of small fish from beneath the canopy to open water, which is related to a decrease in dissolved oxygen beneath the plant. The vegetative mat's borders. Because of the concentration of tiny fish, larger game fish may be attracted to the true "mishmash" at the edge (RK, 2020). As a result of this, recreational anglers may be drawn to the concentration of game fish. Water chestnut has no nutritional or habitat value for fish or waterfowl, but it can have a significant impact on the use of contaminated areas by native species. The sharp, spiny nuts, as previously stated, can cause puncture injuries to swimmers and recreationists walking along the shorelines of contaminated areas.

Composition of Water Chestnut

Biochemical analyses of fruits of Water chestnut in 100 g, consisting of 22.30 and 71.55% carbohydrate in fresh and dry fruit, respective. The protein contents were 4.40% and 10.80% in fresh and dry fruit, respectively The mineral contents of the seeds were 32 and 102.85 mg calcium, 1.4 and 3.8 mg iron, and 121 phosphorus in 100 g, in fresh and dry fruit, respectively (Jan, 2021). In 100 g fresh- and dried seeds of water chestnut produced 115.52 and 354.85 Kcal of energy, respectively (SharadVisht, 2012) [9].

Table 1: Composition of chestnut fruits (in 100 gm)

Analysis	Minimum Value	Maximum Value	Average Value
Shell Thickness (mm)	0.30	0.71	0.51
Protein (g)	3.43	8.27	5.683
Fat (g)	0.66	3.08	1.89
Starch (g)	29.88	63.66	47.32
Fiber (g)	0.06	0.29	0.129
Ash (g)	1.40	4.92	2.809
Phosphorus (mg)	47.68	229.68	133.67
Calcium (mg)	69.71	201.70	87.863
Magnesium (mg)	59.71	202.89	105.87
Zinc (mg)	2.63	21.87	6.970
Iron (mg)	1.84	16.99	6.684
Copper (mg)	0.33	1.29	0.738

Chestnut fruit, in general has 40-45% water, 3-6%, protein, 3-5% fat, 40-45% carbohydrate, 1.3% ash. However, these values may vary based on the ecological conditions, type, genus and process. In the following Table 2, the composition of chestnut fruit under different conditions and nutrition items are illustrated (SharadVisht, 2012) [9].

Table 2: Composition of chestnut fruit in different conditions and nutrition items (in 100 g) (Ghasemzadeh, Jaafar, Rahmat, Feliciano, & Santos-Buelga, 2016).

Analysis	Fresh	Dried	Fried	Scalded	Flour
Carbohydrates	34	57.8	39.0	24.4	63.6
Sugars	9.6	16.1	10.7	7.5	23.6
Starch	24.4	41.7	28.3	16.9	40
Fiber	7.3	13.8	8.3	5.4	14.2
Soluble Protein	0.6	1.1	0.7	0.6	1.0
Insoluble Protein	6.7	12.7	7.6	4.8	13.2
Protein	3.2	6.0	3.7	2.5	6.1
Fat	1.8	3.4	2.4	1.3	3.7
Moisture (%)	52.9	10.1	42.4	63.3	11.4
Calorie(kcal)	160	287	200	120	343

Phenolic Compounds in Water Chestnut

To achieve high resolution, an aqueous acetic acid-acetonitrile gradient and a C18 column were used in this study to isolate phenolic compounds. Depicts a typical HPLC High profile liquid chromatography profile of CWC's phenolic extract. CWC samples had no interfering peaks. Peaks 1, 2, and 3 were identified as (-)-Gallo catechin gallate, (-)-epicatechin gallate, and (+)-catechin gallate, respectively, based on spectral properties and retention times in comparison to commercial pure compounds (SM, 2016). More than 60% of the total phenolic content (2.53 mg/g on a fresh weight basis) was contributed by these major phenolic compounds (Boopathi T. Gopalasatheeskumar K, 2007) [6].

Phytochemicals

Water chestnut contains carotenoids, phenolic acids, phytosterols, and polyphenolic compounds such as flavonoids, proanthocyanins (PAC), and stilbenes, all of which are included in nutrient databases, as well as phytates, sphingolipids, alkylphenols, and lignans (Boopathi T. Gopalasatheeskumar K, 2007) [6]. The phytochemical content of nuts varies greatly depending on nut type, genotype, pre- and post-harvest conditions, and storage conditions Genotype influences phenolic acids, flavonoids, stilbenes, and phytosterols, but data for many other phytochemical classes are lacking. Nut isoflavones, flavanols, and flavanol were found to be more heat resistant than anthocyanins, PAC, and trans-resveratrol during the roasting process. The solvents used to extract polyphenols and phytosterols have a significant impact on their quantification, and studies validating these methods for tree nut phytochemicals are lacking. Nut phytochemicals have been linke to antioxidant, anti-inflammatory, antiproliferative, antiviral, chemopreventive1, and hypocholesterolaemia properties (Vargas-Diez, *et al*., 2014) [37].

