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An updated review on therapeutic and phytochemical profiling of *Acorus calamus* Linn. A natural remedy explored

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Abstract
A phytopharmaceutical preparation, also characterized as a herbal medicine, is a medication made entirel y from a plant or plant parts and synthesized either in a crude form or as a biopharmaceutical formulation that has been purified. *Acorus calamus* Linn is a semi-aquatic herb that grows along marshes, along riverbanks, having long, sword-shaped leaves and creeping rhizomes. *Acorus calamus* L. is tropical evergreen, often referred as, "Sweet Flag", "Indian Vacha" that is indigenous to Europe, Northern Asia Minor, Sri Lanka belonging to family, Acoraceae. Throughout history, multiple civilizations have acknowledged the curative qualities of specific plants and included them into their conventional medical systems. In many traditional medical systems, this tree is recognized for its therapeutic qualities and has a number of traditional uses. This is a description of *Acorus calamus* Linn that include a few of its medicinal benefits like anti-inflammatory, anti-oxidant, anti-convulsant, hypnosis potentiating, anti-microbial activities.
Methodology: A comprehensive literature survey from several recent researches and review articles have been focused to develop mode of safety and efficacy of the phytoconstituents derived from the plant species, as well as studies discussing the therapeutic potential and phytochemical standards.
Discussions: The purpose of this research is conducted to determine the relevant pharmacognostical, physicochemical, and phytochemical standards for *Acorus calamus* Linn in order to accurately identify it for conducting several researches further.

Keywords: Pharmacognostical, physico-chemical, phytochemical, chemical constituents, *Acorus calamus* Linn.

Introduction [1-3]
The power of plants to heal human ailments is one of the gifts Mother Earth has given to humanity and this distinctive trait has been recognized since prehistoric era. According to WHO estimates, conventional medicine alone provides primary healthcare for 80% of the world's population. In addition to having a long number of compounds and a therapeutic nature, medicinal plants are those that include secondary metabolites that may be used to make therapeutic medications. In India, the usage of aromatic and therapeutic herbs dates back as far as human civilization. Over 7500 of the approximately 47,000 plant species found in India, the eighth-largest country in the world, are employed as medicinal herbs. Around the world, plant-based products are the primary source of medication used to treat a variety of human illnesses. Plants have been a significant source of medicinal agents, and traditional herbal medical systems like Ayurveda have led to the resurgence of traditional medical practices since ancient period [1, 2]. Future herbal medications will be made possible by the essential scientific validation of these plant-based medical benefits. Since ancient times, folk medicine has utilized a variety of plants, both whole and in parts, as well as their products, to treat human illnesses. Its possible medical benefits are linked to a number of phytochemical substances that are present in different areas of the tree and have been used for a long time in traditional medicine [3].

Plant Profile [4-7]
The genus Acorus is a member of the family Acoraceae, which is normally composed of about 1800 species and 110 other genera. About 40 distinct species are found in the genus Acorus creatures, such as *A. Calamus* [4]. There are roughly 40 species in the genus Acorus, but only a small number of them-such as *Acorus calamus* Linn. *Acorus christophii*, *Acorus tartarnowii* Schott and *Acorus gramineus* Solandin Ait.-have had their chemical makeup and bioactivities

studied. The rhizome of this plant has been dried and ground has a spicy additive and employing to replace ginger, cinnamon, and jaiphal for its odor. The fragrant rhizomes and leaves have long been utilized as medicine. Owing to the importance in medicine and pharmacology, the plant is the subject of much research [5]. The word 'acorus' comes from Greek. In turn originating from the Greek "COREON", the dioscorids used the word "ACORON". The plant's age has an impact on its surroundings, geographic location that affect the phytochemical composition [6, 7].

