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RESEARCH ARTICLE

PHYTOCHEMICAL ANALYSIS OF AQUEOUS SEED EXTRACT OF *SESBANIA SESBAN* (L) MERR.

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ABSTRACT

The study was designed to explore the phytochemicals present in the aqueous seed extract of *Sesbania sesban* (L) Merr. *Sesbania sesban* is a traditional and native plant of India. The aqueous extract of the plant seed was subjected to qualitative and quantitative phytochemical analysis. The qualitative analysis revealed the presence of many phytochemicals. Phenols, flavonoids, flavonols, tannins and condensed tannins were estimated quantitatively and their values were found to be 28.10 ± 0.18mg /g (Gallic Acid Equivalent) & 33.69 ± 0.06mg/g (Catechin Equivalent), 17.57 ± 0.10mg /g (Quercitin Equivalent) & 20.68 ± 0.09mg /g (Rutin Equivalent), 6.08 ± 0.21mg/g (Caffeic Acid Equivalent), 12.34 ± 0.07 mg/g (Caffeic Acid Equivalent) and 3.84 ± 0.11mg/g (Caffeic Acid Equivalent) respectively. The primary metabolites such as total carbohydrates, total proteins and starch were also estimated and recorded as 166.0 ± 10.07 mg/g, 25.6 ± 1.50 mg/g, and 147.6 ± 6.73 mg/g respectively. The aqueous extract was analysed with FTIR, which revealed the presence of potential functional groups. The GCMS analysis revealed the presence of valuable phyto compounds with significant role in disease prevention.

Keywords: *Sesbania sesban,* aqueous extract, phytochemical, antioxidant, FTIR.

Introduction

Medicinal plants have been used by humans for several decades to treat diseases in both humans and animals through traditional medicinal and healing practices [1]. Plants contain enormous antioxidants which help to provide protection against free radicals associated diseases. The antioxidant compounds are mostly produced in plants in the form of secondary metabolites which counteract the free radicals. Phytochemicals classified as primary constituents includes the common sugars, amino acids, chlorophyll's, purines and pyrimidines of nucleic acids and proteins etc. Others classified as the secondary constituents are the chemicals consisting of alkaloids, flavonoids, terpenes, phenolics, lignans, plant steroids, curcumines, saponins, glucosides. They are the non-nutritive phyto components that possess numerous health benefits and disease prevention properties [2].

As per WHO, there are 21,000 potential medicinal plants and a substantial majority of people worldwide (80 %), rely on herbal remedies to fulfill their principal healthcare requirements. Over three- quarters of individuals globally depend predominantly on medicinal plants or plants compounds to alleviate their illnesses and ailments. A huge percentage of all plant species, were utilized for medicinal purposes at some point in history. As per WHO estimations, phytomedicines make up 25 % of all treatment in wealthy nations like the USA, while they make up 80 % of all medications in under- developed nations like India. The biggest advantage of plant derived drugs is their synchronization with nature and also can be used across all age groups. For these reasons, herbal treatment is gaining popularity all over the world [3].

Sesbania sesban (L.) Merr., a fast-growing leguminous plant widely distributed in tropical and subtropical regions, has attracted considerable research interest due to its diverse medicinal properties. Traditionally, different parts of *S. sesban* have been used for treating inflammatory conditions, infections, liver disorders, and oxidative stress-related ailments [4,5]. Although several studies have reported the phytochemical and pharmacological potential of its leaves, bark, and flowers, the seeds of *S. sesban* remain relatively underexplored despite their potential nutritional and medicinal value.

Currently, there is an emerging significance on the use of aqueous extracts in plant compounds screening as water is the most commonly used solvent in traditional medicine and it is considered as safe and acceptable in all aspects. Aqueous

extracts are particularly relevant as water-soluble phyto compounds such as phenolics, flavonoids, glycosides, carbohydrates and proteins can be obtained in it. Preliminary phytochemical screening of aqueous extracts serves as a vital step in identifying the phytocomponents which will guide through bioactivity based investigations [6].

From a future perspective, comprehensive phytochemical profiling of *Sesbania sesban* seeds can open new avenues for the development of plant-based therapeutics, functional foods, and natural antioxidants. Integrating traditional knowledge with modern phytochemical research supports sustainable utilization of medicinal plants and contributes to biodiversity conservation. Therefore, the present study aims to investigate the phytochemical constituents of the aqueous seed extract of *Sesbania sesban* (L.) Merr., providing scientific insight into its chemical composition and establishing a foundation for future pharmacological and nutraceutical research.

2. Materials and Methods

2.1. Plant material and Preparation of the extract:

The seeds of *Sesbania sesban* were purchased from the local market, Coimbatore. The seeds were shade dried and healthy seeds were selected and grinded well to a coarse powder. 10g of the powdered sample was extracted in 300 ml of water by heating at 80°C. The extract that was obtained was condensed in an oven and was preserved in an air tight container and stored at 4^0C for further use.

2.2 Qualitative Phytochemical analysis

The extract was analysed for phytochemicals qualitatively according to the published standard methods [7].

2.3 Quantitative phytochemical analysis

2.3.1 Determination of total phenolic content [8]

The amount of phenol in the extract was determined spectrophotometrically using the modified method of Zovko with the Folin-Ciocalteu reagent. An aliquot of the extract (1 mg/ml) was mixed with 5 ml Folin-Ciocalteu reagent (previously diluted with water 1:10 *v*/*v*) and 4 ml (75 g/l) of sodium carbonate. The tubes were vortexed for 15 s and allowed to stand for 30 min at 40 °C for color development. Absorbance was then measured at 765 nm using the AJI-C03 UV-VIS spectrophotometer. Results were expressed as mg/g of gallic acid equivalents.

2.3.2 Estimation of flavonoids [9]

The total flavonoids were determined using the method of Ordonez *et al*. A volume of 0.5 ml of 2% AlCl3 ethanol solution was added to 0.5 ml of extract solution. The mixture was incubated for 1 h at room temperature for yellow color appearance; the absorbance was measured at 420 nm. Plant extracts were evaluated at a final concentration of 0.1 mg/ml. Total flavonoids content was calculated as quercetin equivalent (mg/g) using the equation obtained from the curve: Y = 0.255x, R2 = 0.9812, where x is the absorbance and Y is the quercetin equivalent.

2.3.3 Determination of Flavanols [10]

One volume of the sample diluted in methanol was mixed with 2.5 volumes of vanillin and 2.5 volumes of HCl. The mixture was incubated for 20 min at 35 ^{0}C. For each sample, a blank was used in which each vanillin solution was replaced with methanol alone. A standard curve was constructed with catechin. The flavonols was expressed as catechin equivalents mg/g sample.

2.3.4 Determination of Tannins [11]

Pippeted 1ml of the extract and added 5ml of vanillin hydrochloride solution. Read in a spectrophotometer at 500nm after 20 minutes. Prepared a blank with reagent alone. Tannins in the sample were expressed as catechin equivalents mg/g sample.

2.3.5 Determination of Condensed Tannins [12]

A volume of 0.5ml of 0.1mg/ml extract solution was mixed with 3ml of 4% vanillin- methanol solution and 1.5 ml hydrochloric acid. The mixture was allowed to stand for 15min while the absorbance was measured at 500nm. Total condensed tannin content was expressed as catechin equivalents(mg/g).

2.3.6 Estimation of total carbohydrate by anthrone method [13]

0.5 and 1.0 ml aliquots was taken for analysis. Standards were prepared by taking 0, 0.2, 0.4, 0.6, 0.8 and 1.0 ml of the working standard. '0' served as blank. Made up the volume in all the tubes to 1ml including the sample tubes by adding the distilled water. 4ml of anthrone reagent was added to all the tubes and heated in a boiling water bath for eight minutes. They were cooled rapidly, read at 630 nm and a standard graph was drawn. From the graph the amount of carbohydrate present in the sample was calculated.

2.3.7 Estimation of starch by anthrone method [13]

0.1 and 0.2 ml of the processed sample was pipette out and made up the volume to 1ml with water. Standards were prepared by taking 0.2, 0.4, 0.6, 0.8 and 1.0 ml of the working standard and made up the volume to 1ml in each tube with water. 4ml of anthrone reagent was added to all the tubes and heated for eight minutes in a boiling water bath. The tubes were cooled rapidly and read at 630nm. The amount of starch present in the sample was found by multiplying the glucose content by a factor 0.9.

2.3.8 Estimation of protein [14]

Pipetted out 0.2 to 1.0 ml working standard solution. 0.1 ml of the processed sample was taken. The volumes in all the tubes were made up to 1.0 ml with distilled water. Added 5.0 ml of alkaline copper reagent to each tube. Mixed well and allowed to stand for 10 min. Added 0.5 ml of Folin-Ciocalteau reagent. Mixed well and incubated at room temperature for 30 minutes. A reagent blank was also prepared. After 30 minutes, the blue colour developed were read at 660 nm.

2.4 **FTIR spectral analysis**

The analysis was made using Shimadzu FT-IR spectrophotometer at South India Textile Research Association (SITRA), Coimbatore.

2.5 GCMS analysis

The analysis was done at South India Textile Research Association (SITRA), Coimbatore with the following specifications. Equipment: Thermo GC – trace Ultra Ver 5.0, Thermo MS DSQ II, Column:DB5 - MS capillary standard non-polar column, Dimension: 30 Mts, ID: 0.25 mm, Film: 0.25 µm, Carrier gas: He, Flow: 1.0 ml/min, Temp prog: oven temp 40° C raised to 250° C at 5°C /min, Injection Volume: 1microliter, Low Mass(m/z): 50, High Mass(m/z): 650, Instrument Name : DSQ, Run Time(min): 43.17.

3. Results and Discussion

3.1Qualitative phytochemical analysis of aqueous seed extract of *Sesbania sesban (L) Merr.*

Qualitative analysis was carried out to screen the phytochemicals present in the aqueous extract of *Sesbania sesban*. The results of the phytochemical analysis are presented in table 1. Dragendroff test and Meyer's test for alkaloids showed negative and Wagner's test for alkaloids showed positive. Flavonoids were found to be present in the extract and saponins showed no presence. Benedicts test and Fehling's test gave presence for the carbohydrates in the extract. Molisch's reaction also confirmed the presence of carbohydrate in the extract. Millon's reaction was positive with the extract and biuret test also showed positive reaction for the presence of protein. Ferric chloride test and libermann reaction were negative while lead acetate test showed presence of phenols. Salkowski reaction gave a positive result indicating the presence of steroids in the aqueous extract while Libermann-Burchards test showed negative reaction for steroids. Glycosides and resins were found to be absent in the aqueous extract. Thiols were also not detected in the extract. Ferric chloride and lead acetate tests showed presence in extract for the presence of tannins.

The presence of various bioactive compounds that defend the traditional medicinal properties of the plant was recorded. Overall, the qualitative phytochemical analysis confirmed the presence of phenolics, flavonoids, tannins, steroids, carbohydrates and proteins. Flavonoids and phenolics are commonly recognized for their antioxidant and anti-inflammatory properties reported in earlier studies on this plant and other leguminous plants [15,16]. The presence of tannins in the extract may play a role as antimicrobials and astringents [17].

Table 1: Qualitative phytochemical analysis of aqueous seed extract of *Sesbania sesban (L) Merr.*

Phytochemical		Aqueous extract
Alkaloids	Dragendroff test	-
	Wagner's test	+
	Meyer's test	-
Flavonoids		+
Saponins		-
Carbohydrates	Fehling's reaction	+
	Benedicts test	+
	Molisch's reaction	+
Protein	Millon's reaction	+
	Biuret test	+

Phenols	**Ferric chloride test**	**-**
	Lead acetate test	**+**
	Libermann reaction	**-**
Steroids	**Libermann-Burchards**	**-**
	Salkowski reaction	**+**
Glycosides		**-**
Resins		**-**
Tannins	**Ferric chloride**	**+**
	Lead acetate	**+**
Thiols		**-**

3.2 Quantitative phytochemical analysis in aqueous seed extract of *Sesbania sesban* (L) Merr.

The aqueous extracts of seeds of *Sesbania sesban* were analysed for the secondary metabolites such as total phenols, flavonoids, flavonols, tannins & condensed tannins and primary metabolites carbohydrate, protein & starch content. The results of the phytochemical analysis are presented in table 2 & 3.

Table 2 Quantitative secondary metabolites in aqueous seed extract of *Sesbania sesban* (L) Merr.

Total phenols		Flavanoids		Flavonols	Tannins	Condensed Tannins
mg /g (GAE)	mg/g (CE)	mg /g (QE)	mg /g (RE)	mg/g (CAE)	mg/g (CAE)	mg/g (CAE)
28.10 ± 0.18	33.69 ± 0.06	17.57 ± 0.10	20.68 ± 0.09	6.08 ± 0.21	12.34 ± 0.07	3.84 ± 0.11

Values are expressed as mean ± SD (n=3)

Table 3. Quantitative primary metabolites in aqueous seed extract of *Sesbania sesban* (L) Merr.