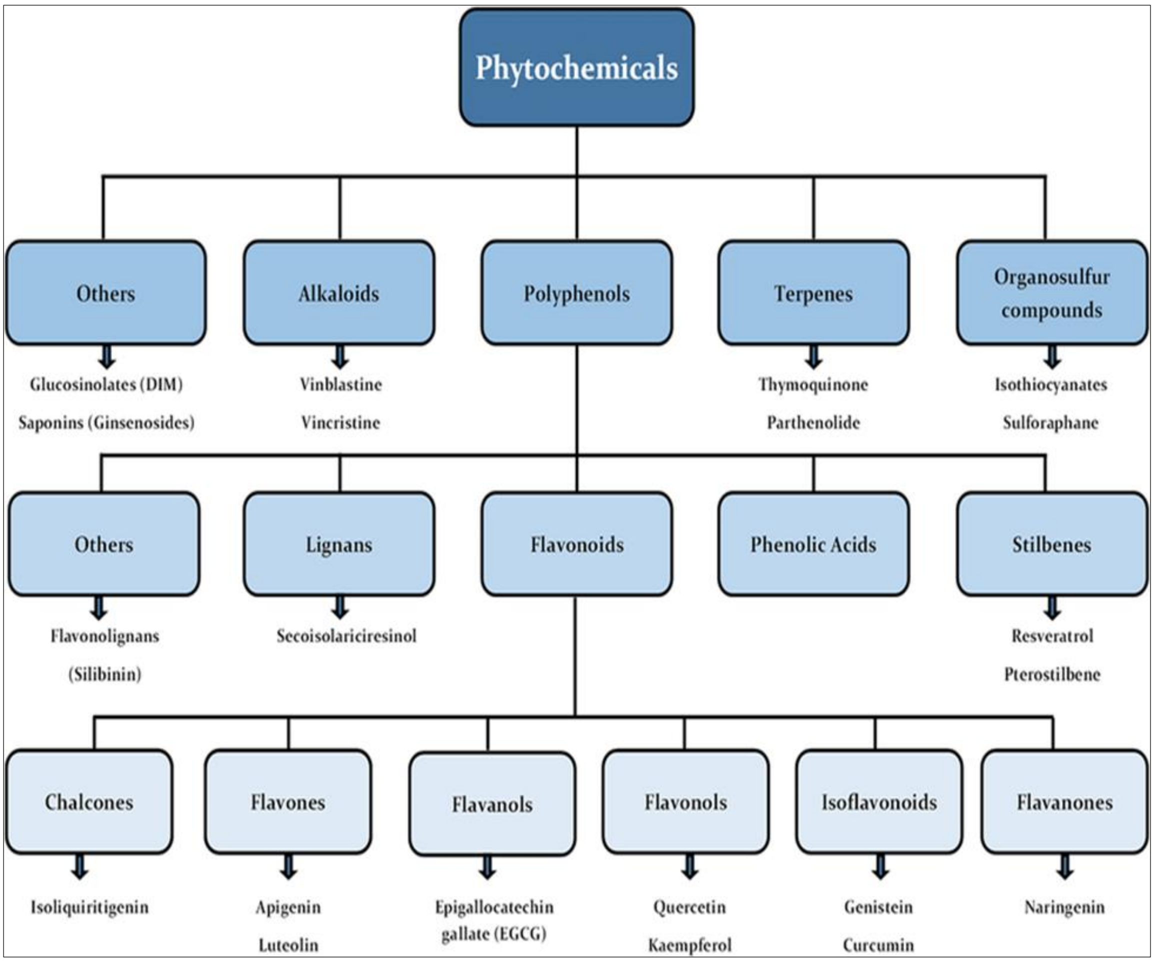

Fig 5: Phytochemicals (Vargas-Diez, *et al*., 2014) [37].

Antioxidants in Water Chestnut

Water chestnut contains high amounts of antioxidants such as flavonoids, flavones and total phenol contents are present. Phytochemical's screening of seed extract of water chestnut fruits reveals the presence of carbohydrates, Saponins, Phytosterols, fixed oils and fat while the pericarp extract of the fruits of water chestnut revealed the presence of tannins, flavonoids and glycosides alkaloids, Saponins, steroids and phenolic compound (Zadernowski, Czaplicki, & Naczk, 2009) [38].

Value Additions of Water Chestnut

Traditionally, water chestnut is eaten after it has been boiled. In India, this is a high-nutritional-value nut that can be used to make sweets and premium chapatti. It is a medium to low-calorie food with maximum nutrients that is gaining popularity for making snacks for people of all socioeconomic backgrounds all over the world (Jana B., 2020) [23]. Malnutrition is a widely recognized issue in developing countries such as India. It is a widespread problem that has been eradicated through extensive scientific work and various attempts prepared by several workers in the field to enrich people's diets with new formulations of food derived from various nutritional source (Das P. K., 2011) [40]. Because water chestnut (Singhara) is high in calcium, potassium, and iron, it is an excellent food supplement. Singhara is primarily grown for human consumption in India. It is commonly consumed as a vegetable, flour (dried), and various sweet dishes depending on personal preference. The water chestnut fruit kernel is delicious and high in carbohydrates, proteins, and essential minerals. Because of the tenderness, sweetness, and good taste of its fruit, water chestnut is one of the most popular starchy sweet dish desserts in Asian countries. In comparison to corn starch, water chestnut starch has less syneresis. In the preparation of frozen products, it can easily replace corn and potato starch (Ambikar D. B. H. U., 2010) [41].

Culinary Uses

The edible component of the nut is the corms, which are a pale colour. They are commonly consumed raw They can also be used after they have been slightly boiled. They're used to make cakes (water chestnut cake). Singhara contains a lot of carbs, fibre, vitamins, and minerals. They're crunchy and crisp. The crunchy texture and fresh mild flavour of water chestnut set it apart. It retains its crunchiness after cooking or canning. It can be eaten raw or cooked, and it can also be used as a meal filler (Das P. K., 2011) [40]. When combined with coriander, rice, noodles, ginger, sesame oil, and bamboo shoots, among other ingredients, they taste crunchy and crispy. It is an important component of the famous Thai dessert 'tabtimkrob' They are consumed in a variety of forms, including powder, juice, cake, flour, sliced, raw, and steamed. This vital vegetable can be used in the following recipes. It promotes fatal growth and aids in the treatment of hypertension in pregnant women to prevent bleeding after delivery, a pregnant woman is fed porridge made with water chestnut flour. The dried seeds are used to treat miscarriage and stop bleeding in women (Peng L, 2006). It also stimulates milk secretion from the mammary gland. The juice extracted from water chestnuts removes bile and phlegm humour and cures a plethora. It also boosts virility. Water chestnuts are being used to cure inflammations and blood impurities. They are energy boosters that alleviate fatigue and slow the flow of blood from the wound. Water chestnuts are high in K, with one cup providing 362.1 mg. This mineral is essential for proper muscle and neural function. Controlling salt regulates water retention and blood pressure. Water chestnuts with snow peas. Because of their excellent cooling properties, water chestnuts are ideal for combating the summer's sweltering heat. They also have numerous curative and supplementary properties. Water chestnut juice is used to treat diarrhea and dysentery, while the fruits are used to treat sore throats, anaemia, fractures, bronchitis, and leprosy. It promotes fetal growt h and aids in the treatment of hypertension in pregnant women (Singh H., 2017) [42]. Peel away the outer brown skin of a freshwater chestnut to reveal the white flesh beneath. The flesh can be eaten raw. They can also be fried, grilled, boiled, or sautéed to add a sweet, crunchy element to a meal. Depending on the dish, they can be served whole, sliced, diced, or ground. They are commonly used in stir-fries, chop suey, and a variety of curries. As a snack, people like candied or pickled water chestnuts. Alternatively, dry water chestnuts and grind them up and add them to a flour mixture or as a thickening agent (Singh H., 2017) [42]. No standard variety of water chestnut is released till now. But nuts with different husk colour like green, red or purple and a blending of red and green colour are recognized. Kanpuri, Jaunpuri, Desi Large, Desi Small etc. are the names of some types of water chestnuts referred to the growers in West Bengal and other parts of eastern. India, it is most commonly used as edible nut. The kernel of water chestnut contains a large amount of protein (up to 20%), starch (52%), tannins (9.4%), fat (up to 1%), sugar (3%), minerals, etc. It is also a good source of fibre and vitamin B along with Ca, K, Fe and Zn. Apart from these it has numerous curative and supplementing properties also. So, they are commonly known as cooling food and are excellent to beat heat of summer season.

