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Systematic Review of Tannin-Rich Medicinal Plants: Classification, Analysis, Extraction and Chemical Properties of Tannins

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Abstract : *Tannins are natural compounds found in different parts of plants, such as bark, leaves, roots, fruits, and seeds. They are important plant compounds because of their antioxidant, antimicrobial, and anti-inflammatory properties. Tannins are mainly classified into two types: hydrolysable tannins and condensed tannins. They can be identified and measured using different chemical tests and analytical methods. Various extraction methods are used to obtain tannins from medicinal plants. Plants such as Haritaki, Ashoka, Arjuna, Black Catechu, Amla, Tea, Coffee, and Mango are important sources of tannins. These plants have been traditionally used for different medicinal purposes. Tannins are also widely used in the pharmaceutical, food, leather, and cosmetic industries. This review focuses on the classification, chemical properties, extraction methods, analysis, and medicinal applications of tannins. Further research may help improve their extraction and develop useful medicinal and industrial products.*

Keywords: Tannins, Medicinal Plants, Classification of Tannins, Chemical Properties, Tannin Extraction, Phytochemical Analysis, Hydrolysable Tannins, Condensed Tannins, Pharmacological Applications, Herbal Medicine, Pharmaceutical Applications

I. INTRODUCTION

The term “tannin” is derived from an ancient Celtic word associated with oak. In 1796, Seguin introduced the term to describe plant extracts capable of converting animal hides or skins into leather (Hagerman, 2002). Tannins are naturally occurring compounds that are mainly obtained from renewable plant sources.[1]Tannins are among the most abundant secondary metabolites found in plants. In vascular plant tissues, they are considered the fourth most abundant compounds after cellulose, hemicellulose, and lignin. Tannins may account for up to one-fifth of a plant’s dry weight, although their concentration can vary depending on environmental conditions.[2]Plant tannins have been studied for many years by ecologists because of their important role in protecting plants against harmful organisms. Food scientists have also investigated tannins due to their effects on human health and nutrition.[3]Natural polyphenols such as lignin, lignans, and tannins are renewable components found in both terrestrial and aquatic biomass. They play an important structural role by providing strength and support to the tissues of vascular plants.[4]Tannins are naturally occurring compounds found in many different plant species. They are high-molecular-weight phenolic substances that are commonly present in various parts of plants, including the roots, bark, stems, and outer tissues.[5]Plant tannins are an important group of antioxidant polyphenolic compounds commonly found in foods and beverages. In recent years, they have gained significant attention due to their diverse properties and potential health benefits.[6]

Classification of Tannin

Classification of Tannins Tannins are water-soluble phenolic compounds (approx. 500-3000Da) that have typical phenolic chemistry. Tannins are able to cause precipitation of alkaloids, gelatins and proteins. As a group tannins can be classified into two subgroups; condensed tannins and hydrolysable tannins.

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Condensed Tannins

These tannins are of greater importance than hydrolysable tannins. Condensed Tannins do however have an unclear chemical structure. When condensed tannins are heated with acids, tannin reds are produced. Condensed tannins are found in nature in heartwood of quebracho trees, and bark of wattle trees. These tannins have traditionally been used within the leather industry to produce high quality leathers.

Hydrolysable Tannins

Hydrolysable tannins are compounds formed by the esterification of sugars with phenolic acids or their derivatives. The sugar component is commonly glucose, although polysaccharides may also occur in certain types. These tannins can undergo acidic, alkaline, or enzymatic hydrolysis, sometimes occurring naturally during the processes of extraction and purification.[7]