Botanical Description [8-13]

Acorus calamus Linn, is a semi-aquatic herb that grows along marshes, along riverbanks, and in lakes. It has long, sword-shaped leaves and creeping rhizomes. At the rhizome forming, that can grow to 2 meters resembling an iris. Below the branched, cylindrical, knobby rhizome, which is as thick as a human finger, are many coarse, fibrous roots [8]. It can reach a height of 6 feet tall, with sword-shaped, fragrant leaves, branched rhizomes, and tiny yellow or green blooms. Acorus, a crucial plant in artificial wetlands, is the main plant chosen for treating water bodies contaminated by heavy metals because it can recover eutrophic water bodies and absorb pollutants like N and P [9]. The leaves are sword-shaped, flat and narrow, tapering into a long, acute point, and have parallel veins. They are erect, yellowish-brown, radical, and have pink sheathing at their bases. The edges of the leaves are smooth and may be crimped or wavy and release fragrance when crushed [10]. The tiny, white or yellow-green flowers of *A.calamus* L. are grouped in an elongated spadix and the flowers are sweetly fragrant. The semi erect spadix of flower-stalk is 5 to 10 cm long, firm, cylindrical, and taper at both ends. Pollens are not powdery, and the wind carries them away as individual grains rather than carrying them very far. The blooming season lasts roughly a month and spans from spring to early summer [11, 12]. Small, berry-like fruits of the herb that differ in ecotypes and have few seeds are produced. Berries often have an angular appearance, are fleshy, and contain one to three seeds. Typically, these seeds have an oblong form [13].

Parts used: Rhizomes, roots, leaves, bark

(A) Natural habitat

(B) Fresh rhizome

(C) Dried rhizome & Root [14, 15]

Fig 1: *Acorus calamus*

Table 1: Taxonomical Classification [16]

Kingdom	Plantae
Subkingdom	*Tracheobionta*
Superdivision	*Spermatophyta*
Division	Magnoliophyta
Class	*Liliopsida*
Subclass	Arecida
Order	Arales
Family	Acoraceae
Genus	*Acorus*
Species	*calamus*

Synonyms [17]

Calamus aromaticus Garsault, opus utique oppr., *Acorus angustifolius* Schott, *Acorus calamus* var. *belangeri* (Schott) Engl.

Vernacular names [18]

Arabic: Vaj, Vash; Assamese: Boch; Bengali: Ghorabach, Sanskrit: Bhadra, Bhutanashini, Hindi: Bach, Safedbach; Kashmir: Vachi, Vaigandar; English: Sweet flag, Calamus, Myrtle grass; Gujarati: Gandhilovaj, Godavaj; Persian: Agar, Agartuki; Kannada: Baje, Vasa; Tamil: Vasambu, Pullai-valathi; Nepali: Bojho

Geographical Distribution [19-21]

The climate, which is crucial in determining plant growth and survival, primarily affects the regional distribution patterns of plant populations. *Acorus calamus* Linn is found all over India and Ceylon, in farmed and wild marshes. *A. calamus* is currently distributed in Europe, Southern Russia, Northern Asia Minor, China, Japan, Burma, Sri Lanka, and the northern United States [19]. It is grown commercially up to 6000 feet in Sikkim, in marshy areas of Kashmir, Sirmoor in Manipur, and in the Naga Hills [20, 21].

Cultivation [22]

Climate & Soil: This medicinal herb is a resilient plant that grows in tropical and subtropical regions. The plant should have access to plenty of sunlight both during growth and after harvest to help dry the rhizomes. The ideal conditions are temperatures between 10 and 38 °C and annual rainfall between 70 and 250 cm. Places without irrigation facilities not to be used for cultivation. This plant thrives in light alluvial soils along riverbanks, clayey loams, and sandy loams [22].