Moreover, mixture of water chestnut powder with water is used as a great reliever of cough. If you experience pain during urination, then drinking a cup of sweet soup of water chestnut can really you in a big way India, it is most commonly used as edible nut. The kernel of water chestnut contains a large amount of protein (up to 20%), starch (52%), tannins (9.4%), fat (up to 1%), sugar (3%), minerals, etc. It is also a good source of fibre and vitamin B along with Ca, K, Fe and Zn. Apart from these it has numerous curative and supplementing properties also. So, they are commonly known as cooling food and are excellent to beat heat of summer season.

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Water chestnut in Food Industry

Food enrichment is the addition of one or more nutrition items that are deficient or absent in order to improve the properties of the food. The amount of research being done to investigate the functional, nutritional, and sensory quality of properties is growing by the day. The primary goal of food production is to provide people with healthy and happy lives by providing safe and nutritious foods (Md. Kabir Hossain, 2020).

Chestnut flour

Chestnut flour is widely used in cake, cookies, pasta, milky pudding products, bread, breakfast cereals, soups, sauces, and gravies. As a result of the potential effects of chestnuts on nutrition quality and health, interest in it is growing by the day (Hussain S., 2020) [63]. In this study, it is predicted that the use of chestnut Four in various foods, particularly bakery products, will contribute to the development of different product markets by improving nutrition value and functional properties. Furthermore, chestnut flour is thought to be used as an alternative flour additive (Md. Kabir Hossain, 2020). The use of chestnut flour is becoming more popular in the food industry due to its nutritional and sensory properties. Because it contains E and C vitamins, unsaturated oils like omega-3 fatty acids, dietary Fibre components, phenolic and antioxidant components, as well as a highly nutritious property content, it is thought that using chestnut flour in food enrichment will benefit human health. Chestnut flour is also in high demand in the cosmetics industry (Ismail B, 2008).

Chestnut Flour Production

Chestnuts are cleaned and separated according to size in the first step of making chestnut flour. For one day, they are submerged in water. As a result, they easily peeled away from their shells. The grinding process begins after the steam pressure system separates softened chestnuts from their shells. The drying process is carried out in low-temperature drying ovens to preserve the nutritional value of chestnuts. Following the drying process, the flour is cooled at room temperature, sifted through appropriate-sized sieves, and the packaging process begins. Storage is carried out under normal conditions (+4°C) (M. Chandana, 2013) [44].

Chestnut Flour and Studies for Utilization

Chestnut flour can be used for celiac patients due to being gluten-free as well as its nutritious properties. Some researchers investigated whether chestnut flour can be used as an alternative to cow milk in the preparation of kid-friendly desserts and soups because lactose in cow milk causes allergic reactions in children. Chestnut flour can also be used to make milky puddings, bread, baby formulas, pasta, and flakes (M. Chandana, 2013) [44]. Chestnut flour has a high protein content, a high sugar content (20-32%), a high starch content (50-60%), dietary fibre (4-10%), essential amino acids (4-7%), and a low-fat content (2-4%). It is also high in vitamins B, C, and E, as well as potassium, magnesium, and phosphorus. The use of chestnut flour is thought to be advantageous at this stage because most gluten-free products are deficient in vitamin B, iron, and fibre. Because of its nutritional value, chestnut flour is also used in gluten-free bread preparation. In a study for gluten-free bread preparation (M. O. Faruk, 2012) [39].

Scope for extraction of bioactive compounds from water chestnut (different extraction techniques)

Several techniques are already used to extract active molecules from multiple plant-based raw materials that are available in laboratory scales. Extraction methods are commonly classified as traditional or modern. Both have been used to recover compounds from plant-based raw materials. The first vital step in the preparation of vegetation formulations is extraction. Modern extraction methods are useful in progressing the advancement of traditional herbal remedies. The development of modern sample-preparation techniques that offer significant advantages over traditional methodologies for the extraction and analysis of medicinal herbs is likely to play a significant role in the overall effort to make sure the access to high herbal products to for consumers worldwide. Sample preparation is critical in the development of analysis methods for the analysis of constituents present in botanicals and herbal preparations (Azmir M. T., 2013). The principles underlying the operation of various extraction techniques are discussed in this article, as well as factors that influence better performance results, research progress, and the strengths and limitations of various extraction strategies. The methods that are solvent and energy-efficient efficient, as well as suitable for thermo labile phytocompounds, are emphasised (Armenta S. G.-T., 2019) [12].

Extraction Technology

1. Collection and authentication of plant material & drying
2. Size reduction
3. Extraction
4. Filtration
5. Concentration
6. Drying & reconstitution

Several factors influence the quality of an extract, including parts of the plant for use as precursor materials, solvent in use for harvesting, removal process, and plant material, solvent ratio, and so on. During extraction, all parameters are optimised and controlled from the laboratory to the pilot scale. Through the selective use of solvents, extraction methods differentiate the soluble vegetation metabolites (Das K, 2011) [40].

An Overview of Extraction Techniques Used in Food Industry

Recent technological advances and the development of methods to improve production and separation have revolutionized biomolecule screening and provided an opportunity to obtain natural extracts that could potentially be used. Besides that, extraction techniques for separating biomolecules have been developed in order to acquire highly purified products that can be used in a variety of applications. Extraction is the detachment of biologically active plant material from inert components such as plant matrix using specific solvents. Extraction method, microwave-assisted extraction, ultrasound extraction, accelerated solvent extraction, and enzyme-assisted extraction is all common biosynthetic pathway extraction techniques. (Handa, 2008). The assumption underlying traditional solvent extraction is use of suitable solvents at extremely high temperatures. This accelerates the extraction process's mass transfer and reaction rate (Azmir M. T., 2013).