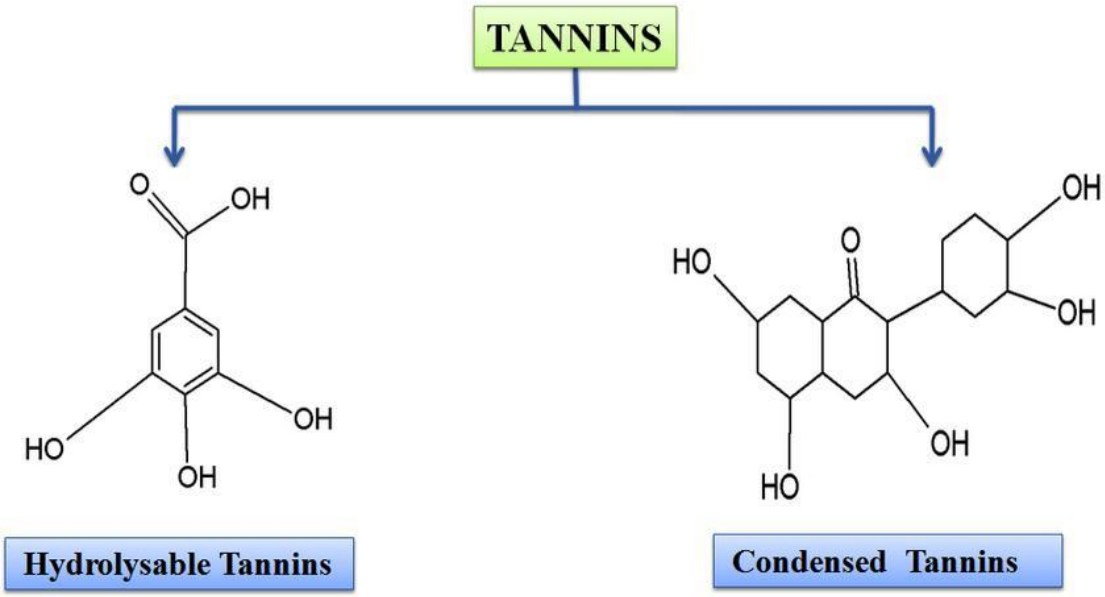


Figure 1: Different types of tannins with their basic chemical structures[8]

Hydrolyzable tannins are polyphenolic compounds composed of a polyol core, commonly glucose, that is linked to phenolic acids such as gallic acid or ellagic acid through ester bonds. They are mainly classified into two groups: gallotannins, including tannic acid, and ellagitannins, which are produced by the oxidative coupling of gallic acid units. These tannins can readily undergo hydrolysis under acidic, alkaline, or enzymatic conditions, resulting in the release of phenolic acids. Their high number of hydroxyl groups contributes to their strong antioxidant properties.Condensed tannins, also known as proanthocyanidins, are polymers composed mainly of flavan-3-ol units such as catechin and epicatechin. These units are connected through stable carbon–carbon bonds, making condensed tannins resistant to hydrolysis. Complex tannins are uncommon compounds that contain characteristics of both hydrolyzable and condensed tannins. In contrast, pseudo-tannins are low-molecular-weight phenolic compounds, such as gallic acid and catechol, which show some tannin-like properties but do not possess a polymeric structure.

Despite their structural differences, tannins generally contain a polyphenolic framework with numerous hydroxyl groups. These functional groups enable tannins to bind with proteins, polysaccharides, and metal ions. Their diverse chemical structures contribute to various nutritional, medicinal, and industrial applications. Tannins are particularly recognized for their antioxidant properties and their ability to influence the absorption, bioavailability, and biological effects of different compounds.[9]

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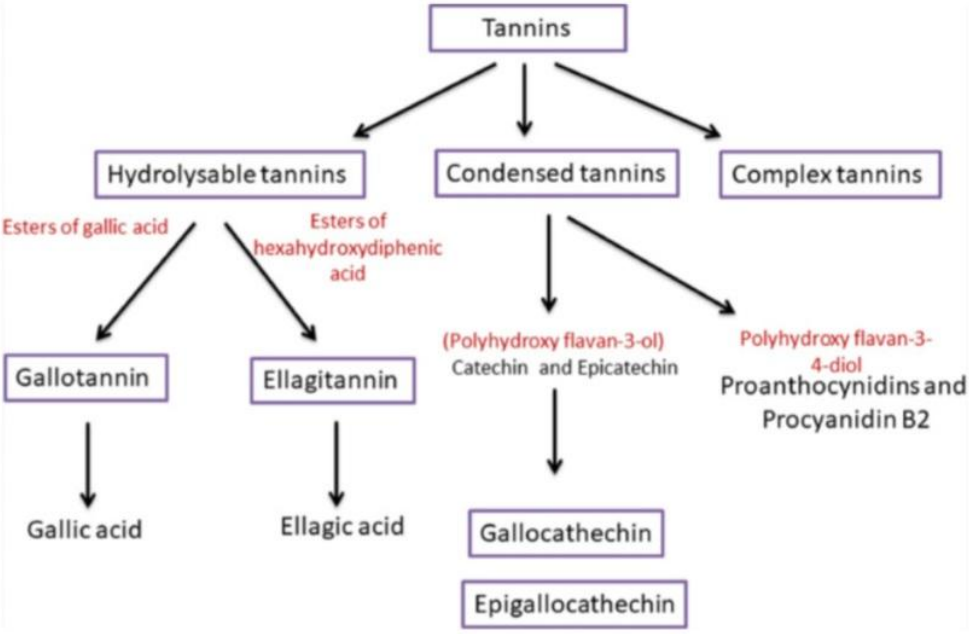