Traditional Uses [23-24]

Since ancient times, the rhizomes and roots have been utilized medicinally, in addition to treating epilepsy, mental illnesses, chronic diarrhea, dysentery, bronchial catarrh, fever, and glandular and abdominal tumors. The amount of essential oil *A.calamus* rhizomes have antispasmodic, carminative, rheumatism, sinusitis, eczema, renal, liver issues, anti-cellular properties and anthelmintic qualities. Roots and rhizomes have recently been established to be antibacterial agents against fish pathogen [23]. On the other hand, when mature green leaves are chopped up and stored with dry goods, they have a number of properties, such as cosmetic industries, insect repellent, antihyperlipidemic, antidiabetic, antipsychotic, and analgesic effects. Calamus relieves headaches brought on by poor digestion as well as enlarged, unpleasant stomachs. In the science of Ayurveda, the Sweet flags work well against a wide range of diseases the ancient manuscripts Charak Samhita and Sushruta Samhita provide ample evidence of the therapeutic usage of *A. calamus*. Calamus, a significant herb, is used as a "rejuvenator" for the nerve system and brain in ayurvedic medicine [24].

Pharmacognostical Study: Pharmacognostical assessment of *Acorus calamus* (Linn) ensures authentication of plant material and has provided further details about physical, chemical and biological characteristics to establish their quality and purity for medicinal use. Processing with hot extraction (by using soxhlet apparatus) and cold extraction with the solvents are ethyl acetate, chloroform, methanol, water and n-hexane, ethyl-acetate, chloroform, methanol and water respectively. Each extract made from utilizing the extractions was mixed with a semisolid material [25].

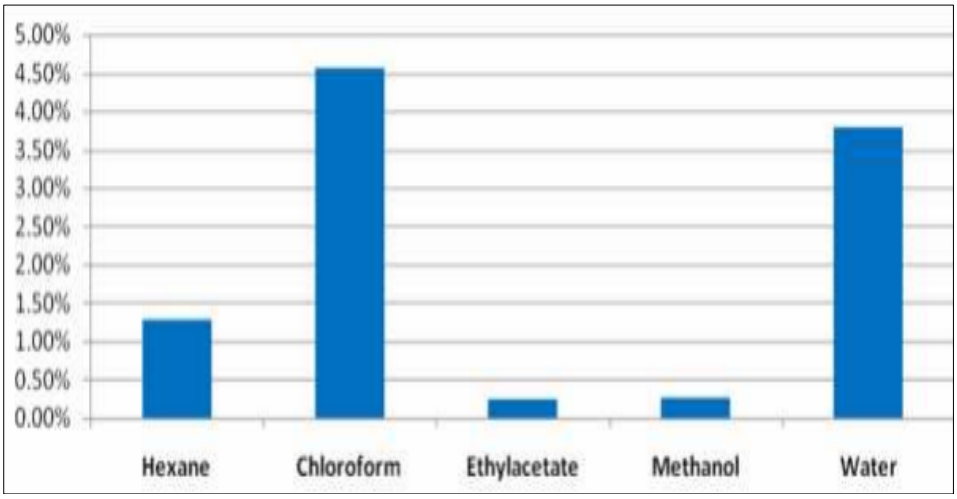


Fig 2: Graphical presentation of extract preparation through hot extraction method (Soxhlet apparatus) in *Acorus calamus* Linn leaf [26].

Physicochemical Study: Physicochemical characteristics and early phytoconstituent screening are crucial details that could prove beneficial in confirming and contaminating this medicinal plant for quality control.

Table 2: Different physicochemical parameters of leaves of *Acorus calamus* Linn [27].

Sl. No.	Parameters		Values (%w/w) Mean ± SEM
1	Ash values	**Total ash**	0.233±0.092
		Acid insoluble ash	0.066±0.456
		Water soluble ash	0.2±0
2	Extractive values (hot)	n-hexane	10.76
		Ethyl acetate	8.88
		Chloroform	5.88
		Ethanol	8.64
		Water	16.96
3	Extractive values (cold)	n-hexane	2.8%
		Ethyl acetate	2%
		Chloroform	0.72%
		Ethanol	3.72%
		Water	3.92%
4	Moisture content		0.933±0.681
5	Foaming index		3.63±0.378
6	Swelling index		1.23±1.6
7	Foreign matter	Adulterants was absent	

TLC Analysis [27]

The leaf oil exhibited spots with Rf values of 0.71 exhibiting distinctive blue fluorescence when exposed to UV 365nm.