Carbohydrate	166.0 ± 10.07 mg/g
Protein	25.6 ± 1.50 mg/g
Starch	147.6 ± 6.73 mg/g

Values are expressed as mean ± SD (n=3)

Quantitative analysis demonstrated appreciable levels of total phenols, flavonoids, flavonols, and tannins. High phenolic and flavonoid contents are strongly correlated with free radical scavenging and antioxidant capacity, which play a crucial role in preventing oxidative stress–related disorders [18]. Flavonoids play important roles in preventing diseases associated with oxidative stress. It has the capacity to transport electrons to free radicals, inhibit oxidases, reduce radicals of alpha tocopherol, activate antioxidant enzymes and chelate metals [19]. The presence of condensed tannins enhances the antimicrobial and anti-inflammatory properties of the extract. Additionally, the significant carbohydrate and starch content observed in the primary metabolite analysis highlights the nutritional value of *S. sesban* seeds, while the detectable protein content supports their use as a

supplementary protein source [20]. Overall, the findings validate the medicinal and nutraceutical importance of *Sesbania sesban*.

3.4 FTIR spectral analysis of aqueous seed extract of *Sesbania sesban* (L) Merr.

Fourier Transform Infrared (FTIR) spectroscopy was employed to identify the major functional groups present in the aqueous seed extract of *Sesbania sesban*. The spectrum exhibited a broad absorption band around 3330–3270 cm^{-1}, corresponding to O–H stretching vibrations, indicating the presence of hydroxyl groups associated with carbohydrates, phenolic compounds, and polysaccharides. The peaks observed in the region of 2920–2850 cm^{-1} were attributed to C–H stretching vibrations of aliphatic chains, suggesting the presence of lipids and alkanes. A prominent absorption band at 1632 cm^{-1} corresponds to C=O stretching and N–H bending vibrations, characteristic of amide groups, confirming the presence of proteins. The bands near 1515–1450 cm^{-1} represent aromatic C=C stretching and C–H bending vibrations, indicating phenolic constituents. Strong peaks around 1220 and 1033 cm^{-1} are associated with C–O and C–O–C stretching vibrations, characteristic of carbohydrates and starch. Overall, the FTIR spectrum confirms the presence of primary metabolites such as carbohydrates, proteins, and starch in the aqueous seed extract.

Figure.1 FTIR spectral analysis of aqueous seed extract of *Sesbania sesban* (L) Merr.

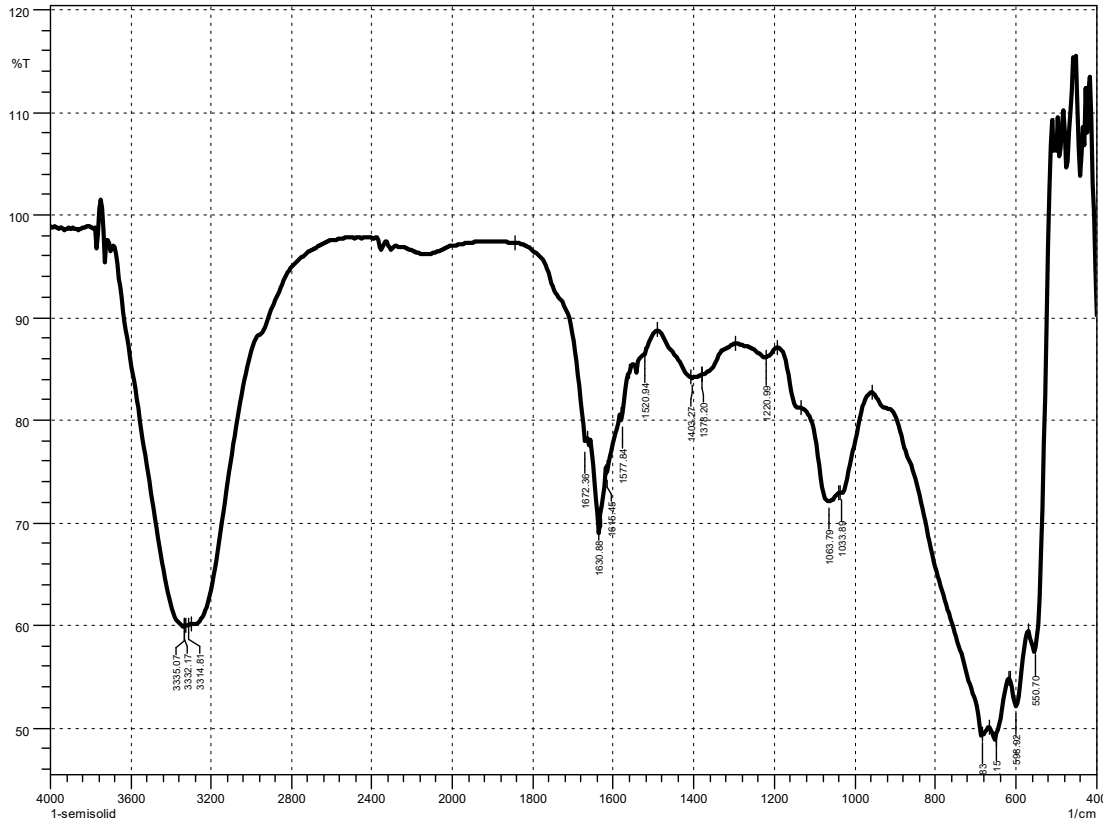

Table 4. FTIR spectral analysis of aqueous seed extract of *Sesbania sesban* (L) Merr.

Peak Value (cm^{-1})	Type of Bond / Functional Group	Type of Compound
3330–3270	O–H stretching	Alcohols, phenols, carbohydrates
2920–2850	C–H stretching	Alkanes, lipids
1632	C=O stretching / N–H bending	Amides, proteins
1580	N–H bending	Proteins, amines
1515	Aromatic C=C stretching	Phenolic compounds
1450	C–H bending	Alkanes, lipids
1382	C–H bending	Carboxylic acids, alkanes
1220	C–O stretching	Polysaccharides, phenols

1033	C–O–C stretching	Carbohydrates, starch
890	β-glycosidic linkage	Polysaccharides
670	C–H out-of-plane bending	Aromatic compounds
600	C–X stretching	Halogenated compounds / fingerprint region

3.5. **GCMS analysis of aqueous seed extract of *Sesbania sesban* (L) Merr.**

GC–MS analysis was employed to identify and characterize volatile and semi-volatile phytochemicals present in the plant extract. The technique enables efficient separation and precise mass-based identification of bioactive compounds, providing valuable insights into the chemical composition and potential biological activities of the extract.

Figure.2. GCMS analysis of aqueous seed extract of *Sesbania sesban* (L) Merr.

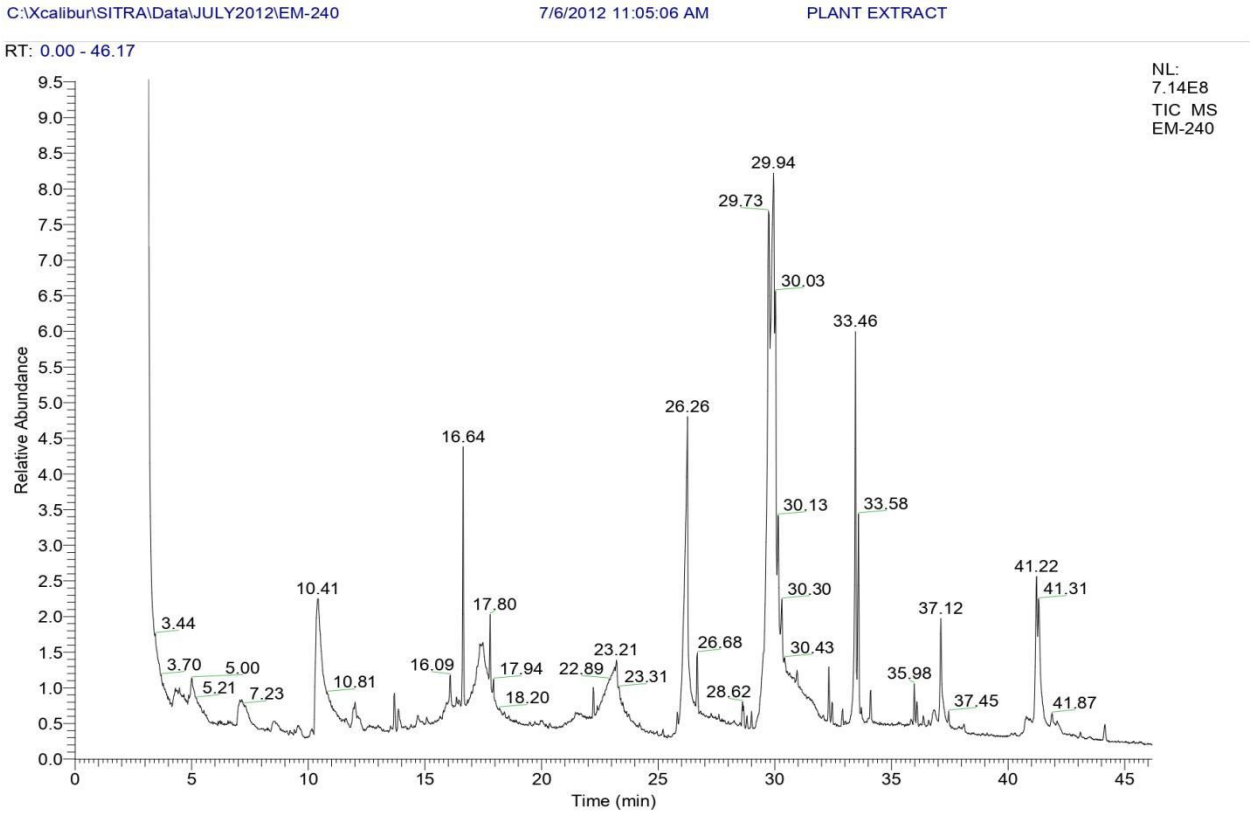

Table.5 GCMS analysis of aqueous seed extract of *Sesbania sesban* (L) Merr.

Retention Time (min)	Compound Name	Molecular Formula	Peak Area (%)	Bioactivity Potential
3.04	Ethanol	C_2H_6O	16.32	Solvent residue; antimicrobial carrier
10.41	5-(Hydroxymethyl)-2-furaldehyde	$C_6H_6O_3$	4.26	Antioxidant, anti-inflammatory
17.80	1-Tetradecanol	$C_{14}H_{30}O$	0.80	Antimicrobial
23.16	Azacyclopentanone derivative	$C_9H_{15}NO_2$	4.26	Bioactive alkaloid derivative
26.68	Ethyl stearate	$C_{20}H_{40}O_2$	0.80	Anti-inflammatory
32.32	Imidazole thione derivative	$C_{12}H_{16}N_4O_2S$	0.59	Antimicrobial
34.11	Artemisia alcohol	$C_{10}H_{18}O$	0.59	Antioxidant
37.12	2-Monostearin	$C_{21}H_{42}O_4$	0.59	Anti-inflammatory
40.78	Oxoapomorphine	$C_{17}H_{13}NO_2$	0.43	Neuroprotective

GC–MS analysis of *Sesbania sesban* plant extract revealed a diverse profile of bioactive compounds including alcohols, fatty acid esters, aldehydes, and nitrogen-containing heterocycles. The presence of hydroxymethyl furfural and long-chain alcohols indicates antioxidant and antimicrobial potential. Fatty acid esters such as ethyl stearate and monostearin contribute to anti-inflammatory activity. Alkaloid and heterocyclic compounds suggest pharmacological relevance. Overall, the GC–MS profile supports the therapeutic potential of *Sesbania sesban* and validates its traditional medicinal use.

4. Conclusion

The plants belonging to sesbania species was reported to have rich phytochemical diversity and many plants with most parts have a significant role in traditional medicine. The present study gave a broad phytochemical characterization of phytochemicals both qualitatively and quantitatively followed by FTIR and GCMS analysis. Qualitative phytochemical analysis confirmed the presence of phenols, flavonoids, steroids, tannins, carbohydrates and proteins revealing the phytochemical richness of the plant sample. Quantitative estimation of phytochemicals further confirmed the quantities of phytochemicals which can be inferred to the antioxidant and therapeutic effect of the seed sample. FTIR analysis exposed characteristic absorption bands matching to functional groups such as hydroxyl, carbonyl, amine, and aliphatic groups, which are often related with phenolic compounds, flavonoids, proteins, and other secondary metabolites. GC–MS analysis enabled the identification of several volatile and semi-volatile compounds with known pharmacological relevance, including antioxidant, antimicrobial, anti-inflammatory, and metabolic regulatory properties.