Fig2 classified of Tannins

Chemical Properties of Tannins

- Potassium dichromate test: Tannins form a precipitate when treated with a potassium dichromate solution.
- Chromic acid test: Addition of chromic acid to tannins results in the formation of a precipitate.
- Ferric chloride test: Tannins produce a brownish-green or bluish-black coloration with ferric chloride solution.
- Ammonia and potassium ferricyanide test: Treatment with ammonia followed by potassium ferricyanide produces a deep-red colored precipitate.
- Phenazone test: Tannins react with phenazone and result in the formation of a precipitate.
- Reaction with metal salts: Tannins can form insoluble precipitates with various metallic salts, including those of copper, lead, and tin.
- Intestinal membrane test: Tannins produce a brownish-black coloration when they react with an intestinal membrane.[10]

In 1796, Seguin introduced the term “tannin,” derived from an ancient Celtic word for oak, to describe plant extracts capable of converting animal hides or skin into leather. Tannins (TNs) are naturally occurring secondary phenolic compounds found in plants. They are mainly obtained from plant sources and are considered renewable and sustainable natural resources.[11]These benefits are generally associated with higher levels of phytochemicals, particularly antioxidant and anti-inflammatory polyphenols, along with compounds possessing anticancer properties. Additionally, organically produced foods are typically linked to lower levels of environmental pollutants compared with foods obtained through conventional farming methods.[12]Tannins possess several important biological activities, including antioxidant effects that help protect the body from oxidative stress and may reduce the risk of degenerative diseases.[13]Tannins play an important role in determining the sensory characteristics of foods and beverages, particularly their astringency, bitterness, aroma, and overall mouthfeel. Despite their numerous health-promoting properties, excessive amounts of tannins may increase bitterness and astringency, which can negatively affect the acceptability and consumption of these products[14]These compounds are widely distributed in plant-based foods,

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especially cereals, nuts, chocolate, legumes, fruits, and vegetables. They are also commonly found in beverages such as wine, cider, tea, [15]

Extraction of Tannins

Tannins have gained considerable interest due to their wide range of potential applications and their abundant presence in nature. However, the concentration of tannins in plants varies depending on factors such as geographical location, biological origin, plant species, population, age, and their position within the tree, particularly between the inner and outer wood.[16]Tannins are important plant compounds because they have many useful applications. They are naturally present in many plants. However, the amount of tannins in a plant can vary depending on factors such as geographical location, plant species, biological origin, age of the plant, and the part of the plant. The amount may also differ between the inner and outer parts of the wood.

Because tannins have many potential uses, research on tannin extraction has increased greatly. However, extracting tannins is still challenging because tannins have a complex and varied chemical nature. Therefore, finding a suitable extraction method is important for their effective use.[17]

Methods of Tannin Extraction

Different methods are used to extract tannins from plants. Each method has its own advantages and disadvantages. The choice of method depends on the type of plant material, the purpose of extraction, and the available resources.

Recently, non-thermal extraction methods have become popular because they do not use high heat. These methods help to protect heat-sensitive compounds and can improve the efficiency of tannin extraction.

Some important non-thermal methods include:

UAE (Ultrasound-Assisted Extraction)

SFE (Scientific name: Terminalia arjuna

EAE (Enzyme-Assisted Extraction)

Ionic liquid-based MAE (Microwave-Assisted Extraction)

These methods are considered more efficient, sustainable, and environmentally friendly alternatives to traditional heating methods.