Fig 3: TLC of *Acorus calamus* essential oil with standard

Physicochemical Parameters

Table 3: (Ash value) of rhizomes of *Acorus calamus* Linn with the elemental analysis of ash [28].

Sl. No.		Weight (%)
ASH Analysis		
1	Total ash value	6.12
2	Water soluble ash	66%
3	Acid insoluble ash	0.01%
4	Acid soluble ash	99.09%

Elemental Analysis	
Carbon	15.07
Oxygen	26.88
Sodium	3.36
Magnesium	1
Silicon	0.27
Phosphorous	5.59
Sulphur	4.45
Chlorine	8
Potassium	29.01
Calcium	6.25

Phytochemical Assessment

The primary goal of phytochemical screening is to determine which secondary metabolites are contained in the plant material. The secondary chemicals' presence facilitates more pharmacological research on the plant. The below table indicated which secondary metabolites the plant contains.

Table 4: Phytochemicals present in methanolic rhizome extract of *A. calamus* Linn [29]

SL. No	Phytochemicals	HX	CH	EA	ME	AQ
1	Phytosterols & Triterpenoids	-	-	+	+	+
2	Proteins & Amino acids	-	-	-	+	+
3	Saponins	-	-	+	+	+
4	Alkaloids	-	-	-	-	-
5	Glycosides	+	+	+	+	+
6	Tannins	-	-	-	+	+
7	Phenols	+	+	+	+	+
8	Flavonoids	-	+	+	+	+

* (+) present, (-) absent. [HX-Hexane; CH-Chloroform, EA-Ethyl acetate, ME-Methanol, AQ-water]

Fluorescence Analysis

The qualitative analysis of phytochemicals offered valuable insights into the different phytoconstituents exist in the various extracts of the same plant material, which may aid in selecting a particular extract for further investigations aimed at isolating the active compound. The examination of fluorescence in powdered crude drug revealed different colors based on the chemical treatments applied to the powder under both visible and ultraviolet light. Fluorescence analysis is a crucial method for screening materials that might exhibit a range of colors when exposed to UV light [30].

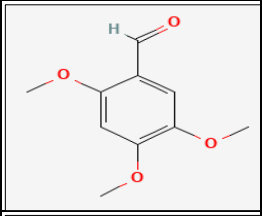
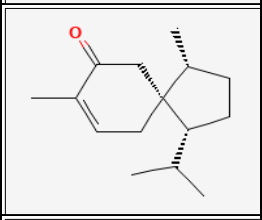
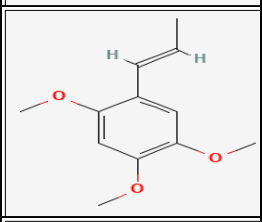
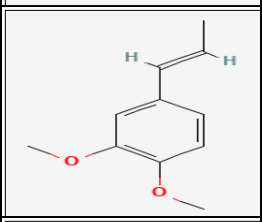
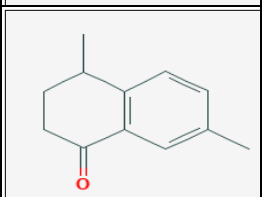
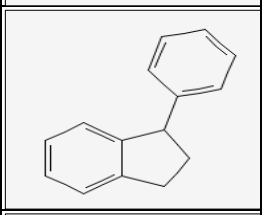
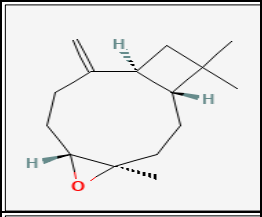
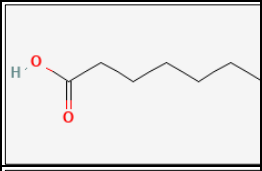
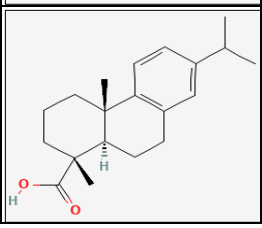
Table 5: Fluorescence analysis of *Acorus calamus* Linn leaf powder [27]