Table 3: An Overview of Recent Extraction Technologies Used in Food Industry

Extraction Systems	Types of Extraction	Mechanisms
Microwave-assisted extraction	Physical extraction	Electric and magnetic fields, ionic conduction, and dipole rotation
Ultrasound-assisted extraction	Physical extraction	Cavitation phenomenon
Enzyme-assisted extraction	Physical extraction	Binding of enzymes onto the active sites of plant matrix and its solubilization
Soxhlet Extraction Method	Exhaustive extraction technique	Fat extractor uses the solvent reflux and siphon principle to continuously extract the solid matter by pure solvent
Enzyme-Assisted Extraction	Physical extraction	Ability of enzymes to hydrolyse cell wall components and disrupt the structural integrity of the plant cell wall

Different types of extraction methods

1. Soxhlet Extraction Method
2. Ultrasound-Assisted Extraction Method
3. Microwave-assisted Extraction Method
4. Accelerated Solvent Extraction
5. Enzyme-Assisted Extraction

Soxhlet extraction method

Soxhlet extractor is a piece of laboratory tools designed by Franz von Soxhlet in 1879. The figure represents the construction of Soxhlet extractor. A circular bottom flask, syphon tube, distillation path, growth converter, condenser, water cooler, heat source, and thimble include Soxhlet extractor setup. The powdered sample is enclosed in a porous bag or "thimble" made of strong filter paper or cellulose, which is placed in the thimble chamber of the Soxhlet apparatus.

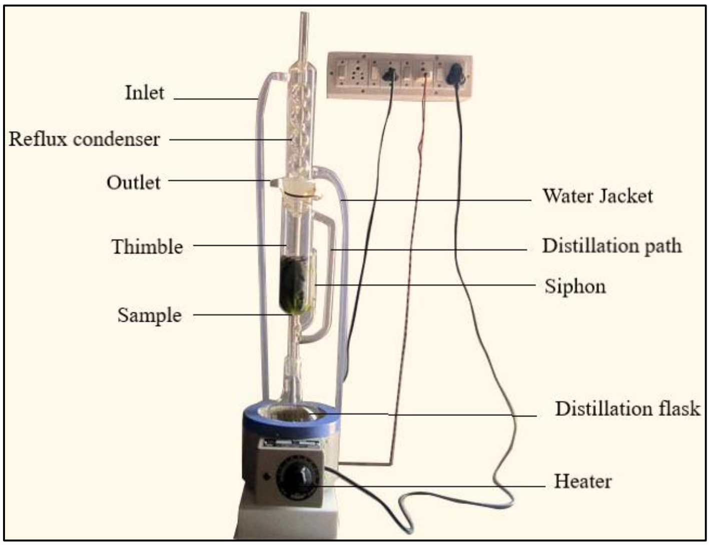

Fig 6: Soxhlet Extraction apparatus

The extraction solvent is placed in a circular bottom flask and heated with a heat source like a heat blanket. The temperature of the heater is determined by the solvent used for extraction. (Das HB, 2009) [10]. Due to the heat, the solvent in the lower flask evaporates and drips back to the sample thimble. When the liquid content reaches the arm of the syphon, it is poured back into the lower flask, and the path is indicated by a clear solution in the syphon tube. The advantage of this system is that instead of multi-component solvent being transferred to a sample, only one set of solvent is recycled. This method is not suitable for hot labile compounds because prolonged heating can cause composite degradation. Using heat from an abortion flashlight, this method maintains a high output temperature. There is no need for filtering the output, and the transfer of the transfer equilibrium is done by bringing the new solvent into contact with the solid matrix on a regular basis (SharadVisht, 2012) [9].

Table 4: Various Types of Solvents Are Selected for Active Constituent Extraction for Soxhlet Extraction Process (SubalDebnath K. M., 2010) [11]

	Polar solvents	Semi Polar solvent	Non-Polar solvent
Examples	Water	Ethanol, Acetone	Petroleum ether, chloroform and Diethyl ether
Phyto constituents	Anthocyanins Starches Tannins Saponins Terpenoids Polypeptides Lectins	Tannins Polyphenols Polyacetylenes Flavanol's Terpenoids Sterols Alkaloids.	Alkaloids Terpenoids Coumarins Fatty acids flavonoids

Pre-Extraction Preparation of Plant Samples for Soxhlet Extraction

The first step in studying traditional medicine is to make plant samples to preserve the phytochemical nutrients in the plants before they are released. Plant material such as leaves, stems, bark, roots, fruits, and flowers are then used for extraction. The following criteria are essential prior to the extraction.

Selection and Collection of Plant Materials

Plant material selection and collection are critical steps in achieving efficient phyto constituent isolation. Only disease-free and wholesome plants are chosen for plant extraction, which is free of weeds and insects. And numerous factors are involved in the plant material collection. The Plant Materials Program of the NRCS (Natural Resources Conservation Service) published guidance for accumulating plant material, which includes seed and vegetative collection (Boopathi T. Gopalasatheeskumar K, 2007) [6].

Selection of Solvent for Soxhlet Extraction

Soxhlet extraction solvent is selected using the Phyto constituent isolation process. The solvent should be non-toxic and easy to remove. Generally, solvents are selected in the order of increasing polarity, such as acetone, petroleum ether, ethyl acetate, chloroform, methanol, ethanol, and water (Bounty Y, 2017) [7]. Petroleum ether is commonly used to extract steroids and saturated fats, as well as to extract chlorophyll from leaf powder; some researchers use petroleum ether to reduce plant matter After dilution, a primary solvent, such as alcohol or aqueous extraction, was used. Fat reduction is necessary for some plant materials because aromatic substances cause emulsification and solvent degradation and interfere with the extraction process. Methanol is a semi-polar solvent that can produce many phytoconstituents, and water is a soluble polar solvent that is cheap and non-toxic (Ashraful M, 2008) [8]. Water separates the amount of cooling material and is suitable for animal and human studies. In addition, some researchers are extracting plant material using the Soxhlet method. (Pandey, 2018).

Table 5: Different Types of Aquatic Plant Materials are used in the process of Soxhlet Extraction Method.