On the whole, the outcomes authenticate the medicinal significance of *Sesbania sesban* seeds and highlight the suitability of aqueous extraction for isolating biologically active phytochemicals. The study delivers a scientific basis for further in-depth investigations, including bioactivity-guided fractionation, in vitro and in vivo pharmacological evaluations, and the development of plant-based therapeutic formulations.

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Conflict of interest:

The authors declares no conflict of interest.

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RESEARCH ARTICLE

A REVIEW ON POLYMER-ZINC OXIDE HYDROGELS FOR WOUND HEALING

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Abstract

Background & Aims

Recovery of wound is an intricate process. The stages of wound healing consist of four stages. Hemostasis, Inflammation, Proliferation, and Remodeling phases are overlapping with each other. Growth factor is an essential key role in wound healing and it is a specific endogenous polypeptide secreted by six cells such as platelets, macrophages, keratinocytes, fibroblasts, mast cells and neutrophils. Over the past few decades, researchers have used hydrogels to generate wound dressing material.

Methods

In this study, a systematic review of all published articles in Elsevier, MDPI and cell Press from 2016 to 2024 was conducted to investigate the several polymer zinc oxide hydrogels involved in wound healing.

Results

Hydrogels are three-dimensional polymeric materials and porous in nature. Hydrogels are extensive properties such as excellent biocompatibility, biodegradability, water imbibing capacity and non-toxicity. However, hydrogels have relatively little antibacterial activity. To combat this problem, zinc oxide hydrogel with bioactive ingredients such as polymers are a promising option for wound treatment. Zinc oxide nanoparticles are even in trace amount is considered as crucial for wound healing application. Hydrogels' crosslinking and hydrophilic properties allow them to absorb enormous amounts of water to promote wound healing.

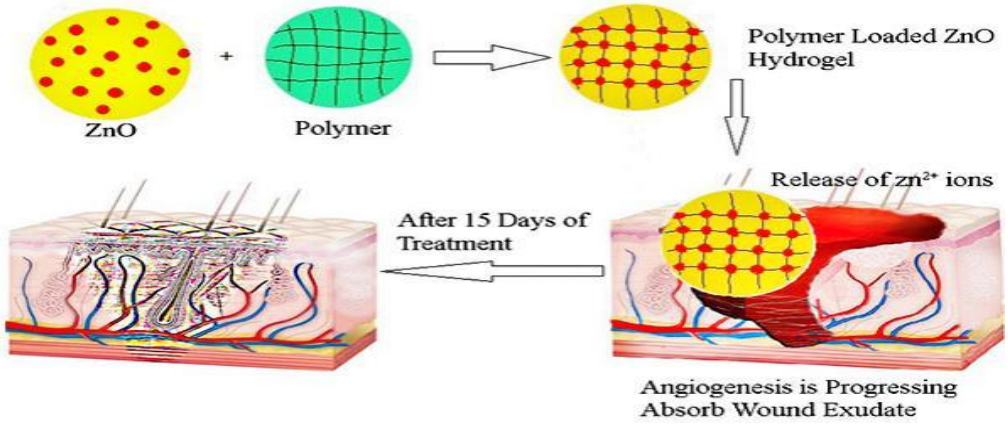
Conclusion

This review summarised up by outlining the present obstacles and potential paths forward for polymer-ZnO hydrogel optimization as next-generation wound care materials.

KEYWORDS

Polymer, Zinc Oxide, Hydrogel, Wound healing, Nanofiber, Extracellular matrix.

Graphical Abstract :



The Schematic illustration show the formation of zinc oxide hydrogel effectively inhibits bacterial growth and promotes a clean wound environment for rapid healing

Introduction

Hydrogels are promising material composed of both natural and synthetic polymers. Hydrogel synthesis involves the utilization of natural polymers such as chitosan, collagen, alginate, hyaluronic acid, starch, acacia gum, dextran, gelatin, fibrin, and silk fibroin. Hydrogels made of zinc oxide have antibacterial and hinder the oxidative stress. In addition to ensuring the wound healing process, zinc oxide hydrogels give moisture to the wound site. 3D printed hydrogel framework are used in dressing material as novel for wound treatment. Electrospinning is a highly efficient and economical technique for creating polymeric nanofibers with various structures, including hollow, porous, and core-shell nanofibers. Antibiotic resistance in humans is caused by the excessive use of oral antibiotics. Polymer hydrogel dressing is used to prevent this issue. Hydrogels are used in more diverse areas like tissue engineering, gene therapy, wound care, skin grafts, drug delivery, 3D bio-printing, dye removal from the textile industry and harmful micro-pollutants from industrial wastewater.ZnO polymer hydrogel is a promising material to catalyze the angiogenesis process. Zinc oxide possesses multifunctional property such as low cytotoxicity, anti-microbial activity, anti-inflammatory and anti-oxidant property will promote rapid healing when incorporated with Hydrogels [1]. Now Let us discuss the various polymer-ZnO hydrogel for wound healing application.

1. Chitosan Incorporated Zinc Oxide Hydrogel

Chitosan is a natural polymer that can be extracted from chitin. It can be found in crustaceans and insects. Reza Monfared et al., [2] developed a double-layered sponge that contains zinc oxide is incorporated with chitosan, carbon dots and sodium alginate used as a wound dressing. It mimics the composition and functions of Extra Cellular Matrix. Zinc Chloride is a precursor for Zinc Oxide nanoparticle and glutaraldehyde acted as a cross linking agent. Three different concentrations of Zn, 1 %, 2 % and 4 % were studied and compared the results with pristine and the concentration of Zn was optimized as 4 % which exhibited good result. The prepared zinc oxide hydrogel was employed *in vitro* blood clotting and anti-bacterial activity. The research group further investigated the morphology of the hydrogel. The TEM image reveals the morphology of spherical particles are less than 100 nm in size. The SEM image demonstrates that the hydrogel has a double layer and uniformly connected porous network. The porosity of hydrogel is essential for the angiogenesis process. The research team found that porosity of the hydrogel decreases as the concentration of Zn nanoparticles increases. More exudate can be absorbed from the infected wound site because of high porosity of great wound dressing material. The contact angle of oxide hydrogels were less than 90, shows it is hydrophilic in nature. The research team further investigated about the water retention efficiency of the as-synthesized Hydrogel's and they found that zinc oxide hydrogel exhibit higher value of 34.3 % than the hydrogel without ZnO. The research group also investigated the antibacterial activity of the hydrogel against gram-positive bacteria Staphylococcus aureus and gram-negative bacteria Pseudomonas aeruginosa by agar disk diffusion method. These are the two important bacteria cause wound infection. The inhibition zone of P.aeruginosa was 41mm for 4 % ZnO hydrogel sample, which is greater than ciprofloxacin inhibition zone 36 mm. The inhibition zone of S.aureus was 25 mm of 4 % ZnO hydrogel. This sponge hydrogel is more resistant to gram-negative bacteria. The research team further revealed that Chitosan-ZnO hydrogel facilitate the rapid blood clot [6].

Elmehbad et al., [3] synthesized 1 % and 3 % ZnO hydrogels at two distinct chitosan chains. Oxalyl dihydrazide was used to crosslink between the chitosan Schiffs base (OCsSB) and chitosan chain (OCs). Antimicrobial inhibition evaluated by Minimum inhibitory concentration assay, Minimum biofilm inhibitory concentration assay and Anti-clostridium difficile activity assay. Human lung fibroblast cells were used to study cytotoxicity, which was found to be safe for human cells. XTT assay measured by four Gram positive and four Gram negative bacteria and compared by vancomycin. When it comes to inhibitory activity of chitosan chain performs better than oxalyl dihydrazide. It will employed in the pharmaceutical industry.

2. Chitosan and Polyvinyl Alcohol Incorporated Zinc Oxide Hydrogel

Khorasani et al., [4] reported the formation of hydrogels using PVA and chitosan combined with zinc oxide nanoparticles. Freeze-thaw method was used to synthesize hydrogel by varying thawing time, thawing temperature and F-T cycles. The addition of PVA creates an interpenetrated network of polymers, which gives the material its elastic and rubbery qualities while also being non-toxic and non-carcinogenic. The research team investigated anti-bacterial property, biocompatibility, *in vitro* wound healing, cytotoxicity, morphology and mechanical properties and they found that at -20 °C, the polymer chain freezes. The FTIR and XRD results supports the formation of ZnO in chitosan-PVA-ZnO hydrogel. The Scherrer equation yielded average dimensions of 18 nm for the nano ZnO structure, which was hexagonal wurtzite. They identified the average pore size of 13.5 micrometer from SEM investigation and at 5 °C and 6 F-T cycles, the time dropped to 2 hours, and the pore size increased to 19.1 micrometer. Whereas the temperature increased to 15 °C and 6 F-T cycles, the time 4.65 h

average pore size again increased to 18.2 micrometer. The research team also investigated the biocompatibility of hydrogels in L-929 and HDF cells and the results indicated that no toxicity. Furthermore, they evaluated the antibacterial activity by disc diffusion method against E.coli and S.aureus and the results demonstrated higher inhibition zone was observed in S.aureus.

3. Gelatin Incorporated Zinc Oxide Hydrogel

Ya-Chu Ya and coworkers [5] developed gelatin composite hydrogel with zinc oxide nanoparticles by in situ form. Initially, they form a polypeptide chain of gelatin, when it reacts with methacrylic anhydride. Further they added a photo initiator 2-hydroxy 4-(2-hydroxyethoxy)-2-methyl propiophenone to the gelatin composite hydrogel to form polypeptide chain. The research team prepared Zinc oxide nanoparticles at three different concentrations 1, 10, 30 mM. From SEM results they revealed that the particle size of hydrogel was in the range of 12–14 nm. According to TGA data, they confirmed that zinc oxide hydrogel had greater thermal stability. When an increases the zinc oxide concentration the swelling ratio falls to aid the healing process. The antibacterial study was evaluated by CFU assay and the inhibition percentage in EHEC 99.89 %, S.flexneri 99.78 % and 98.98 % in S.aureus. The cell viability assay test was performed using NIH 3T3 and BEAS-2B cells and the results showed above 70 % demonstrated the recommendation of hydrogel in biomedical engineering.

Another hydrogel consisting of Zinc doped cerium oxide nanoparticles combining methyl acrylate gelatin which is modified with dopamine was reported by Zhoa et al. [6]. Antibacterial activity, *in vitro* biocompatibility, *in vivo* wound healing, *in vitro* antioxidant and proangiogenic properties were evaluated and they found that the inhibition efficiency in E. coli and S. aureus were 70% and 80 % respectively. This doped hydrogel showed higher wound closure rate of 98.5 % in rat model at 14 days of treatment.

Liu et al., [7] developed gelatin, tannic acid and oxidized sodium alginate with zinc oxide nanoparticles. *In-vitro* swelling property, Zn^{2+} release assay, *in vitro* antioxidant activity, *in-vitro* antibacterial activity, hemolysis assay and cytocompatibility assay were examined to study how the hydrogel stimulates the wound healing process. The research team found that Zn^{2+} ions are released continuously, killing bacteria at the wound site. The release rate was 0.54 mg/mL in 48 h. The *in vitro* coagulation property is connected to the crosslinking structure of the hydrogel. The blood clotting function of gelatin composite hydrogel is greater than the blood's own clotting time which may due to the positively charged amino group on the hydrogel electrostatically interacting with the negatively charged platelets. The property of antibacterial activity measures the hypostatic rate of S. aureus and E. coli and it was 97.8 % and 96.6 % respectively. The developed multifunctional hydrogel was acted as a wound dressing material with therapeutic impact.

4. Cellulose and Grape Fruit Seed Extract Incorporated with Zinc Oxide Hydrogel

Dharmalingam and co-workers [8] fabricated ether derivatives of cellulose fabricated with zinc oxide in presence of three distinct concentrations of grapefruit seed extract (GFSE) 0.25 %, 0.5 % and 1 %. Citric acid was added as a crosslinking agent. sodium carboxy methyl cellulose and hydroxyl propyl methyl cellulose were ether derivatives of cellulose that are hydrophilic, biocompatible and biodegradable. The ester, OH and carbonyl groups in the zinc oxide hydrogel were confirmed by FTIR data. The polymer and citric acid react to generate an ester bond. The Raman spectrum showed the primary characteristic peak of wurtzite ZnO. They prepared hydrogel films of 30-100 nm in size which was confirmed by FESEM analysis. GFSE concentration increases structural changes occur in hydrogel film leads to decreased tensile strength. Highest elongation value was observed in 1 % GFSE hydrogel film. The antioxidant activity was followed by DPPH assay revealed 1% of GFSE have more inhibition of DPPH free radical. The anti-bacterial activity was measured in E.coli and S.aureus bacteria. The research team found that as the concentration of GFSE increases the antibacterial activity increases. Hence this research team underlined that ZnO in the hydrogel favor the healing of wound.