Sl. No.	Drug powder with testing reagent	Vis radiation	U. V. Radiation at 254nm	U.V. Radiation at 365nm
1	Drug powder tested with sodium hydroxide	Brown	Green	White
2	Drug powder with Picric acid	Yellowish	Dark green	Light green
3	Drug powder with conc. HCl	Slightly brownish	Green	Intense brown
4	Powder drug with sulphuric acid	Light brownish black	Light green	Black
5	Powder drug with water	Brown	Light green	Brown
6	Powder drug with methanol	Brown	Light green	Light brown
7	Powder drug with nitric acid	Dark orange	Dark green	White
8	Powder drug with chloroform	Brown	Dark green	Brown

Chemical Profile of *Acorus calamus* Linn.

The rhizomes, leaves, and essential oil of *Acorus calamus* Linn have been proven to have a wide range of chemical components. Geographical location, plant age, climate, and plant ploidy all affect the amount and makeup of chemical components in plant sections [31]. *Acorus calamus* Linn is a source of essential oil that was first isolated practically in Frankfurt in 1592 and in the dispensatorium Noricum in 1589. But in recent period, the isolation of various components from the oil has been hugely elongated by forming of the techniques of gas-chromatography [32]. The plant contains glucoside, alkaloids, and essential oils that contain sesquiterpenes, calamen, asarone, acorine, eugenol, pinene, and camphene are also present. 53 organic volatile chemicals were extracted and identified from *Acorus calamus* Linn rhizome including alcohol (11), aldehyde (14), ester (3), furan (1), hydrocarbon (19), ketone (4), and N-containing miscellaneous (1). Asarone was identified as a significant bioactive component (46.78%) [33].

Table 6: The chemical conformations of "calamus oil", that are extracted from various plant sections

Sl. No.	Constituents	Rhizome	Leaf	Structure [34]	Reference
1	Asaronaldehyde	+	-		[35]
2	Acorenone (1S,4S,5S)-1,8-dimethyl-4-propan-2-ylspiro[4.5]dec-7-en-9-one	+	-		[36]
3	β-Asarone 1,2,4-trimethoxy-5-[(*E*)-prop-1-enyl]benzene	+	+		[37]
4	β-methyl isoeugenol 1,2-dimethoxy-4-[(*E*)-prop-1-enyl]benzene	+	+		[38]
5	Calamenone 4,7-dimethyl-3,4-dihydro-2H-naphthalen-1-one	+	-		[39]
6	Phenyl indane 1-phenyl-2,3-dihydro-1*H*-indene	+	-		[40]
7	Caryophyllene oxide (1R,4R,6R,10S)-4,12,12-trimethyl-9-methylidene-5-oxatricyclo[8.2.0.04,6]dodecane	+	-		[41]
8	Heptylic acid (heptanoic acid)	+	-		[42]
9	Dehydroabietic acid (1*R*,4*aS*,10*aR*)-1,4*a*-dimethyl-7-propan-2-yl-2,3,4,9,10,10*a*-hexahydrophenanthrene-1-carboxylic acid	+	+		[37]

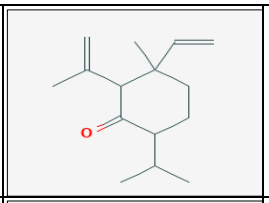
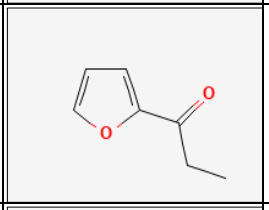
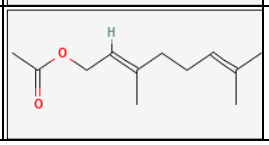
10	Epishyobunone (3-ethenyl-3-methyl-6-propan-2-yl-2-prop-1-en-2-ylcyclohexan-1-one)	-	+		[36]
11	Furyl ethyl ketone 1-(furan-2-yl)propan-1-one	+	+		[35]
12	Geranyl acetate [(2E)-3,7-dimethylocta-2,6-dienyl	+	-		[43]