S. No	Plant Name	Part of the Plant	Solvent For extraction Percentage yield	Active Components	Medical Uses
1	*Nelumbo nucifera*	Lotus root, stem, leaf, flower and Seed	Ethyl acetate,	Phenolics acids, Alkaloids, Flavonoids, and steroids	Immune functions, Diabetics, and anti-inflammatory activities
2	*Eichhornia crassipes (water hyacinth)*	Leaves	Ethyl alcohol, Ethanol	Amino acids, Flavonoids, Leucine and Phenylalanine.	Anti-inflammatory, antifungal, antibacterial function
3	*Panicum repens L.*	Roots and Rhizomes	Ethanol	Phenolics and Flavonoids	Analgesic activity
4	*Hydrilla Verticillata (Hydrilla)*	Stem, Leaves and Tubers	Ethanol and Water,	Flavonoids, Glycosides, Alkaloids, Amino acids, Proteins, Steroids and	Anti-inflammatory
5	*Vallisneria spiralis*	Aerial parts	Petroleum Ether, Chloroform and Ethanol	Tannins, Steroids, Flavonoids	Refrigerant, stomachic.
6	*Pestia*	Aerial parts	Ethanol, Petroleum ether	Tannin, Alkaloid,	Anti inflammatory

Ultrasound- Assisted Extraction

Furthermore, the USAE may act in extraction via single or multiple mechanisms such as fragmentation, erosion, capillarity, detexturation, and sonoporation. The sum of USAE effects in the extraction medium facilitates the disruption of the physical structure of the raw material, reduces sample particle size, improves diffusional and convective mass transfer, and thus increases extraction efficiency through improved solute-solvent contact. The main works of the USAE to obtain phenolic compounds from by products, including their operational parameters, USAE device types, and most important compounds analysed. Different solvents were tested to extract polyphenols from raw material, but it was ascertained that 80 percent acetone (v/v) promoted the highest target compound yield, resulting in three-fold higher extraction efficiency than the same process performed with pure water as the solvent (Annegowda, 2012) [14]. The effects of different solvents (Pure Water, ethanol (50-100 percent v/v), and methanol (50-100 percent v/v) on the extraction of phenolics from apple pomace were evaluated, with 80 percent methanol (v/v) being the best solvent for recovering phenolic compounds. To extract phenolics (e.g., flavonoids) from apples, organic solvents such as ethanol or its mixtures are most commonly used. There were no significant differences when trying to extract phenolics from apple wood with organic solvent mixtures ranging from 40 to 80 percent (v/v solvent/water) at 60 ° C. for 30 minutes using USAE. However, ethanol outperformed the other acetone (Methanol and Acetone) in extracting these substances. In contrast, pure water is great for extracting polar compounds like phenol acids. Different properties of each solvent are responsible for improving the extraction of a specific class of compounds. Water acts as an emollient in the samples, eluting the most polar compounds, whereas organic solvents easily penetrate the samples, extracting compounds with less polarity than water. Extractions with a gradient solvent could thus be an excellent alternative for recouping sequentially different compounds in specific fractions, trying to maximize the biomass's full potential. Furthermore, because the solvent temperature may reach the boiling point depending just on ultrasound power and exposure time, this cause's solvent loss by volatilization (Md Salehan, 2016) [15]. Temperature is another parameter which must be carefully controlled in USAE so because robotic process of ultrasonic waves could be dissipated as heat, resulting in overheating the solvent and degradation of the active compounds. Furthermore, the heat transferred to the system may result in an additional cost to the process (in costs and environmental terms). For example, phenolics were extracted from apple pomace at room temperature using ethanol as the solvent. Otherwise, For the recovery of phenolic compounds from apple pomace, different temperatures (10 to 40 C) were tested using ethanol as the extraction solvent. They discovered that the highest extraction yields were obtained at 40 degrees Celsius, using 50 percent ethanol, 0.142 W/g, 25 kHz, in 45 minutes, and they studied the phenolic extraction from unripe fruit at various temperatures and extraction times from 50 to 70 ° C., and from 20 to 30 minutes, respectively. The lowest temperature and longest time produced the highest total phenolic yield (13.26 0.56 mg GAE/g), according to the authors. (Mahailovi'C, 2018). To extract polyphenolics from apple skin and pulp, researchers tested different temperatures (20–80 C) and extraction times (20–40 min). In this case, 65 C and 33 min with pure methanol were considered the best circumstances for apple skin, while 80 C and 40 min only with 20% methanol was the best condition for pulp; thus, different matrixes and solvent compositions mildly interfered with the results regarding time and temperatures (Chua, 2012) [16]. Still, in temperature, a recent review work provided by, higher the temperature Three different hypotheses may impact the extraction yield of the USAE operation. Pertaining to one theory, extreme temps increase solvent vapor in the cavitation bubble, lowering the pressure gradient between inside and outside the bubble. As a result, even though the number of cavitation bubbles is big, they implode with less power at high temperatures, causing less damage to the cell and decreasing yield. According to the second hypothesis, increased shear stress causes degradation of the desired component due to the large number of cavitation bubbles formed at higher temperatures and subsequent collapse. Furthermore, the third hypothesis involves lowering the solvent surface tension at higher temperatures, which reduces the intensity of a microbubble bubble. As a consequence, the temperature must be carefully evaluated to determine the specific range that maximizes extraction performance while trying to prevent the degradation of the compounds. The bandwidth interval used to recover phenolic compounds from different apple samples ranged from 21 to 40 kHz, in addition to temperature (Chemat, 2017) [17]. Low-frequency USAE (120 kHz) has been reported to be preferable for extracting bioactive compounds from natural raw materials; the low-frequency USAE allows the formation of fewer cavitation bubbles with larger diameters than high-the frequency US (>120 kHz). Higher bubbles boost the cavitation effect by damaging the cell structure and releasing the target compounds, resulting in a higher extraction yield. (Chemat, 2017) [17]. Interestingly, evaluated the effects of frequency (21 or 40 kHz) and extraction time (0–30 min) on the phenolics from apple tissue after being treated by USAE, concluding that 21 kHz for 30 min or 40 kHz for 5 min displayed the highest yield of total phenolics compounds of extraction, namely 543.4 21.3 mg chlorogenic acid/100 g d.m. and 1046.5 18.9 mg chlorogenic acid/100 g d.m. According to the authors' findings, an increase in frequency requires less extraction time and results in a higher yield, and thus there may be a frequency inflection point to maximize the extraction yield. However, as there are few studies focusing on the effect of this parameter, the frequency remains a fertile field for research. Furthermore, very high frequencies (above 500 kHz) can be used for reversible and irreversible nonoperation, as seen in biological applications (molecules cell uptake and cell destruction, respectively)(Chemat el al., 2017) [17]. However, further research is needed to verify the above issue for natural material extraction.