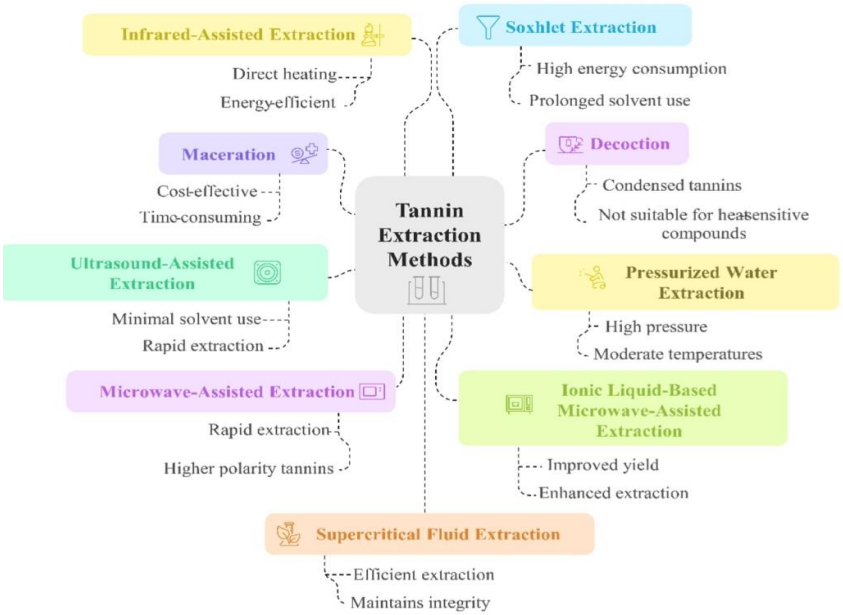


Figure 3 shows the different methods used for the extraction of tannins.[18]

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Analysis

Lead Acetate Method

Tannins are treated with lead acetate.

A precipitate called lead gallo-tannate is formed.

It is then treated with hydrogen sulphide and processed further to estimate the tannin content.

Ferrous Tartrate Method

Tannic acid solution is mixed with ferrous tartrate reagent.

The pH is adjusted to 7.

The tannin concentration is measured using a spectrophotometer at 540 nm.

Bovine Serum Method

Bovine serum (a component of cow's blood) is used to precipitate tannins.

The precipitate is treated with SDS–triethanolamine reagent.

The resulting solution is analysed using a spectrophotometer to estimate the tannin content.[19]

Medicinal Plants Containing Tannins

1.Myrobalan (Haritaki)

Myrobalan is commonly known as Haritaki. It is obtained from the dried and ripe fruits of Terminalia chebula. It belongs to the Combretaceae family.

It is found in West Bengal, Madhya Pradesh, Assam, and Maharashtra in India. It is also found in Southeast Asia.

Characteristics:

The fruits are odourless and have an astringent taste.

They are yellowish-brown in colour.

They are oval-shaped, very hard, and stone-like.

Chemical Constituents: Myrobalan contains hydrolysable tannins such as pyrogallol, chebulic acid, ellagic acid, gallic acid, and chebulinic acid. It also contains glucose and sorbitol.

Uses:

It is used as a laxative to relieve constipation.

It acts as an astringent.

It is used to improve digestion.

It helps in the treatment of intestinal worms.

It is used to control bleeding.

It is used in Ayurvedic formulations.

It is used in the dyeing industry.

It is used in traditional remedies for piles

2. Ashoka

Scientific name: Saraca indica

Family: Leguminosae

Part used: Dried stem bark.

Distribution: It is found in South Asian countries such as India, Sri Lanka, Indonesia, and Malaysia.

Appearance: The bark is dark blackish-brown in colour.

Odour: Odourless.

Taste: Astringent (bitter and dry taste).

Chemical constituents: It contains condensed tannins, leucocyanidin, leucopelargonidin, haematoxylin, saponins, ketosterol, and minerals.

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Uses:
It is used as a sedative.
It acts as a uterine tonic.
It is traditionally used to manage excessive menstrual bleeding (menorrhagia).
It is used traditionally to help control uterine bleeding.