Table 7: Pharmacological Activity [44-55]

Plant part	Pharmacological Activity	Extract	References
Leaves	Antioxidant activity, anti-inflammatory activity and antimicrobial activity	DMSO extract	[44]
Rhizomes	Broad-spectrum antibacterial activity and synergistic interactions with ampicillin	Hexane	[45]
Whole plant	Antioxidant,antimicrobial, polymerase inhibition and anticancer	Methanol, ethanol, propanol, ethyl acetate, acetone, acetonitrile and water	[46]
Rhizomes	Antioxidant potential, Anti-nociceptive effects, Hypothermic activity, dose-dependent anti-inflammatory activity, anti-nociceptive activity	Methanol, n-hexane, ethyl-acetate, n-butanol and water	[47]
Leaves	Apoptosis induction	Hydro-methanol	[48]
Leaves	Photocatalytic and *in vitro* antimicrobial activity	Water	[49]
Rhizomes	Repellant and insecticidal	Water (Essential oil)	[50]
Rhizomes	Neuro-development disorder[Autism spectrum disorder (ASD)],Decreased cholesterol and triglyceride levels	Methanol	[51]
Leaves	Anti-convulsant activity	Methanol	[52, 53]
Rhizomes	Acrylamide induced neurotoxicity	Hydro-ethanol	[54, 55]

Table 8: Materials and reagents for chemical analysis [56-59]

Chemical analysis	Chemical name	Purity	Grade
Quantitative of alpha-asarone by HPLC	Methanol	99.8%	LC
	Distilled water		
	Filter paper		
	C-18		
Total phenolic content (TPC)	Gallic acid	97.5-102.5	Analytical
	Anhydrous sodium carbonate	99.9	
	Methanol	≥96%	
	Folin-Ciocalteu's reagent		
	Distilled water		
Total flavonoid content (TFC)	Catechin	≥98%	HPLC
	Aluminium chloride-6-hydrate	97.0%	
	Sodium nitrite		
	1M sodium hydroxide		
	Distilled water		
2,2-diphenyl-1-picrylhydrazyl (DPPH) scavenging activity	Trolox	98.1%	HPLC Analytical
	Methanol	≥96%	
	2,2-diphenyl-1-picrylhydrazyl		
Ferric reducing antioxidant Power (FRAP)	Gallic acid	97.5-102.5%	
	Methanol	≥96%	
	Potassium hexacyanoferrate	99.0%	Analytical
	Disodium-hydrogen phosphate monohydrate	99.0%	Analytical
	Sodium-dihydrogen phospahate	99.0-102%	Analytical
	Trichloroacetic acid	99.0%	Analytical
	Ferric chloride	99.0%	
Haemolytic Activity	Methanol	≥96%	Spectrophotometer
	Distilled water		
	Human erythrocytes		
	NaCl as assay buffer (0.9%)	≥95%	
	Triton X-100 (0.625%)	98.0%	
Total Saponin Content (TSC)	Ethanol		HPLC_DAD chromatogram
	Distilled water		
	Diosgenin	96.6%	
	Ursolic acid(0.69±0.083)mg		

Table 9: The values of alpha-asarone in various solvent-based crude extracts of A. calamus.Linn [56], Mean ±SD, Alpha-asarone content%

	Leaf	Rhizome
Methanol	0.27±0.04^{a1}	0.46±0.04^{b1}
Hexane	0.762±0.126^{a2}	2.98±0.11^{b2}
Water	0.01±0.00^{a3}	0.01±0.00^{a3}

Total phenol content (TPC) [56]

The methanol leaf extract exhibited the highest total phenolic content (TPC) among the samples analyzed; however, no significant difference (p>0.05) was observed in TPC between the methanol leaf extract and extract of rhizome.