5. Cysteine Conjugated Chitosan-Cellulose Hydrogel with Zinc Oxide Nanoparticles for Naringenin Drug Delivery

Dhanya George and coworkers [9] developed chitosan–cellulose conjugated with cysteine incorporated zinc oxide nanoparticles to employ Naringenin drug release. Cysteine is an essential precursor for glutathione synthesis. Dialdehyde cellulose as a green crosslinker derived from sugarcane bagasse. Naringenin is a flavone with excellent anti-oxidant and anti-inflammatory properties. The research team investigated about the biological performance of cysteine conjugated chitosan-cellulose hydrogel with ZnO nanoparticles and the biological studies include biocompatibility, anti-microbial and anti-cancer. Naringenin drug release was carried out in varying pH 5, 6.8 and 7.4. At acidic pH 5 shows better drug release of about 72.78 % in 12 hours and where the initial concentration of drug was 1.0 mg/ ml. The L-929 fibroblast epidermal cells were utilized for anti-bacterial activity in S.aureus. Anti-fungal activity executed in Trichophyton rubrum. They found that the antibacterial activity increases as the concentration of ZnO and drug increases. Cysteine conjugated with chitosan and cellulose plays a major

role in apoptosis and exhibit more cell viability and act as a cytoprotective activity against programmed cell death. The anti-cancer activity carried out in human skin cancer cells such as A431 showed great performance against skin carcinoma. Hence the researcher ensured that the prepared hydrogel is suitable for both microbial infection and skin cancer treatment.

6. Gum Acacia and Poly Sodium Acrylate Hydrogel Loaded with Zinc Oxide Nanoparticles

Bajpai et al., [10] synthesized zinc oxide nanoparticles loaded with gum acacia and sodium acrylate in-situ form by hydrothermal method. Potassium persulphate as an initiator for this reaction. N, N – methylene bis –acrylamide as a cross linking agent. The formation of ZnO nanoparticles within the hydrogel matrix was assessed by surface Plasmon Resonance Spectrum showed a sharp peak at 364 nm. The research group confirmed the hydrogel matrix by XRD and FTIR results. They evaluated the swelling behavior of hydrogel in phosphate buffer saline at pH 7.4 by gravimetric method. According to SEM analysis they revealed the average size between 40- 60 nm. Anti-bacterial activity against E.coli bacteria was studied and the inhibition zone was 3.2 ± 0.07 mm. So this hydrogel is suitable for biomedical application.

7. Sodium Alginate Embedded with Zinc Oxide Nanoparticles for Chronic Wounds

The development of 3D-printed sodium alginate hydrogel impregnated with zinc oxide nanoparticles was reported by Cleetus et al. [11]. Calcium chloride was employed as a crosslinker. Rheological analysis, cytocompatibility, humidity sensor, swelling assay were analyzed. The characteristic XRD peaks are quite crystalline and resemble the JCPDS data card. SEM results revealed that synthesized zinc nanoparticles are spherical in shape and homogeneous size distribution, with a particle size of 4-6 nm. Staphylococcus epidermidis, which causes common wound infections, has been the subject of an antibacterial investigation. The growth of bacteria was inhibited by the addition of zinc oxide. Swelling behavior was examined in manually casted gels and 3D bio-printed gels. From this result, 3D bio-printed gels have a prominent wound healing scaffold. Hence, Zinc oxide-loaded 3D-printed hydrogels showed significant promise as an antimicrobial treatment for chronic wounds.

8. Poly Acrylic Acid and Polyvinyl Pyrrolidone Hydrogels Incorporated with Zinc Oxide Nanoparticles

By free radical polymerization approach, Mohsen Shahrousvand et al. [12] created a novel wound dressing material by combining zinc oxide hydrogel with PAA and PVP polymer hydrogel. In hydrogel synthesis potassium persulphate is used as an initiator while N, N- methylene bisacrylamide is a crosslinker. Due to their high solubility in water, PAA and PVP are referred to as superabsorbents because of their increased ability to absorb and hold onto water. PAA can break down the cell membranes of bacteria that cause infections, which increases antibacterial activity. Zinc concentrations include 0 %, 1 %, 2 % and 4 %, whereas PVP percentage ranges from 0 to 2.5, 5, 7.5 and 10. The team observed that the swelling behavior of the hydrogel because it allows the body to absorb more exudate from the wound. More water absorption behavior was exhibited by the 7.5 % PVP sample, making it appropriate for used as a dressing material. From SEM investigation, they revealed that PAA and PVP had a strong polar interaction. Further, they found that during TGA analysis, zinc oxide material remains in the structure where hydrogel degraded in the form of gas. Anti-bacterial activity was examined in S.aureus and P.aeruginosa bacteria. The Research team investigated their newly designed wound dressing material in a rat excisional wound model, the result revealed that complete wound closure was observed after 21 days of treatment. Hence the team insisted this PAA-PVP-ZnO hydrogel can act as a good choice of dressing for wound healing.

9. Berberine Encapsulated with Zinc Oxide Nanocolloids Hydrogel

Xuechen yin et al., [13] developed berberine encapsulated with zinc oxide nano colloids in injectable form. Polyvinyl alcohol, sodium alginate, berberine, zinc sulphate were the precursors for hydrogel preparation. The hydrogel have superior antifungal, antibacterial, anti-oxidative stress and anti-inflammatory qualities are the key results of the bioactive component berberine. In diabetic patients, the accumulation of reactive oxygen species causes a delay in the wound-healing process. The prepared ZnO-Berberine polymer hydrogel could eliminate reactive oxygen species when treated with fibroblast cells. The intensity of UV spectrum peak increased denotes the stable release of berberine from the hydrogel. After 15 days of treatment, the wound healing rate in rats by *in vivo* test was 92.9 %.

CONCLUSION

In this review, several polymers were incorporated with zinc oxide hydrogel which has significant potential for wound healing due to its ability to encourage wound closure, fight bacterial infection and enhance tissue regeneration. These polymer hydrogels have an active anti-S. aureus bacterial effect. Despite these benefits, issues including optimizing ZnO concentration, ensuring stability over time and reducing cytotoxicity must be resolved for broad clinical application. Enhancing the formulation, investigating new biomaterials for synergistic effects, and carrying out comprehensive clinical trials to confirm their safety and effectiveness should be the main goals of future

research. Hydrogel wound dressing material is a great alternative to conventional dressings because of its self-healing properties. Overall, ZnO hydrogels represent a promising and creative approach to wound care treatment.

AUTHOR CONTRIBUTIONS

M. Krishna veni: Writing - original draft; Methodology; Project administration; Resources; Writing – review & editing. J. Indira: Investigation; Supervision; Validation; Formal analysis. K. Santhiya: data curation, software.

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CONFLICT OF INTEREST

The authors declare no conflict of interest.

TRANSPARENCY STATEMENT

The lead author, Krishna Veni, affirms that this manuscript is an honest, accurate, and transparent account of the study being conducted reported.

DATA AVAILABILITY STATEMENT

As this study is a systematic review, no original data are available in the original and supplementary data.

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RESEARCH ARTICLE

GREEN TEMPLATES ASSISTED SYNTHESIS OF NANO HYDROXYAPATITE AND ITS APPLICATIONS- A COMPREHENSIVE REVIEW

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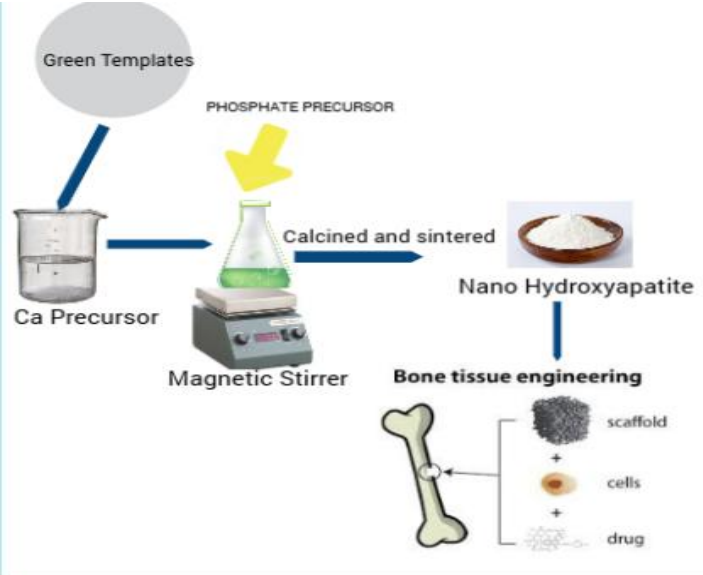
Abstract

Hydroxyapatite (HAP) is a calcium phosphate mineral that has the composition very similar to that of bone and teeth and it is used in a variety of biomedical applications such as implants in orthopaedic field, dental filling material and tissue engineering. Hydroxyapatite can be synthesised using precursors of calcium and phosphate with the addition of various chemical or natural occurring templates. Templates play a significant role in controlling the size and morphology of nanoparticles. In this article we have discussed the various templates which were occurred naturally such as banana peel, licorice root extract, tamarind, pear fruit, grapes, neem leaf extract, tea saponin, Moringa Oleifera flower extract, Manoon Longifolium leaf extract and Wrightia tinctoria for the synthesis of nano hydroxyapatite. Also how the properties such as size and morphology of hydroxyapatite are significantly influenced by the addition of these templates have been highlighted.

KEYWORDS

Biomaterial, Hydroxyapatite, Nanoparticle, Synthesis, Green Templates

Graphical Abstract :



Introduction

Hydroxyapatite is a biocompatible inorganic material which has the chemical formula $Ca_{10}(PO_4)_6(OH)_2$ and it has been used widely in bone and teeth replacement applications such as scaffold filler for bones, coating for bones and tooth implant and also in the delivery of various drugs[1,2]. The properties such as antimicrobial activity, biocompatibility, particle size and morphology of HAP plays a major role in the manufacturing of bone implants and scaffolds [3,4,5]. Researchers find a great deal of interest in synthesizing nano hydroxyapatite with various morphology and size. Synthesis of HAP can be performed by wet method and dry method. The wet method consists of chemical precipitation and hydrothermal whereas the dry method consists of solid state synthesis and mechanochemical

method [6,7]. In recent years nanoparticles synthesised by means of green route have gained much importance because of its sustainability and environmental friendliness.

This review demonstrated the synthesis of hydroxyapatite using green templates which were available in natural sources such as banana peel, licorice root extract, tamarind, pear fruit, grapes, neem leaf extract, tea saponin, Moringa Oleifera flower extract, Manoon Longifolium leaf extract and Wrightia tinctoria leaf extract.

The various Green Templates employed for the synthesis of HAP is presented in table 1:

Table 1: Green templates employed for the synthesis of HAP

S.No	Sources of Template	Applications	Reference
1	Banana Peel Extract	Antibacterial	[8]
2	Licorice Root Extract	-	[10]
3	Tamarind fruit Extract	Antibacterial	[12]
4	Pear Fruit Extract	Antibacterial	[14]
5	Grape Fruit Extract	-	[16]
6	Neem Leaf Extract	-	[19]
7	Tea Saponin Extract	-	[21]
8	Moringa Oleifera flower Extract	Antibacterial, Antifungal	[23]
9	Manoon Longifolium leaf Extract	Fluoride ion removal from water	[25]
10	Wrightia tinctoria leaf Extract	Antibacterial	[26]

BANANA PEEL EXTRACT

Gopi et. al., [8,9] reported the synthesis of Hydroxyapatite nanoparticles using pectin as the template which was derived from banana peel extract and the resultant product were investigated with various analytical techniques. The synthesised HAP was evaluated for its antibacterial activity using gram positive and gram negative bacteria such as Staphylococcus aureus (S. aureus) and Escherichia coli (E. coli), respectively.

They varied the concentration of pectin ranging from 0.01-0.15 wt.% and from the SEM result they concluded that the optimum concentration of pectin for controlling the particle size of HAP nanoparticles was 0.15 wt. %. The research group also found that the antibacterial activity of synthesised HAP nanoparticles increases with increase in the concentration of HAP from 25 µl to 100 µl.

LICORICE ROOT EXTRACT

Ashraf and his co workers [10,11] reported the synthesis of HAP nanorods by means of microwave hydrothermal method using Licorice root (Glycyrrhiza glabra) extract as the green template and it contains Glycyrrhizic acid (GA), a water soluble biosurfactant.