3. Arjuna
Scientific name: Terminalia arjuna
Family: Combretaceae
Part used: Dried bark or stem bark.
Distribution: It is found in South Asian countries, especially India. In India, it grows in places such as Madhya Pradesh and Uttarakhand, including the Dehradun region. It is commonly found in forests.
Appearance: The bark is greyish-brown and flat.
Odour: Odourless.
Taste: Astringent.
Chemical constituents: It contains hydrolysable tannins, ellagic acid, saponins, arjunolic acid, arjunic acid, arjungenin, arjunetine, arjunine, β-sitosterol, and minerals.

Uses:
It is traditionally used to treat dysentery.
It acts as a cardiotonic (a substance that supports heart function).
It is traditionally used as a febrifuge (a substance used to reduce fever).
It may help widen blood vessels (vasodilation).
It may help lower blood pressure.
It has diuretic properties, which help increase urine production.
It may help decrease the heart rate.
Identification test: The bark, especially its ether extract, shows a pink colour under ultraviolet (UV) light.

4. Black Catechu
Black catechu is also known as Kattha or Cutch. It is obtained from the dried aqueous extract of the heartwood of Acacia catechu. The plant belongs to the Leguminosae family.
Characters: Black catechu is brownish-black in colour. It is odourless and has an astringent taste. It is cube-shaped and porous.
Chemical Constituents: It contains acacatechin, catechutannic acid, catechin, catechol, quercetin and quercitrin.
Uses:
It is used to treat diarrhoea and ulcers.
It helps relieve cough.
It has astringent properties.
It is used in the dyeing industry.
It is used to treat skin eruptions

Coffee
Coffee is a very popular beverage in India and other countries. It is obtained from the dried, ripe seeds of Coffea arabica. The plant belongs to the Rubiaceae family.
Source: Coffee is found in India, Brazil, Mexico, Indonesia, Vietnam, Sri Lanka and Ethiopia.
Characters: Coffee seeds are rounded in shape and dark brown in colour.

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Chemical Constituents: It contains tannins such as caffeotannic acid and chlorogenic acid. It also contains caffeine, proteins, sugars and fixed oil.

Uses:

It acts as a diuretic and increases urine production.

It acts as a stimulant and helps increase alertness.

5.Tea

Tea is obtained from the leaf buds and leaves of Thea sinensis. It belongs to the Theaceae family.

Source: Tea is found in India, China, Sri Lanka, Japan and Indonesia.

Types of Tea:

Black tea

Green tea

Characters: Tea is obtained from a small plant. Its leaves are dark green in colour, have a characteristic smell and a bitter taste.

Chemical Constituents: Tea contains tannins such as gallotannic acid. It also contains caffeine, theobromine and theophylline.

Uses:

It acts as a diuretic and increases urine production.

It acts as a CNS stimulant and helps keep the mind alert.

6. Cinchona

Cinchona is also known as Peruvian bark. The dried bark of Cinchona calisaya is used medicinally. It belongs to the Rubiaceae family.

Source: Cinchona is found in India, Sri Lanka, Indonesia, Colombia, Peru, Bolivia, Tanzania and Ecuador. In India, it is cultivated in West Bengal and Tamil Nadu.

Characters: The bark is curved in shape and brownish-grey in colour. It has a characteristic smell and a bitter, astringent taste.

Chemical Constituents: It contains tannins such as cinchotannic acid and phlobatannin. It also contains quinine, quinic acid, cinchonine, quinidine, cinchonidine and other related compounds.

Uses:

It is used to reduce fever.

It acts as a stomachic and helps improve digestion.

Quinine is used in the treatment of malaria.

Certain cinchona alkaloids, such as quinidine, are used to treat heart rhythm disorders.

It has been used in the treatment of conditions such as atrial fibrillation and tachycardia.

7. Amla (Indian Gooseberry)

Amla is also known as Indian Gooseberry. The part used is the fresh or dried fruit. Its scientific name is Emblica officinalis, and it belongs to the Euphorbiaceae family. It is commonly found in India, Myanmar, and Sri Lanka, especially in forests.

The fruits are hard and yellowish-green in colour. They have an astringent taste and are odourless.

Chemical Constituents: Amla contains tannins, fats, minerals, phyllemblin, and vitamin C.

Uses:

It has antioxidant activity.

It acts as a diuretic, laxative, and refrigerant.

It is used to treat diarrhoea and dysentery.