Total flavonoid content (TFC) [56]

The total flavonoid content in *A. calamus* extracts was influenced by the choice of solvents and the specific plant parts utilized for extraction. The methanol solvent emerged as the most significant and effective medium (p<0.05) for extracting flavonoids from both leaf and rhizome samples, with water and hexane following in effectiveness. It was noted that the influence of solvents on total flavonoid content (TFC) mirrored that on total phenolic content (TPC) in the leaf extracts.

DPPH-Free radical scavenging activity [56, 57]

All the extracts demonstrated varying degrees of DPPH radical-scavenging activity. The methanol extracts from both the rhizomes and leaves exhibited the most significant levels of DPPH scavenging activity. Furthermore, no significant difference (p>0.05) was identified as the DPPH scavenging ability between the leaf and rhizome extracts derived from both methanol and hexane.

Ferric reducing antioxidant power (FRAP) [58]

The reducing power exhibited variability across different solvent systems. When compared to the leaf extracts, the rhizome extracts demonstrated a significantly greater reducing power (p<0.05), in the hexane solvent system; however this trend was reversed in the water system. Methanol extracts from both leaves and rhizomes demonstrated the highest reducing power, followed by extracts obtained from hexane and water. The Ferric Reducing Antioxidant Power (FRAP) assay revealed a correlation with both Total Phenolic Content (TPC) and Total Flavonoid Content (TFC). Notably, TFC exhibited a stronger correlation (r=0.855) compared to TPC (r=0.555), indicating a greater correlation coefficient.

However, Total Antioxidant Capacity (TAC) was not showing any correlation with the reducing power.

Total saponin content (TSC) [59]

Acorus calamus L., total saponin content was evaluated using the vanillin-sulfuric acid technique. This extract was combined with vanillin (8 w/v%) and sulfuric acid (72 w/v%). The mixture was incubated at 60 1C for 10 min, cooled in an ice water bath for further 15 min followed by the absor bance measurement at 538nm. Ursolic acid was employed as a reference standard and the amount of total saponins was reported as ursolic acid equivalents (UA mg/mg extract).

Discussions

Acorus calamus Linn, commonly known as “Sweet Flag”, belonging to the family Acoraceae, native to central Asia, India, and the Himalayas, found in damp marshy areas. The main purpose of this review is to compile data regarding the plant's pharmacognostical, phytochemical and pharmacological and analytical characteristics. Several number of secondary metabolites, including alkaloids, amino acids, phenol, terpenoid, cardiac glycoside, saponins and flavonoids, were discovered to be present in this plant after various research. The multipurpose medicinal plant *Acorus calamus* Linn is a unique source of different kinds of compounds with a range of biological activities since the vedic and ancient eras. Numerous biological activities were demonstrated by its phytochemical constituents, including acorenone, sesquiterpenes, and α-, β-asarone. High levels of antimicrobial, anti-inflammatory, antioxidant, antiulcer, antispasmodic, immunosuppressive, and mitogen inhibitory activity were observed in the compounds. It is generally believed that substantial evidence supporting the use of the botanical sources in varieties, provided by detailed information in analysis of phytochemical, biological and chemical effects of Indian Vacha. For effectively utilizing this botanical treasure’s of *Acorus calamus* Linn therapeutic potential,future research is essential.

Author Contribution

- Amrita Ghosh, conceptualized the study, literature search, designed the framework and plays the centre part of total formatting of the paper.
- Rajat Das and Jyochhana Priya Mohanty, responsible for providing instructions for the review article on how to draft, design and reference the manuscript.
- Shreetama Roy, contributed to data collection and referencing.

Conflict of Interest

The author declares that there is no conflicts of interest regarding the publication of this paper.

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