They analysed the purity of the samples using FTIR and Raman Spectroscopy and demonstrated that HAP is free of carbon. The Particle Size Distribution analysis (PSA) was done for the synthesised HAP and they found that the nanorods of HAP with average dimensions of 105 nm length and 25 nm width.

TAMARIND FRUIT EXTRACT

Synthesis of Hydroxyapatite nanorods using fruit extracts as templates was reported by Gopi and his colleagues [12,13]. They employed the extracts of banana, tamarind and grape fruit as green templates. The research team identified that tamarind extract plays a vital role in lowering the particle size and crystallinity when compared to other fruit extracts such as banana and grapes. Further they revealed from the investigation that the particle size distribution depends on the concentration and nature of tartaric acid from natural sources.

They found that the biocompatibility of as synthesised HAP samples using antibacterial studies with the pathogenic gram negative bacterial strains such as E. Coli, and *Klebsiella*. The antibacterial activity of HAP using tamarind as a green template showed more inhibition zone even at lower concentration when compared to other natural sources of tartaric acid such as banana, grape and commercially available tartaric acid.

PEAR FRUIT EXTRACT

Gopi et. al.,[14,15] reported the synthesis of Hydroxyapatite nanoparticles using pectin as template and it was derived from peel of pear (*Opuntia ficus indica*) fruits. The various concentrations of pectin like 0.01, 0.04, 0.07, 0.1, 0.15, 0.2 and 0.25 wt.% were used for the synthesis of HAP. The research team found from the XRD data that the crystallinity of the HAP nanoparticles increases with increase in the concentration of pectin from 0.15 wt%.

They revealed from the SEM results that the particle size of the synthesised HAP reduced significantly when the concentration of pectin increased from 0.01 to 0.15 wt.%. Finally they concluded that the concentration of pectin plays a major role in controlling the morphology of HAP nanoparticles.

The research group also investigated the antibacterial activity of synthesised HAP in the absence and presence of pectin using the S. aureus, E. coli, and C. albicans bacterial strains. The inhibition zone of HAP with 0.15 wt.% pectin was shown to be higher ie., 11.4 mm for 100 µl than the HAP synthesised with absence of pectin (2.3 mm for 100 µl).

GRAPE FRUIT EXTRACT

Maritza and coworkers [16,17] synthesised Hydroxyapatite Nanorods using fruit extracts such as mango, grapes and ripe tamarind as green templates by hydrothermal method. The hydroxyapatite nanorods were characterised for the study of their morphology and formation using Scanning Electron Microscopy (SEM), X-ray Diffraction, Infrared spectroscopy analysis. They concluded that grape fruit extract used for the synthesis of HAP showed that the particle size reduced significantly by about 41.7% when compared to mango and tamarind fruit extracts.

Vijayalakshmi and her research team [18] investigated about the synthesis of hydroxyapatite nanoparticles using different green templates such as banana peel extract, grape fruit extract, tamarind leaves extract and pear fruit extract and compared the properties of synthesised HAP.

They concluded from the DLS data that the particle size of the HAP was found to be lower by using grapes (292 nm) and pear (291.3 nm) as the green template when compared to banana (422.1 nm) and tamarind fruit (319.8 nm) extract. They declared from the XRD data that the crystallinity of the HAP nanoparticles reduced by using grape as a green template (129 nm) when compared to banana peel (188 nm), tamarind leaves (192 nm), and pear fruit (187 nm). They found that uniform particle size was observed by using grape fruit as the template when compared to other templates.

NEEM LEAF EXTRACT

Punita and her research team [19,20] reported the synthesis of hydroxyapatite nanoparticles using the egg shell waste and the addition of neem leaf (*Azadirachta indica*) extract as the green template by microwave assisted and also conventional wet precipitation method. They reported from the SEM and TEM analysis data that the synthesised HAP using neem extract by microwave method possesses less agglomeration when compared to conventional method and without the addition of neem leaf extract.

They demonstrated that the average size of HAP in the absence of neem leaf extract for both the methods was found to be 30-31 nm and 53-55 nm whereas in the presence of neem leaf extract it was 27-28 nm and 44-46 nm in width and length respectively. They found that the crystalline size was reduced for the synthesised HAP by means of microwave method in the presence of neem leaf extract.

TEA SAPONIN

Tao Zhang et. al., [21,22] reported the synthesis of hollow porous hydroxyapatite microspheres by the addition of tea saponin as green template. They varied the concentration of tea saponin from 0 to 0.15% and found from the XRD data that the crystallinity of HAP reduced with increase in the concentration of tea saponin.

The research team concluded from the SEM analysis data that the size and the morphology of HAP varies significantly with the concentration of tea saponin. With zero concentration of tea saponin HAP exhibits rod or ellipse like granules. The spherical nanorods of HAP were obtained with the average diameter of 2.0 µm at 0.002% concentration of tea saponin whereas with 0.008% of tea saponin the HAP formed as a sheet like structure with the average diameter of 2.3 µm.

The research team revealed from the surface and pore analysis data that the average pore size was reduced from 57.6 nm to 29.7 nm with an increase in the concentration of tea saponin from 0 to 0.11% respectively. Further they concluded that HAP synthesised using tea saponin was mesoporous in nature.

MORINGA OLEIFERA FLOWER EXTRACT

Kalaiselvi and her research team [23,24] reported the green synthesis of Hydroxyapatite nanorods using Moringa Oleifera flower extracts by microwave assisted method. The green synthesised HAP nanorods and chemically synthesised HAP nanorods were compared for its antimicrobial properties. They carried out the antibacterial activity using both gram positive and gram negative bacterial strains.

The zone of inhibition for the chemically synthesised HAP using gram positive bacteria species such as Monococcus Luteus, Staphylococcus aureus and Bacillus subtilis were found to be 10 mm, 11 mm and 9 mm respectively whereas the high antibacterial activity were observed for the green synthesized HAP nanorods and found to be 15 mm, 13 mm and 14 mm respectively.

Likewise for gram negative bacterial species such as Salmonella paratyphi, Pseudomonas aeruginosa and Klebsiella pneumoniae, the Zone of inhibition for chemically synthesized HAP were found to be 10 mm, 9 mm and 9 mm respectively, whereas for green synthesized HAP it was observed as 12 mm, 10 mm and 10 mm respectively.

The research team also carried out the antifungal studies using Aspergillus fumigatus, Aspergillus niger and Candida albicans for HAP deived frrom chemical method and green method. They concluded that more antifungal property was seen for green synthesized HAP when compared to chemically derived HAP.

MANOON LONGIFOLIUM LEAF EXTRACT

The removal of Fluoride ions using green synthesised hydroxyapatite nanoparticles was reported by Dawit Darcha Ganta et. al., [25]. Manoon Longifolium Leaf Extract was used as template for the synthesis of HAP. They found that the percentage of removal of Fluoride ions and adsorption capacity increases from 73% to 93% with increase in pH of the solution from 1 to 7. Further increase in the pH of the solution results in the decrease of the percentage removal of Fluoride ions to 81%. They emphasised that the optimal pH for the removal of Fluoride ions from the aqueous solution is at pH 7.

They also studied the adsorption capacity by varying the adsorbent dose from 0.1 g/L to 1.0g/L. They reported that the percentage of removal of Fluoride ions significantly increases upto 0.75 g/L of adsorbent dosage and beyond that no significant change in the adsorption capacity.

WRIGHTIA TINCTORIA LEAF EXTRACT

Ragunath et. al., [26] reported the green synthesis of Hydroxyapatite nanoparticles and its antibacterial activity using Wrightia tinctoria. They carried out the XRD and SEM analysis and found that the crystals of HAP were hexagonal in shape and polycrysatalline in nature. They also reported that the high antibacterial activity of HAP was observed against various bacterial strains such as Psuedomonas aeruginosa, Klebsiella pneumonia, Escherichia coli and Staphylococcus aureus.

CONCLUSIONS

In this review article we have discussed the synthesis of Hydroxyapatite nanoparticles using different green templates such as Banana peel extract, Licorice root extract, Tamarind fruit extract, Pear fruit extract, Grape fruit extract, Neem leaf extract, Tea saponin, Moringa Oleifera flower extract, Manoon Longifolium leaf extract and Wrightia tinctoria leaf extract. We conclude that addition of green templates played a significant role in controlling the morphology, crystallinity, shape and size of synthesised nano hydroxyapatite. Even though many chemically derived templates are employed for the synthesis of HAP, nowadays scientists are of keen interest in employing naturally available green templates due to its environmental sustainability. The Green templates are readily available, low cost, non toxic and biocompatible in nature. In this era green synthesis of nanoparticles gained much importance due to its benefits to the environment and human health.

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RESEARCH ARTICLE

SOFT αωÏ$_s$ – NORMAL AND REGULAR SPACES IN SOFT IDEAL TOPOLOGICAL SPACES

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Abstract

In this paper, we introduce a soft αωÏ$_s$ – Normal and Regular spaces in soft ideal topological spaces. Furthermore, we introduce to Enlightment and Edification of some properties, theorems and examples, which is the of the concept of soft mappings in soft ideal topological spaces.

KEYWORDS

Soft set, soft ideal topological space, Soft αωÏ$_s$ -Closed set, Soft αωÏ$_s$ – Hausdorff space, Soft αωÏ$_s$ – Normal space, Soft αωÏ$_s$ – Regular space.

Introduction

1. Introduction

The concept of soft set theory was introduced by Molodstov [5] and the concept of soft ideal theory, soft local function was introduced by A.Kandil,et.al [1]. The concepts of soft αω-closed sets was introduced by S.Jafari,et.al [12]. The concepts of soft αωÏ$_s$- Closed sets was introduced by N.Chandramathi and V.Kiruthika [7]. The concepts of Soft Hausdorff space, Soft Normal space and Soft Regular Space was introduced by M. Shabir and M. Naz [6].

2. Preliminaries

Let U be an initial universe and E be a set of parameters. Let P(U) denote the power set of U.

2.1 Definition [5]

Let D be a non-empty subset of E and a soft set over U is a parameterized family of subsets of an initial universe U. For a particular e ∈ E, F(e) may be considered the set of e-approximate elements of the soft set (F,E) and if e ∉ E, then F(e) = ∅ ,that is, $(F, E) = \{f(e): e \in Đ \subseteq E, f: E \rightarrow P(U)\}$ is called a soft set over U. Then the family of all these soft sets denoted by $SS(U)_E$.

2.2 Definition[5]

Let τ_s be the collection of soft sets over U. Then τ_s is said to be a soft topology on U if satisfies the following axioms:

i. $(\emptyset, E), (U, E)$ belongs to τ_s.
ii. The union of any number of soft sets in τ_s belongs to τ_s.
iii. The intersection of two number of soft sets in τ_s belongs to τ_s.

The triplet (U,τ_s,E) is said to be soft topological space and we note that the member of τ_s are said to be τ_s-soft open sets.

2.3 Definition [1]

Let $\bar{I}$ be a non-null collection of soft sets over an initial universe U with the same set of parameter E. Then $\bar{I}$ containing $SS(U)_E$ is called as a soft Ideal on U with same set E if,

i. $(F, E) \in \bar{I}$ and $(G, E) \in \bar{I}$ then $(F, E) \cup (G, E) \in \bar{I}$.
ii. $(F, E) \in \bar{I}$ and $(G, E) \subseteq (F, E)$ then $(G, E) \in \bar{I}$.

2.4 Definition[11]

Let (U,τ_s,E) be a soft topological space and x,y ∈ U such that x ≠ y. Then (U,τ_s,E) is called a soft Hausdorff space, if there exist soft open soft sets (F, E) and (G, E) such that x ∈ (F, E), y ∈ (G, E) and $(F, E) \cap (G, E) = (\emptyset, E)$.

2.5 Definition [11]

Let $(U,\tau_s,E, \bar{I})$ be a soft ideal topological space and x,y ∈ U such that x≠y. Then $(U,\tau_s,E, \bar{I})$ is called a soft - $\bar{I}$- Hausdorff space, if there exist soft $\bar{I}$- open soft sets (F, E) and (G, E) such that x ∈ (F, E), y ∈ (G, E) and $(F, E) \cap (G, E) = (\emptyset, E)$.

2.6 Definition[2]

Let (U,τ_s,E) be a soft topological space over U; (H,E) and (K,E) be two disjoint soft closed sets over U, if there exist soft open sets (F,E) and (G,E) such that $(H,E) \subseteq (F,E)$, $(K,E) \subseteq (G,E)$ and $(F,E) \cap (G,E) = (\emptyset, E)$, then (U,τ_s,E) is called a soft normal space.