USAE power is also an essential property to optimize since it affects the aforementioned USAE mechanisms, that also affect extraction performance. reported a direct relationship between USAE power as well as phenolic extraction yield from apple pomace Put another way, USAE power (420–560 W) was tested to extract phenolics from unripe apples. They found that the highest power reduced compound recovery, with 50 percent ethanol (v/v) at 519.39 W, 30 min, and 50 degrees Centigrade being the best of the tested conditions. Using ultrasonic probes, researchers investigated different temperatures (25–40 C) and irradiation time (0–400 W) for extracting polyphenols from apple skin. Remarkably, the authors discovered that the optimal condition was achieved at a reduced capacity (50 W) and in a shorter extraction time (30 min). As a result, the USAE power, like the temperature, should be thoroughly considered for same reasons. Works have reported that increasing the USAE power favours extraction yield up to a certain point, and that above that point, the USAE mechanisms are affected by the bubbled formed; a high concentration of high bubbles leads to an inter-bubble collision, deformation, and no spherical collapse, resulting in less impact between bubbles and raw material, which negatively impacts the yield. Furthermore, very high power may affect aim compound extraction yield due to molecular degradation, especially when combined with water as a solvent. The US can detach water molecules in to the free radicals, which can end up causing chemical oxidation and bond breaking Rhizophora mucronata is a very potent natural antioxidant source (Chemat F. R.-T.-V., 2017) [17].

Microwave-Assisted Extraction Method

Microwave-assisted extraction of bioactive compounds is in its early stages. Over the last two decades, new studies have been prompted by an increasing demand for more efficient extraction techniques that are automatable. The main goals were to reduce extraction times, reduce solvent consumption, and save energy and money. Advances in microwave extraction have resulted in a number of novel techniques as a result of these goals. Microwaves are produced by electric and magnetic fields oscillating perpendicular to each other. When exposed to microwave radiation, ionic conduction and dipole rotation of solvent molecules cause super boiling. The solvent molecules try to line up with the changing electric field. However, when the solvent molecules fail to realign along the electric field, the solutions become heated due to frictional resistance (M. letellier, 1999) [22]. As a result, only dielectric materials with permanent dipoles can be used in microwave extraction. Microwave-assisted extraction uses less solvent, has a shorter operational time, high recoveries, and produces high yields from extraction. Because it is less expensive and simpler to use, this technique outperforms SFE. Another advantage of using microwave-assisted extraction is that it saves time. When exposed to microwave radiation, the moisture present within plant cells heats up (Liu H. Z., 2006). This causes moisture to evaporate and places a great deal of strain on the cell wall, causing it to rupture. The ruptured cells release phytoconstituents, increasing their extraction yield. Soaking the plant material in high polarity solvents for a specific time period improves the extraction yield of biomolecules. Within plant cells, cellulose is targeted and degraded over time. As the biomolecule solubility improves at higher temperatures, the extraction yield increases, escalating the extraction cost. penetrability of solvents into plant cells (M.Kratchanova, 2004) [19]. SEM images of normal plant material, heat-refluxed extract, and MAE extract were collected in one case. The plant cell wall structure remained intact in both the heat refluxed extract and the normal extract. The cell walls of the MAE-treated extract were completely fragmented and broken. Heat-reflux extraction does not rupture cell walls because it involves permeation and eventually solubilization processes to extract phytoconstituents from the substrate. Microwave-assisted extraction parameters to optimise include solvent selection, microwave irradiation time, microwave power, and solid-loading ratio. Any extraction reaction requires careful solvent selection. Nonpolar solvents are microwave radiation transparent and thus unsuitable for microwave extraction. Polar solvents, such as water, absorb microwaves well and thus heat up quickly, enhancing the extraction process. Scientists have even experimented with a combination of different levels of microwave-absorbing solvents to achieve high extraction yields (M.D. Luque de Castro, 1999) [20]. To promote green extraction technology, researchers created solvent-free MAE systems in which no solvent was used and the water present within the cell walls aided the extraction process. MAE relies heavily on solid loading. There must be enough solvent volume to submerge the plant material in during the extraction reaction. In the case of traditional extraction, a bigger solvent volume leads to higher extraction yields. Because of the non-uniform exposure of the reaction mixture in MAE, a higher liquid volume may reduce the extraction efficience (L.E. Garcia-Ayusa, 2000) [21]. Another parameter studied by MAE is heating time. So because the reaction mixture has been exposed to microwaves for just a longer period, temperature-sensitive components may become unstable. Microwave power and microwave reaction time are interdependent. Microwave reactions are typically run at low or intermediate power for extended periods of time. High microwave power is not appropriate for thermally sensitive compounds. Researchers used very high microwave power and discovered that it had no significant effect on flavonoid yield. At higher temperatures, solvent viscosity decreases while solubility and penetrability increase. The higher the surface area of the plant combination, the higher the extraction yield. This is accomplished by milling, grinding, and homogenizing the plant matrix to reduce particle size MAE was used on powdered seeds to obtain flavonoids from Annona squamosa and Carica papaya seeds. They observed an increase in flavonoid extraction yield because they used finely ground seeds with small particle sizes. Nowadays, 2 categories of high - frequency applications are in use: focused microwave ovens and multimode extraction beaker. A multimode system extracts utilising controlled pressure and temperature (O. Zuloaga, 1999). The focused microwave-assisted system only directs microwave irradiation to the area of the extraction container containing the reaction mixture. Microwaves randomly reflect within the microwave vessel in a closed microwave system, and every part of the vessel is equally irradiated Several microwave extraction systems have been modified. Vacuum-induced microwave-assisted extraction of thermos labile substances at gentle operating conditions, nitrogen-protected microwave-assisted extraction, in which nitrogen is used to pressurize the extraction vessel to avoid oxidation of oxygen-sensitive sensitive molecules during extraction, ultrasonic microwave-assisted extraction, in which a synergy of microwaves and ultrasonic waves augment the mass transfer, which then, Combining microwave-assisted extraction with the other extraction methods has recently gained attention as a way to overcome the limitations of a single extraction technique and achieve satisfactory extraction efficiency (M.J. Alfaro, 2003) [25]. To isolate lycopene from tomatoes, a novel extraction method merging microwave and ultrasound was developed. The results showed that the new method's extraction rate was higher than that of ultrasonic-assisted extraction (97.4 % vs. 89.4 percent) Concerns about environmental damage, resource depletion, and food safety have recently fuelled research into alternative methods of extracting bioactive substances from seedlings without using solvents, especially organic ones like methanol (Zhang, 2011) [59]. The extraction of flavanols from veggies using solvent-free microwave hydro dispersion and gravity extraction was optimized. For the isolation of antioxidants from Hippophaerhamnoides berries, a protocol of pressurized solvent-free microwave-assisted extraction was developed. When compared to maceration, pressurized hot water extraction, and having to press extraction, microwave techniques resulted in the highest antioxidant capacity of the crude extract (Budzinski., 1999) [23].