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It helps protect the body against ageing.
It is used in various Ayurvedic formulations.
It is used in the treatment of jaundice and anaemia.
It helps in the treatment of indigestion.
It is used for respiratory problems such as bronchitis and asthma.
It is used in cosmetics such as shampoos and hair oils.

8. Amra (Mango)

Amra is commonly known as Mango or Aam. It is widely found in India. The part used is the dried stem bark. Its scientific name is Mangifera indica, and it belongs to the Anacardiaceae family.

The bark is dark greyish-brown in colour. It has an astringent taste and a pleasant odour. The bark is thick and has a rough surface.

Chemical Constituents: Amra contains tannins such as protocatechuic acid and catechin. It also contains glycine, shikimic acid, alanine, mangiferin, and aminobutyric acid.

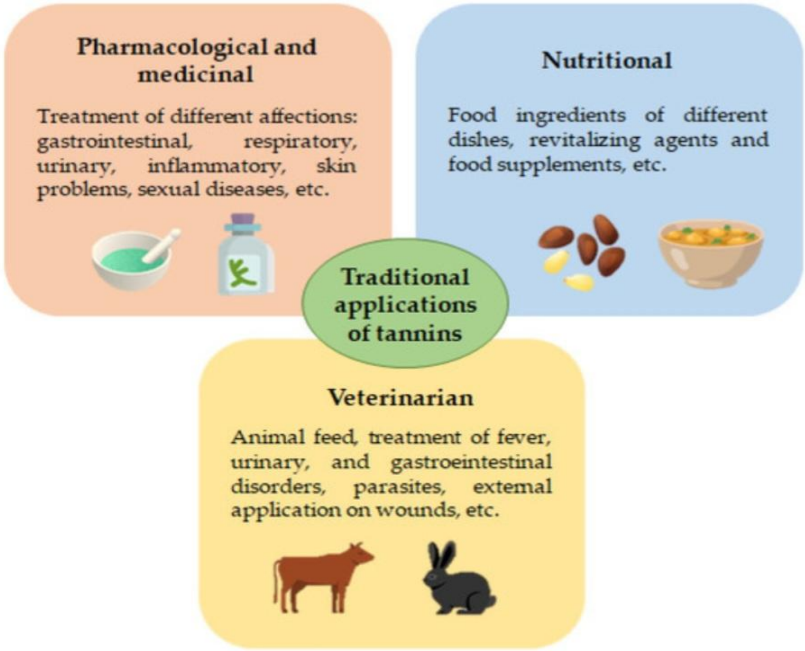
Uses:

It has antioxidant activity.
It shows antimicrobial activity, which helps fight microorganisms.[20]

Application of Tannins

Tannins are natural plant compounds that can be used as raw materials in many traditional and modern industries. They have useful properties such as antimicrobial, antioxidant, pharmaceutical, and Biosecticide activities.

Tannins are used in various industries, including the food, wood, leather, pharmaceutical, and cosmetic industries. They are also useful in the production of natural biomaterials and nutraceutical products.



Thus, tannins are important natural materials that can help reduce the use of petroleum-based products and protect the environment.[21]

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Many Ayurvedic, Siddha, and Unani medicines, such as Churna, Rasa, Bhasma, and Khurs, contain different types of tannins as ingredients. Many tannin-rich plant materials are commonly used to prepare traditional and Indian medicines. These materials are used in folk medicine to help treat various diseases.[22]

II. CONCLUSION

Tannins are natural plant compounds found in different parts of plants, such as bark, leaves, fruits, roots, and seeds. They are important because of their antioxidant, antimicrobial, and anti-inflammatory properties. Tannins are mainly classified into hydrolysable tannins and condensed tannins. Different chemical tests and analytical methods are used to identify and estimate the amount of tannins.

Many medicinal plants, such as Haritaki, Ashoka, Arjuna, Black Catechu, Tea, Coffee, Amla, and Mango, contain tannins and are used in traditional medicine. Tannins are also useful in the food, leather, pharmaceutical, cosmetic, and other industries. Different extraction methods help obtain tannins from plant materials efficiently.

In conclusion, tannins are valuable natural compounds with medicinal and industrial applications. Further research on their extraction, properties, and uses may help develop safer, more effective, and environmentally friendly products.

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