2.7 Definition[2]

Let $(U,\tau_s,E,\bar{I})$ be a soft ideal topological space over U; (H,E) and (K,E) be two disjoint soft closed sets over U, if there exist soft $\bar{I}$ - open sets (F,E) and (G,E) such that $(H,E) \subseteq (F,E)$, $(K,E) \subseteq (G,E)$ and $(F,E) \cap (G,E) = (\emptyset, E)$, then $(U,\tau_s,E,\bar{I})$ is called a soft $\bar{I}$ - normal space.

2.8 Definition[2]

Let (U,τ_s,E) be a soft topological space over U and let (H,E) be a soft closed in U and $x \in X$ such that $x \notin (H,E)$, if there exist soft open sets (F_1,E) and (F_2,E) such that $x \in (F_1,E)$, $(G,E) \subseteq (F_2,E)$ and $(F_1,E) \cap (F_2,E) = (\emptyset, E)$, then (U,τ_s,E) is called a soft regular space.

2.9 Definition [2]

Let $(U,\tau_s,E,\bar{I})$ be a soft ideal topological space over U and let (H,E) be a soft closed in U and $x \in X$ such that $x \notin (H,E)$, if there exist soft $\bar{I}$ - open sets (F_1,E) and (F_2,E) such that $x \in (F_1,E)$, $(G,E) \subseteq (F_2,E)$ and $(F_1,E) \cap (F_2,E) = (\emptyset, E)$, then $(U,\tau_s,E,\bar{I})$ is called a soft $\bar{I}$- regular space.

3. SOFT $\alpha\omega\ddot{I}_s$ – HAUSDORFF SPACE IN SOFT IDEAL TOPOLOGICAL SPACES

In this section we introduce and study about a new Hausdorff space is known as soft $\alpha\omega\ddot{I}_s$ – Hausdorff space in Soft ideal topological spaces.

3.1 Definition

Let $(\dot{V},\tau_s,Q,\ddot{I}_s)$ be a soft ideal topological space and $(x,Q),(y,Q) \in (\dot{V},Q)$ such that $(x,Q) \neq (y,Q)$. Then $(\dot{V},\tau_s,Q,\ddot{I}_s)$ is called a soft $\alpha\omega\ddot{I}_s$ - Hausdorff space, if there exist soft $\alpha\omega\ddot{I}_s$ - open sets (F,Q) and (G,Q) such that $(x,Q) \in (\dot{X},Q)$, $(y,Q) \in (\dot{Y},Q)$ and $(\dot{X},Q) \cap (\dot{Y},Q) = (\{\},Q)$.

3.2 Example

Let $\dot{V} = \{\alpha, \beta, \gamma, \delta\}$,

$Q = \{\sigma\}$,

$\tau_s = \{(\{\},Q),(\dot{V},Q),(\mathcal{F}_1,Q),(\mathcal{F}_2,Q),(\mathcal{F}_3,Q)\}$

$\ddot{I}_s = \{(\{\},Q),(\mathcal{F}_4,Q),(\mathcal{F}_5,Q),(\mathcal{F}_6,Q)\}$ where

$(\mathcal{F}_1,Q) = \{\{\},\{\alpha\}\}$, $(\mathcal{F}_2,Q) = \{\{\beta\},\{\alpha,\beta\}\}$,

$(\mathcal{F}_3,Q) = \{\{\dot{V}\},\{\beta\}\}$,

$(\mathcal{F}_4,Q) = \{\{\},\{\gamma\}\}$,

$(\mathcal{F}_5,Q) = \{\{\},\{\beta,\delta\}\}$,

$(\mathcal{F}_6,Q) = \{\{\beta,\delta\},\{\beta,\gamma,\delta\}\}$

are soft sets over $\dot{V}$.

Here, $\{\{\},\{\beta,\delta\}\}$ and $\{\{\},\{\gamma\}\}$

are soft $\alpha\omega\ddot{I}_s$ – Hausdorff space in $(\dot{V},\tau_s,Q,\ddot{I}_s)$.

3.3 Theorem

Let $(\dot{V},\tau_s,Q,\ddot{I}_s)$ be a soft ideal topological space. Then every soft Hausdorff space is soft $\alpha\omega\ddot{I}_s$ – Hausdorff.

Proof: Let $(\dot{V},\tau_s,Q)$ be a soft Hausdorff space and we let two distinct points

$(x,Q) \neq (y,Q)$ in $(\dot{V},Q)$.

Then there exist two disjoint soft open sets $(\dot{X},Q),(\dot{Y},Q) \in \tau_s$ with $(x,Q) \in (\dot{X},Q)$ and $(y,Q) \in (\dot{Y},Q)$ and $(\dot{X},Q) \cap (\dot{Y},Q) = (\emptyset, Q)$.

Since every soft open set is soft $\alpha\omega\ddot{I}_s$ – open, then $(\dot{X},Q)$ and $(\dot{Y},Q)$ are soft $\alpha\omega\ddot{I}_s$ – open. Thus (x,Q) and (y, Q) are separated by soft $\alpha\omega\ddot{I}_s$ – open neighborhoods. Therefore the space is soft $\alpha\omega\ddot{I}_s$ – Hausdorff.

3.4 Theorem

Let $(\dot{V},\tau_s,Q,\ddot{I}_s)$ be a soft ideal topological space. Then every soft ω – Hausdorff is soft $\alpha\omega\ddot{I}_s$ – Hausdorff.

Proof: Suppose that $(\dot{V},\tau_s,Q,\ddot{I}_s)$ be the soft ω – Hausdorff. Then for any two distinct points $(x,Q) \neq (y,Q)$ there exist soft ω– open sets $(\dot{X},Q)$ and $(\dot{Y},Q)$ with $(x,Q) \in (\dot{X},Q)$, $(y,Q) \in (\dot{Y},Q)$ and $(\dot{X},Q) \cap (\dot{Y},Q) = (\{\},Q)$. But we know that every soft ω– open set is soft $\alpha\omega\ddot{I}_s$ – open, so $(\dot{X},Q)$ and $(\dot{Y},Q)$ are soft soft $\alpha\omega\ddot{I}_s$– open and disjoint. Hence the space is soft $\alpha\omega\ddot{I}_s$– Hausdorff.

The converse of the above theorem need not be true as seen from the following Example.

3.5 Example

Let $\dot{V} = \{\alpha, \beta, \gamma, \delta\}$,

$Q = \{\sigma\}$,

$\tau_s = \{(\{\},Q),(\dot{V},Q),(\mathcal{F}_1,Q),(\mathcal{F}_2,Q),(\mathcal{F}_3,Q)\}$

$\ddot{I}_s = \{(\{\},Q),(\mathcal{F}_4,Q),(\mathcal{F}_5,Q),(\mathcal{F}_6,Q)\}$

Where

$(\mathcal{F}_1,Q) = \{\{\},\{\alpha\}\}$,

$(\mathcal{F}_2,Q) = \{\{\beta\},\{\alpha,\beta\}\}$,

$(\mathcal{F}_3,Q) = \{\{\dot{V}\},\{\beta\}\}$,

$(\mathcal{F}_4,Q) = \{\{\},\{\gamma\}\}$,

$(\mathcal{F}_5,Q) = \{\{\},\{\beta,\delta\}\}$,

$(\mathcal{F}_6,Q) = \{\{\beta,\delta\},\{\beta,\gamma,\delta\}\}$

are soft sets over $\dot{V}$.

Here, $\{\{\beta\},\{\alpha,\beta\}\}$ and $\{\{\},\{\beta,\delta\}\}$

are not soft ω– Hausdorff space in $(\dot{V},\tau_s,Q,\ddot{I}_s)$.

3.6 Theorem

Let $(\dot{V},\tau_s,Q,\ddot{I}_s)$ be a soft ideal topological space.

i. Let $\ddot{I}_s = (\{\},Q)$. Then $(\dot{V},\tau_s,Q,\ddot{I}_s)$ is soft $\alpha\omega\ddot{I}_s$ – Hausdorff if and only if it is soft ω – Hausdorff.

ii. Let $\ddot{I}_s = P(\dot{V}, Q)$. Then $(\dot{V}, \tau_s, Q, \ddot{I}_s)$ is soft Hausdorff if and only if it is soft $\alpha\omega\ddot{I}_s$ – Hausdorff.

Proof:

i. Let $\ddot{I}_s = (\{\},Q)$. Then $(\mathcal{F},Q)\omega^* = Cl(\mathcal{F},Q)$ and $\omega Cl^{*s}(\mathcal{F},Q) = (\mathcal{F},Q) \cup (\mathcal{F},Q)\omega^* = Cl(\mathcal{F},Q)$ for every subset $(\mathcal{F},Q)$ of $(\dot{V},Q)$. Therefore, we have soft α-

Ïs – open set is equal to the soft open set and hence, (Ỿ,Ƈ s,Q,Ïs) is soft αωÏs – Hausdorff if and only if it is soft ω – Hausdorff.

ii. Let Ïs = P({Ỿ, Q). Then (Ƒ, Q)ω* = ({}, Q) and ωCl*s(Ƒ,Q) = (Ƒ,Q) for every soft subset (Ƒ,Q) of Ỿ. Let (Ƒ, Q) belongs to soft α-Ïs – open. Then (Ƒ,Q) ⊆ ωCl*s(int(Ƒ,Q)) = int (Ƒ,Q) and hence, (Ỿ, Ƈ s,Q,Ïs) is soft Hausdorff if and only if it is soft αωÏs – Hausdorff.

4. Soft $\alpha\omega$ïs – Normal Space In Soft Ideal Topological Spaces

In this section we introduce and study about a new normal space is known as soft αωÏs – Normal space in Soft ideal topological spaces.

4.1 Definition

A soft ideal topological space (Ỿ,Ƈ s,Q,Ïs) is said to be soft αωÏs – Normal space, if for every pair of disjoint soft closed sets (F,Q) and (G,Q), there exist soft αωÏs – open sets (Ẋ,Q) and Ẏ,Q such that (F,Q) ⊆ (Ẋ,Q) and (G,Q) ⊆ (Ẏ,Q).

4.2 Example

Let Ỿ = { α, β, γ },

Q = { σ },

Ƈ s = {({},Q),(Ỿ,Q),(Ƒ1,Q),(Ƒ2,Q)},

Ïs = {({},Q), (Ƒ3,Q)}

where

(Ƒ1,Q) = {{},{ α }},

(Ƒ2,Q) = {{ β },{ α, β }},

(Ƒ3,Q) = {{ β }},{ γ }} are soft sets over Ỿ.

Here, {{ β },{ α, β }} and {{ β }},{ γ }}

are soft αωÏs – Normal space in (Ỿ,Ƈ s,Q,Ïs).

4.3 Theorem Let (Ỿ, Ƈ s,Q,Ïs) be a soft ideal topological space then the following statements are equivalent:

i. (Ỿ,Ƈ s,Q,Ïs) is soft αωÏs – Normal space.
ii. For all soft αωÏs – closed set (F,Q) and for each neighborhood (Ẋ,Q) of (F,Q) there exist soft αωÏs – open neighborhood (Ẏ,Q) of (F,Q) such that soft αωÏsCl(Ẏ,Q) ⊆ (Ẋ,Q)
iii. For each pair of the soft αωÏs – closed set (F,Q) and (G,Q) there exists soft αωÏs – open neighborhood (Ẋ,Q) of (F,Q) such that soft αωÏsCl(Ẋ,Q) ∩ (G,Q) = ({},Q).
iv. For each pair of the soft αωÏs – closed set (F,Q) and (G,Q) there exists soft αωÏs – open neighborhood (Ẋ,Q) of (F,Q) and (Ẏ,Q) of (G,Q) such that (Ẋ,Q) ∩ (Ẏ,Q) = ({},Q).

Proof:

(i) ⇒ (ii) Let (Ỿ,Ƈ s,Q,Ïs) is soft αωÏs – Normal space. Let (F, Q) soft αωÏs – closed set and $(\dot{X}, Q)$ be any open neighborhood (F, Q). Let the soft αωÏs – closed set (F, Q) and

$(\dot{Y}, Q) - (\dot{X}, Q)$ and $(F, Q) \subseteq (\dot{X}, Q)$

implies that

$(F, Q) \cap ((\dot{Y}, Q) - (\dot{X}, Q)) = (\{\}, Q)$.

Since $(\dot{Y}, Q)$ is soft αωÏs – Normal space there exist soft αωÏs – open neighborhood $(\dot{Y}, Q)$ of (F, Q) and $(\dot{Z}, Q)$ of $((\dot{Y}, Q) - (\dot{X}, Q))$

such that

$(\dot{Y}, Q) \cap (\dot{Z}, Q) = (\{\}, Q)$.

Now

$(\dot{Y}, Q) \cap (\dot{Z}, Q) = (\{\}, Q)$

which implies that

$(\dot{Y}, Q) \subseteq ((\dot{Y}, Q) - (\dot{Z}, Q))$.