Accelerated Solvent Extraction

Accelerated solvent extraction (ASE), as well known as pressurised solvent extraction (PSE) or pressurised liquid harvesting (PLE), is a method that has been evolved as an alternative to traditional extraction techniques including such Soxhlet, maceration, percolation, or reflux, with advantages in terms of extract concentration, solvent consumption, harvesting yields, and reproducibility. It boosts extraction yield by using organic solvents at high pressure and temperature Temperature increase accelerates the extraction kinetics, while additional pressure keeps the solvent liquid, allowing for safe and rapid extractions. Furthermore, pressure difference forces this same solvent into to the matrix pores, facilitating analyte extraction. High temperatures reduce the viscosity of the solvent, allowing for greater matrix penetration and weaker solute matrix interactions (Gomez-Ariza JL, 2002) [26]. Furthermore, higher temperatures increase the diffusivity of the solvent, resulting in faster extraction. The linear polarization of the element being analysed, as well as compatibility with just about any post-extraction extraction processing stages and quantitative equipment, influence solvent selection. Use of adsorbent materials in the test sample alongside the sample sometimes can provide the greatest standard of selectivity in the ASE procedure. Typically, the sorbents is packed into the test sample first (outlet end), followed by the sample (Bijorklund E, 2001) [27]. The stream of solvent during in the separation is such that undesirable compounds may be retained in the cell by the adsorbent. However, these are dependent on the types and physiochemical of the solvents and goal analytes, as well as undesired substances in the specimens. ASE works by passing the solvent through with an extraction cell sample holder. The specimen is heated by an unmediated connection to the oven. The separation was carried out by trying to contact the data set with the hot solvent both in static or dynamic modes. When the removal is finished, compressed nitrogen transports all the solvent from of the cell to the vial for analysis. The filtration extract is removed from the sample and stored for later analysis (Sporring S, 2004) [28]. The additional pressure keeps the solvent inside the liquid state during the separation process and keeps the solvent in contact with the material. According to some researchers, pressure had very little effect on the extraction. Others, on the other hand, proposed that high pressure could increase extraction yield by forcing this same solvent into matrix pores, demonstrating that the impact of the new was matrix-dependent. In their studies, ASE performed on tea at temperatures ranging from 70 to 100°C yielded lower caffeine yields whenever the pressure was raised above 100 bar. The increased pressure may have compressed the soft tea sequence, reducing the efficiency of transporting molecules out from the plant matrix and infiltration of the solvent into the entire matrix. ASE is typically performed at extremely high temperatures to improve extraction kinetics by interrupting plant matrix as well as analyte interactions, increasing solvent molecular motion, and increasing analyte solubilization in the extraction solvent due to the elevated temperature. The diffusion of compounds from the plant matrix into the solvent occurs during the static phase of extraction without the overflow of solvent from the extraction thimble. Finally, the extract is accumulated by quickly supplying the harvesting cell with new solvent as well as nitrogen as just an inert gas. An increase in static removal efficiency generally increases extraction efficiency until equilibrium is reached, growing the static duration does not improve compound recovery any further. The flush volume, which is 40%–60percentage points of the cell size, is the amount of fresh solvent used to sluice the sample after the process is finished. While lesser flush volumes were found to increase active compound yields from Angelica sinensis, they had no effect on Cortex Dictum extraction yields. The use of an inert packing material to reduce vessel void volume ensures better solvent-matrix interaction, lessens analyte combustion due to the presence of air, and lowers solvent consumption. Diatomaceous earth is frequently used, particularly if the material to be extracted is a fine powder. Neutral glass was also used as a dispersing agent in order to reduce the amount of solvent used in extraction. The obvious advantages of ASE include fast extraction for a wide range of sample quantities, drastic reduction in solvent quantities used, a broad variety of opportunities, and trying to deal with acidic or alkaline matrices. This technique offers a lower cost per reaction, reducing solvent utilization significantly (Poerschmann J, 2006) [29].

Table 6: Examples of Synergistically Used Extraction Techniques

Extractions	Substrates for Extraction	Extraction Conditions	Yield
Ultrasound-assisted three-phase partitioning	Three-phase extraction with ultrasound on recovery of Andrographis paniculate	40% w/w ammonium sulphate, 32 min, pH 7, 1:1 slurry to *t*-butanol ratio, 30°C	35.28 mg/g of andrographolide
Hydro trope extraction coupled with ultrasound	Optimization of ultrasound-assisted extraction of defatted wheat germ proteins by reverse micelles	Power 363 W, ultrasonic time 24 min, and pulse mode 2.4sec on and 2 s off	Extraction efficiency of 45.6%
Microwave-assisted enzymatic extraction	Microwave-assisted aqueous enzymatic extraction of oil from pumpkin seeds	Enzyme concentration of 1.4%, w/w, at 44°C, 66 min, power 419 W	64.17% oil recovery
Ionic liquids-based enzyme-assisted extraction	Application of ionic liquids-based enzyme assisted extraction of chlorogenic acid from eucommiaulmoides leaves	1-alkyl-3methylimidazolium ionic liquid, 0.5 M cellulose, 120 min, pH 3, 50°C	8.32 mg/g chlorogenic acid
Ultrasound assisted compound enzymatic extraction	Ultrasound -assisted compound enzymatic extraction of polysaccharides from black currant	Enzyme concentration 1.575%, pH 5.3, ultrasonic time 25.6 min	14.28% polysaccharides

Enzyme-Assisted Extraction

The need for eco-friendly extraction technologies has sparked interest in enzyme extraction processes among researchers. Enzymes are highly specific and efficient. Enzymes act on the active site of the cell wall, breaking it down and going to release the desired biomolecules with a better extraction yield. Enzymes provide the benefits of enzyme reusability without significantly affecting biomolecule activity. A wide range of compounds, including carbs, essential oils, natural colours, fragrances, and medicinally valuable compounds, have been extracted using enzyme-assisted extraction of their substrates (Heo, Park, Lee, & Jeon, 2005) [30]. The basic principle of enzyme-assisted separation is that the catalysts hydrolyse and totally interrupt the plant cell wall under ideal experimental conditions, going to release the intracellular components. Enzymes interact with plant cell walls by binding to their active site. This causes the enzyme to change shape in order to fit into the substrate's active site, leading to maximum interaction between both the enzyme and substrate. The change in shape of the enzyme creates the bonds of the cell wall to break, trying to release the active constituents (Park, Shahidi, & Jeon, 2004) [31]. The extraction efficiency is affected by system temperature, enzyme mechanism of action, extraction duration, enzyme loading, substrate availability, and system pH.