Since

$(\dot{Y}, Q) - (\dot{Z}, Q)$ is soft αωÏs – closed, soft αωÏsCl$(\dot{Y}, Q) \subseteq$ soft αωÏsCl$((\dot{Y}, Q) - (\dot{Z}, Q)) = (\dot{Y}, Q) - (\dot{Z}, Q)$.

Therefore soft αωÏsCl$(\dot{Y}, Q) \cap (\dot{Z}, Q) = (\{\}, Q)$ and soft αωÏsCl$(\dot{Y}, Q) \cap ((\dot{Y}, Q) - (\dot{X}, Q)) \subseteq$ soft αωÏsCl$(\dot{Y}, Q) \cap (\dot{Z}, Q) = (\{\}, Q)$, thus soft αωÏsCl$(\dot{Y}, Q) \subseteq (\dot{X}, Q)$.

(ii) ⇒ (iii) Let (F, Q) and (G, Q) be disjoint soft αωÏs – closed sets.

Since

$(F, Q) \cap (G, Q) = (\{\}, Q)$ and $(\dot{Y}, Q) - (G, Q)$ be soft αωÏs – open, we have (H,Q) ⊆ $(\dot{Y}, Q) - (G, Q)$.

Hence

$(\dot{Y}, Q) - (G, Q)$ is soft αωÏs – open neighborhood $(\dot{X}, Q)$ of (F, Q) such that soft αωÏsCl$(\dot{X}, Q) \subseteq (\dot{Y}, Q) - (G, Q)$. Therefore, soft αωÏsCl$(\dot{X}, Q) \cap (G, Q) = (\{\}, Q)$.

(iii) ⇒ (iv) Let (F, Q) and (G, Q) be disjoint soft αωÏs – closed sets. By (iii) there exists soft αωÏs – open neighborhood $(\dot{X}, Q)$ of (F, Q) such that soft αωÏsCl$(\dot{X}, Q) \cap (G, Q) = (\{\}, Q)$. Now (G, Q) and soft αωÏsCl$(\dot{X}, Q)$ are disjoint soft αωÏs – closed sets. Hence by (iii), there exists soft αωÏs – open neighborhood $(\dot{Y}, Q)$ of (G, Q) such that soft αωÏsCl$(\dot{Y}, Q) \cap (G, Q) = (\{\}, Q)$.

(iv) ⇒ (i) Let (F, Q) and (G, Q) be disjoint soft αωÏs – closed sets. By (iv) there exists soft αωÏs – open neighborhood $(\dot{X}, Q)$ of (F, Q) and $(\dot{Y}, Q)$ of (G, Q) such that $(\dot{X}, Q) \cap (\dot{Y}, Q) = (\{\}, Q)$. Since $(\{\}, Q) \subseteq (\dot{X}, Q) \cap (\dot{Y}, Q) = (\{\}, Q)$. Hence, (Ỿ,Ƈ s,Q,Ïs) is soft αωÏs – Normal.

4.4 Theorem

Let (Ỿ,Ƈ s,Q,Ïs) be a soft ideal topological space. Then every soft ω– Normal is soft αωÏs – Normal.

Proof:

Suppose ((Ỿ,Ƈ s,Q,Ïs) is soft ω-Normal. Let (F, Q) and (G, Q) be disjoint soft ω – closed sets. Then $(F, Q) \cap (G, Q) = (\{\}, Q)$, if (F, Q) and (G, Q) are soft ω – closed sets. By inclusion of soft ω –closed classes, each of (F, Q) and (G, Q) are also soft αωÏs – closed. Since the space is αωÏs – Normal space. Then there exist soft αωÏs-open sets $(\dot{X}, Q)$ and $(\dot{Y}, Q)$ such that $(F, Q) \subseteq (\dot{X}, Q)$ and $(G, Q) \subseteq (\dot{Y}, Q)$, $(\dot{X}, Q) \cap (\dot{Y}, Q) = (\{\}, Q)$.

The converse of the above theorem need not be true as seen from the following Example.

4.5 Example

Let Ṿ = $\{\alpha, \beta, \gamma, \delta\}$,

$Q = \{\sigma\}$,

$\mathcal{T}_s$ = {({},Q),(Ṿ,Q),($\mathcal{F}_1$,Q),($\mathcal{F}_2$,Q),($\mathcal{F}_3$,Q)}

Ïs = {({},Q),($\mathcal{F}_4$,Q), ($\mathcal{F}_5$,Q)} where

($\mathcal{F}_1$,Q) = {{},{α}},

($\mathcal{F}_2$,Q) = {{β},{α, β}},

($\mathcal{F}_3$,Q) = {{Ṿ}, {β}},

($\mathcal{F}_4$,Q) = {{},{γ}},

($\mathcal{F}_5$,Q) ={{β, δ},{β, γ, δ}}

are soft sets over Ṿ.

Here, ($\mathcal{F}_3$,Q) and ($\mathcal{F}_4$,Q) are soft ω – Normal but not soft αωÏs – Normal space in (Ṿ,$\mathcal{T}$ s,Q,Ïs).

4.6 Theorem

Let (Ṿ,$\mathcal{T}$ s,Q,Ïs) be a soft ideal topological space which is soft αωÏs – Normal. Then the following hold:

i. For every soft closed set (F, Q) and a soft ω-open set (G, Q) containing (F, Q), there exist soft αωÏs – open set ($\dot{X}, Q$) such that (F, Q) ⊆ int$_s^*$($\dot{X}, Q$) ⊆ ($\dot{X}, Q$) ⊆ (G, Q).

ii. For every soft ω-closed set (F, Q) and every open set (G, Q) containing (F, Q), there exists soft αωÏs – open set ($\dot{X}, Q$) such that (F, Q) ⊆ ($\dot{X}, Q$) ⊆ cl$_s^*$($\dot{X}, Q$) ⊆ (G, Q).

Proof:

(i) Let (F, Q) be a soft closed set and (G, Q) be a soft ω-open set containing (F, Q). Then (F, Q) ∩ (($\dot{V}, Q$) – (G, Q)) = ({}, Q) where (F, Q) be a soft closed and ($\dot{V}, Q$) – (G, Q) is soft ω-closed set. Then there exist disjoint soft αωÏs – open set ($\dot{X}, Q$) and ($\dot{Y}, Q$) such that (F, Q) ⊆ ($\dot{X}, Q$) and (($\dot{V}, Q$) – (G, Q)) ⊆ ($\dot{Y}, Q$). Since ($\dot{X}, Q$) ∩ ($\dot{Y}, Q$) = ({}, Q), we have ($\dot{X}, Q$) – (G, Q) ⊆ ($\dot{Y}, Q$). Therefore, (F, Q) ⊆ int$_s^*$($\dot{X}, Q$) ⊆ ($\dot{X}, Q$) ⊆ (($\dot{V}, Q$) – (G, Q)) ⊆ (G, Q).

(ii) Let (F, Q) be a soft ω - closed set and (G, Q) be a soft α-Ïs-open set containing (F, Q). Then (($\dot{V}, Q$) – (G, Q)) be a soft α-Ïs-closed set contained in the soft ω – open set (($\dot{V}, Q$) – (G, Q)). By (i), there exist soft αωÏs – open set ($\dot{Y}, Q$) such that ($\dot{X}, Q$) – (G, Q) ⊆ int$_s^*$($\dot{Y}, Q$) ⊆ ($\dot{Y}, Q$) ⊆ (($\dot{V}, Q$) – (F, Q)). Therefore, (F, Q) ⊆ (($\dot{V}, Q$) – ($\dot{Y}, Q$)) ⊆ cl$_s^*$(($\dot{V}, Q$) – ($\dot{Y}, Q$)) ⊆ (G, Q). If ($\dot{X}, Q$) = (($\dot{V}, Q$) – ($\dot{Y}, Q$)), then (F, Q) ⊆ ($\dot{X}, Q$) ⊆ cl$_s^*$($\dot{X}, Q$) ⊆ (G, Q) and so ($\dot{X}, Q$) is the required soft αωÏs – closed set in (Ṿ,$\mathcal{T}$ s,Q,Ïs).

5. SOFT αωÏs – REGULAR SPACE IN SOFT IDEAL TOPOLOGICAL SPACES

In this section we introduce and study about a new regular space is known as soft αωÏs –Regular space in Soft ideal topological spaces.

5.1 Definition

A soft ideal topological space (Ṿ,$\mathcal{T}$ s,Q,Ïs) is said to be soft αωÏs – Regular space, if for each pair of point x and a soft closed set (G,Q) not containing (x,Q), there exist disjoint soft αωÏs – open sets (Ẋ,Q) and Ẏ,Q such that x ⊆ (Ẋ,Q) and (G,Q) ⊆ (Ẏ,Q).

5.2 Example 2

Let Ṿ = $\{\alpha, \beta, \gamma, \delta\}$,

$Q = \{\sigma\}$,

$\mathcal{T}_s$ = {({},Q),(Ṿ,Q),
($\mathcal{F}_1$,Q),($\mathcal{F}_2$,Q),($\mathcal{F}_3$,Q)}

Ïs = SS (Ṿ)$_Q$ where

($\mathcal{F}_1$,Q) = {{},{α}},

($\mathcal{F}_2$,Q) = {{},{α, β}},

($\mathcal{F}_3$,Q) = {{Ṿ}, {β}}

are soft sets over Ṿ.

Then (Ṿ,$\mathcal{T}$ s,Q,Ïs) is soft αωÏs – Regular space..

5.3 Theorem

Let ((Ṿ,$\mathcal{T}$ s,Q,Ïs) be a soft ideal topological space and x ∈ (Ṿ,Q). Then the following are equivalent :

i. (Ṿ,$\mathcal{T}$ s,Q,Ïs) is soft αωÏs – Regular space.

ii. For every soft ω – closed set (F, Q) such that (x,Q) ∩ (F,Q) = ({},Q), there exist disjoint soft ω – open set (G$_1$,Q) and (G$_2$,Q) such that (x,Q) – (G$_1$,Q) ∈ Ïs and (F,Q) – (G$_2$,Q) ∈ Ïs.

Proof:

(i) ⇒ (ii) For every soft ω – closed set (F, Q) such that (x,Q) ∩ (F,Q) = ({},Q). Then x ∉ (F,Q). By hypothesis, there exist disjoint soft αωÏs – open sets (G$_1$,Q) and (G$_2$,Q) such that (x,Q) – (G$_1$,Q) ∈ Ïs and (F,Q) – (G$_2$,Q) ∈ Ïs.

(ii) (ii) ⇒ (i) Let (F,Q) be a soft ω – closed set such that x ∉ (F,Q). Then (x,Q) ∩ (F,Q) = ({},Q). there exist disjoint soft αωÏs – open sets (G$_1$,Q) and (G$_2$,Q) such that (x, Q) – (G$_1$, Q) ∈ Ïs and (F,Q) – (G$_2$,Q) ∈ Ïs. Therefore, (Ṿ,$\mathcal{T}$ s,Q,Ïs s) is soft αωÏs – Regular space.

5.4 Theorem

A soft subspace (Ṿ$_1$,$\mathcal{T}$ 1s,Q,Ï1s) of a soft αωÏs – Regular space (Ṿ,$\mathcal{T}$ s,Q,Ïs) is soft αωÏ1s – Regular space.

Proof:

Let y ∈ Ṿ$_1$ and (G,Q) be a soft ω – closed set in Ṿ$_1$. Such that y ∉ (G$_1$,Q).

Then (G,Q) = (Ṿ$_1$,Q) ∩ (F,Q) for some soft ω – closed set (F,Q) in Ṿ and y ∉ (F,Q).

Since ((Ṿ,$\mathcal{T}$ s,Q,Ïs) is soft αωÏs – Regular space, there exist disjoint soft ω – open set (F$_1$, Q) and (F$_2$,Q) in Ṿ such that y ∈ (F$_1$,Q) and ((F,Q) −(F$_1$,Q)) ∈ Ïs. Then, we have ((F,Q) −(F$_2$,Q)) ∩ (Ṿ$_1$,Q) ∈ Ï$_1$s. Since (Ṿ$_1$,Q) ∩ (F$_1$,Q) and (Ṿ$_1$,Q) ∩ (F$_2$,Q) are disjoint soft ω – open sets, (Ṿ$_1$,$\mathcal{T}$ 1s, Q ,Ï1s) is soft αωÏ1s – Regular space.

5.5 Theorem

Let $m_{\rho\mu} : SS(\dot{V})_Q \rightarrow SS(\hat{W})_N$ be a soft function which is bijective, soft irresolute and soft open irresolute. If $(\dot{V},\dot{C}_s,Q,\ddot{I}_s)$ is soft $\alpha\omega\ddot{I}s$ – Regular space, then $(\hat{W},\dot{Q}_s,N,\ddot{I}_s)$ is a soft $\alpha\omega$-$m_{\rho\mu}(\ddot{I}_s)$ – Regular space.