There are several limitations to enzyme extraction technology. One of the major barriers to commercial viability is the high cost and stability of enzymes. Enzymes on the market today are unable to completely solubilize the bonds in plants, limiting the release of the active components from within them.

Enzyme technology is being used to extract a wide range of biomolecules, including curcumin from turmeric, oil from grape seed, and Mangifera from mango leaves. Ultrasound rays were used in combined with enzymes to extract phytochemicals from mulberry (Fleurence, Massiani, Guyader, & Mabeau, 1995) [32]. Using these hybrid engines not only improved quality of the product but also significantly reduced retention time. Enzymes are also used as a pre-treatment technique for plant materials. Enzymes such as papain, cellulases, lipases, and pectinases are frequently used to rupture the plant matrix, thereby growing plant yield of phytoconstituents. With Within in pre-treatment for ionic liquid extraction of curcumin from Curcuma longa, enzymes like -amylase and amyl glucosidase were used. This expanded the curcumin extraction efficiency by 60 percent. A recent example of the use of an enzyme system is in the processing of pectin polysaccharides to enhance antioxidant extraction. An enzymatic concentration of 0.1 percent w/w massively higher antioxidant extraction yield. In a second case, the researchers used cellulases and pectinases to perform enzyme-assisted extraction of lycopene from tomato tissues, which increased the lycopene yield. For oil extraction, enzymes such as cellulases, -amylase, and pectinase are prevalently used. Oils extracted with hexane are of lower quality than oils extracted to enzymes Higher dye (anthocyanin) extraction was observed after enzyme-assisted extraction of grape skin during the vinification process. In comparison to a nonenzymatic process, oil extraction from puree berry seeds powder using enzymes did result in a 60% rise in phenolic compound yield. Enzyme extraction technology is a new field of study in food technology. A detailed assessment of the cell structure of the plant matrix, mixed with the use of various enzymes which strike the active site of the substrate, could be used as a strategic plan for enhanced hydrolysis (Denis, le Jeune, Gaudin, & Fleurence, 2009) [33].

Health Benefits of Water Chestnut

Water chestnuts contain several antioxidants that reduce the risk of many chronic diseases and other diseases. The potassium in water chestnuts may reduce your risk of stroke and high blood 1pressure. The antioxidants which are present in water chestnuts reduce your risk of developing different types of cancer cells in the body. In the current generation, people who are following a weight loss plan may benefit from water chestnuts which is having low-calorie content in them. Water chestnuts are high in fibres, which helps the body digest food more efficiently. Fibres aid in digestion by helping food move through the large intestine. Fibbers also absorb water, which softens stools and allows them to pass more smoothly (Bhatiwal Shalabh, 2012) [34].

Antiulcer Activity

In one study, the antiulcer activity of the fruits of Water Chestnut was studied on Wister rats. The antiulcer activity of 50% ethanolic extract at two dose levels was tested as a result of pyloric ligation and aspirin plus pyloric ligation (Poerschmann J, 2006) [29]. The tests extract exhibited significant antiulcer activity possibly related to the increasing concentration of sugar and modulation of the mucosal barrier in the stomach as a result of the increase of carbohydrate content. These results suggest that the water chestnut ethanolic extract may possess antiulcer properties (Bhatiwal Shalabh, 2012) [34].

Providing Antioxidants

Water chestnuts contain a number of antioxidants, which assist the body's immune system in battling free radicals, potentially harmful molecules. When free radicals accumulate to a certain extent, they can cause oxidative stress, which can compromise the body's natural defences. Studies indicate that oxidative stress is linked to an increased risk of developing chronic illnesses. However, research-backed by trusted sources suggests that anti-oxidants found in water chestnut peel can help neutralize the effects of free radicals. (Fletcher, 2019) [23].

Slowing Tumour Growth

The antioxidant found in water chestnuts is ferulic acid. Studies have found that ferulic acid may help reduce or slow the growth of cancer cells. For example, test-tube studies of breast cancer found that ferulic acid both killed and reduced the growth of cancer cells. However, more studies in humans will be needed to determine whether water chestnuts are capable of fighting cancer (Poerschmann J, 2006) [29].

Lowering Calorie Consumption

Water chestnuts are very low in calories, with half a cup containing just 60 calories. However, they are packed with various nutrients, including fibre, protein, copper, potassium, magnesium, riboflavin and vitamin B-6 (Park, Shahidi, & Jeon, 2004) [31].

Lowering High Blood Pressure and Associated Risks

Researchers found that increasing consumption of potassium could reduce blood pressure in people with hypertension. High Blood Pressure can cause strokes and Heart Disease Potassium is found in water chestnuts and has been linked to decreasing blood pressure and also found moderate-quality evidence to suggest that a higher potassium intake could reduce the risk of stroke by 24 percent. This review considered a higher intake to consist of 3,500–4,700 milligrams (mg). Half a cup of sliced water chestnuts contains 362 trusted sources of potassium (Park, Shahidi, & Jeon, 2004) [31].

Limitations and Future Prospects

Water chestnut crop residues can easily decompose, adding plant nutrients to the soil, including organic matter for a sustainable horticultural production system. Therefore, it is important to take the necessary actions in order to maintain ecosystem vibrancy and maximize the benefits of crop production. Keeping its quality during processing, which is essential for export, which deserves particular attention, is difficult. Water chestnut cultivation is also a form of bio-remediation in nature. It is a profitable crop that requires mass awareness about nutritional qualities and consumption techniques for health-conscious people. If grown successfully, water chestnut can greatly improve the livelihood of rural Indian farmers (Jana B., 2020) [23].

Conclusion

Consuming water chestnuts could help reduce free radicals in the body as well as lower blood pressure, among other benefits. Water chestnuts are an excellent source of nutrients and antioxidants, which makes them a healthy addition to any diet. Phenolic and flavonoid bioactive compounds from Chinese water chestnut are more precisely extracted using ethanol as a solvent. With the help of different types of novel extraction methods, we can extract the phytochemicals, and antioxidants.

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