Proof: Let (G,N) be a soft ω – closed set in $(\hat{W},N)$ and (w,N) ∈ $(\hat{W},N)$ such that (w,N) ∉ (G,N). Since $m_{\rho\mu}$ is a homeomorphism soft function, then there exist $(\dot{v},Q) \in (\dot{V},Q)$ such that $m_{\rho\mu}(\dot{v},Q)$ = (w,N) and (F,Q) = $m^{-1}{}_{\rho\mu}$(G,N) is a soft ω – closed set in $(\dot{V},Q)$ such that $(\dot{V},Q) \notin$ (F,Q). By hypothesis, there exist disjoint soft ω – open set (F_1,Q) and (F_2,Q) such that $(\dot{V},Q) \in (F_1,Q)$ and (F_2,Q) – (F,Q) ∈ $\ddot{I}_s$. It follows that, (F,Q)∈ $F_Q(e)$ for all e ∈ Q and $m_{\rho\mu}[(F_2,Q) - (F,Q)] \in m_{\rho\mu}(\ddot{I}_s)$. Hence $m_{\rho\mu}(\dot{v},Q)$ = (w,N) ∈ $m_{\rho\mu}[F_Q(e)]$ for all e ∈ Q. Therefore, $(\hat{W},\dot{Q}_s,N,\ddot{I}_s)$ is a soft $\alpha\omega$-$m_{\rho\mu}(\ddot{I}_s)$ – Regular space.

5.6 Theorem

Let $(\dot{V},\dot{C}_s,Q,\ddot{I}_s)$ be a soft ideal topological space and $(\dot{v},Q) \in (\dot{V},Q)$then the following statements are equivalent:

i. $(\dot{V},\dot{C}_s,Q,\ddot{I}_s)$ is soft $\alpha\omega\ddot{I}_s$ – Regular space.
ii. For all soft $\alpha\omega\ddot{I}_s$ – open set (F,Q), there exist soft $\alpha\omega\ddot{I}_s$ – open neighborhood $(\dot{v},Q) \in (F,Q)$ and soft $\alpha\omega\ddot{I}_s Cl(F,Q) - (\dot{X},Q) \in \ddot{I}s$.
iii. For all soft $\alpha\omega\ddot{I}_s$ – closed set (G,Q), there exist soft $\alpha\omega\ddot{I}_s$ – open neighborhood $(\dot{v},Q) \notin (G,Q)$ and soft $\alpha\omega\ddot{I}_s Cl(\dot{X},Q) \cap (G,Q) \in \ddot{I}s$.

Proof:

(i) ⇒ (ii) Let (F,Q) be a soft $\alpha\omega\ddot{I}_s$– open set such that $(\dot{v},Q) \in (F,Q)$. Then $(F,Q)'$ is a soft $\alpha\omega\ddot{I}_s$– closed set such that $(\dot{v},Q) \notin (F,Q)'$. It follows by (i), there exist disjoint soft $\alpha\omega\ddot{I}_s$ – open sets (H, Q) and (K,Q) such that $(\dot{v},Q) \in$ (H, Q) and $(F,Q)'$ – (K, Q) = (K, Q)' – (F, Q) ∈ $\ddot{I}_s$. Since (H, Q) ∩ (K,Q) = ({}, Q). Then (H, Q) ⊆ (K,Q)'. So soft $\alpha\omega\ddot{I}_s Cl$(H, Q) ⊆ (K,Q)'. Hence, soft $\alpha\omega\ddot{I}_s Cl$(H, Q) − (F, Q)⊆ (K,Q)' − (F, Q) ∈ $\ddot{I}_s$ which implies that soft $\alpha\omega\ddot{I}_s Cl(F,Q) - (\dot{X},Q) \in \ddot{I}_s$.

(ii) ⇒ (iii) Let (G,Q) soft $\alpha\omega\ddot{I}_s$– closed set such that $(\dot{v},Q) \notin (G,Q)$. Then $(G,Q)'$ soft $\alpha\omega\ddot{I}_s$– open set such that $(\dot{v},Q) \in (G,Q)'$ from (ii), there exist soft $\alpha\omega\ddot{I}_s$– open set (J, Q)

such that $(\dot{v},Q) \in (J,Q)$ and soft $\alpha\omega\ddot{I}_s Cl(J,Q) - (G,Q)'$= soft $\alpha\omega\ddot{I}_s Cl(J,Q) \cap (G,Q) \in \ddot{I}_s$.

(iii) ⇒ (i) Let (K,Q) be a soft $\alpha\omega\ddot{I}_s$– closed set such that $(\dot{v},Q) \notin (K,Q)$. From (iii) there exist soft $\alpha\omega\ddot{I}_s$– open set (J, Q) such that $(\dot{v},Q) \in (J,Q)$ and soft $\alpha\omega\ddot{I}_s Cl(J,Q) \cap (G,Q)$ = (J,Q) − [soft $\alpha\omega\ddot{I}_s Cl(J,Q)$]' ∈ Ïs, where, (J,Q) and [soft $\alpha\omega\ddot{I}_s Cl(J,Q)$]' are disjoint soft $\alpha\omega\ddot{I}_s$– o pen sets. Therefore, $(\dot{V},\dot{C}_s,Q,\ddot{I}_s)$ is soft $\alpha\omega\ddot{I}_s$ – Regular space.

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RESEARCH ARTICLE

ABUTILON INDICUM: A REVIEW ON ITS ETHNOBOTONY, PHYTOCHEMICAL AND PHARMACOLOGICAL PROFILE

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Abstract

Medicinal plants have been used worldwide for a long time to treat human ailments, acting as a dependable source of medicine for various diseases and conditions within complementary healing systems. It is a native plant of tropical and subtropical regions of India, known for its significant medicinal benefits. The wide-ranging pharmacological impacts of *Abutilon indicum* arise from the existence of various categories of active biological substances within it. Traditionally, *A. indicum* has been employed to address various conditions, such as urinary issues, rheumatism, leprosy, ulcers, elevated fever, jaundice, pulmonary tuberculosis, gonorrhoea, as an aphrodisiac, bronchitis, mumps, urinary retention, along with specific neurological and hearing problems. Research has previously been carried out worldwide on the pharmacological, biological, and isolation of metabolites and biologically active compounds from this plant. Nevertheless, the research to assess the overall therapeutic properties of this plant still requires to be conducted. This document offers a concise summary of the pharmacological traits of *A. indicum* that could assist in upcoming clinical and experimental studies

KEYWORDS

Abutilon indicum, Pharmacological activities, therapeutic values, human diseases.

Introduction:

A. indicum (Indian abutilon, Indian mallow) is a small shrub belonging to the Malvaceae family, originating from the tropical and subtropical areas of India. In Sanskrit or Hindi, it is referred to as "Atibala." The term "Ati" means to "Very," while "Bala" signifies "Powerful," highlighting the attributes of this plant as highly potent. Malvaceae, also known as the mallows, is a family of flowering plants thought to encompass 244 genera with 4225 recognized species. Notable economically significant members comprise okra, cotton, cacao, roselle, and durian. Certain genera include well-known ornamental plants, including Alcea (hollyhock), Malva (mallow), and Tilia (lime or linden tree). The genera with the highest species counts are Hibiscus (434 species), Pavonia (291 species), Sida (275 species), Ayenia (216 species), Dombeya (197 species), and Sterculia (181 species). Traditional and folk medicine have long noted that *A. indicum*plants possess various pharmacological and therapeutic benefits. The phytoconstituents of *Abutilon indicum*, comprising roots, leaves, flowers, bark, seeds, and stems, have been used in traditional medical practices. *A. indicum* is utilized in traditional medicine as a pulmonary agent and sedative (leaves), aphrodisiac, laxative, and diuretic [1]. Additionally, various parts of plants hold unique phytoconstituents that are accountable for their biological effects. Additionally, a vast array of literature exists highlighting the effectiveness of different plants from this species in addressing pharmacological disorders and health issues [2]. This plant serves as both a medicinal and decorative species, with its roots and leaves utilized in treating fevers. It has been extensively introduced beyond its original habitat and is deemed invasive in some tropical island regions

Plant description:

A. indicum is a lasting shrub, gently hairy and reaching up to 3 meters in height. The leaves are persistent, base-cordate, stipulate, filamentous, ovate, acuminate, serrated, occasionally subtrilobate, and measure 1.9-2.5 cm in length. Petiole 1.5-1.70cm in length, cylindrical, with a yellowish hue, star-shaped, and hairy. The flowers have a yellow hue, with the peduncle jointed above the center. The petioles measure 3.8-7.5 cm in length; stipules are 9 mm long; pedicels typically range from 2.5-5 mm, solitary in axils, jointed just below the apex, and the seeds are 3-5 mm, kidney-shaped, reniform, tuberculate or finely stellate-hairy, black or dark brown. *A. indicum* has been utilized as anthelmintic, antiemetic, anti-inflammatory, for urinary or uterine

secretion, hemorrhoids, and as an antidote. It is utilized in the treatment of fever, dry cough, bronchitis, gonorrhea, and leprosy.

Table 1: Description of *A. indicum* Plant [1].

Picture	Parts	Description
	Flower	Flowers are yellow, the peduncle is joined above the middle. The petioles 3.8-7.5 cm long; stipules 9 mm long; pedicels often 2.5-5 mm long, calyx 12.8 mm long, divided in to the middle, lobes ovate, apiculate and corolla 2.5 cm diameter.
	Seed & Fruit	Fruits are capsule, densely pubescent, with conspicuous and horizontally spreading beaks & seeds are 3-5 mm, reniform, tubercled or minutely stellate-hairy, black or dark brown
	Stem & Leaves	The stems are stout, branched, 1-2 m tall, and pubescent & Leaves are ovate, acuminate, toothed, rarely subtrilobate and 1.9-2.5 cm long

Distribution:

The species is found in various tropical and subtropical regions and climates. The plant occurs in India, Sri Lanka, tropical areas of America and Malaysia. It is regarded as a weed in sub-Himalayan regions, on hills up to 1200m, and in the warmer areas of India. An instance can be found in sections of the 'Great Barrier Reef' islands of the 'Coral Sea' [3].

Taxonomical classification:

Kingdom	:	Plantae
Clade	:	Tracheophytes
Clade	:	Angiosperms
Clade	:	Eudicots
Clade	:	Rosids
Order	:	Malvales
Family	:	Malvaceae
Genus	:	Abutilon
Species	:	A. indicum

Vernacular names of Abutilon indicum:

Tamil	:	Tutti, Paniara, Hutti
Hindi	:	Kanghi, Kakahi
Telugu	:	Utturu benda Duvvenakaya, Duvvena Kayalu
English	:	Country mallow, Indian mallow
Bengali	:	Petari
Malayalam	:	Dabi, Uram , Vellula
Guajarati	:	Khapat, Kansi, Dabli
Marathi	:	Mudra, Petari
Arabian	:	Masthul Gola
Kannada	:	Tutti
Farsi	:	Darakhtashaan

Common Name: Abutilon, Indian mallow

PHYTOCHEMISTRY:

Various researchers have examined *A. indicum* phytochemically and discovered it contains several chemical constituents.

Table 2: Phyto constituents of *A. indicum* [1].

Plant Parts	Phyto constituents of *A. indicum*
Whole plant	The entire plant has mucilaginous compounds, asparagines, saponins, flavonoids, alkaloids, hexoses, and n-alkane blends. Key components found in the plant include β-sitosterol, vanillic acid, p-coumaric acid, caffeic acid, fumaric acid, Abutilon A, (R)-N-(1'-methoxycarbonyl-2'phenylethyl)-4-hydroxybenzamide, hydroxybenzoic, galacturonic, β-D-glycosyloxybenzoic and amino acids. The plant *A. indicum* possesses essential oil primarily composed of α-pinene, caryophyllene, caryophyllene oxide, endesmol, farnesol, borneol, geraniol, geranyl acetate, element, and α-cineole.
Roots	Non-drying oil derived from the roots contains a variety of fatty acids, including linoleic, oleic, stearic, palmitic, lauric, myristic, caprylic, capric, and a rare fatty acid with a C17 carbon structure, along with sitosterol and amyrin obtained from unsaponifiable substances.
Leaves	The plant's leaves have carbohydrates, steroids, sapogenins, and flavonoids. Eudesmic acid, ferulic acid, and caffeic acid were extracted from the methanol leaf extract, while fatty acids and esters were identified in the ethanolic leaf extract.
Flowers	Seven flavonoid compounds—luteolin, chrysoeriol, luteolin 7-O-betaglucopyranoside, chrysoeriol 7-O-betaglucopyranoside, apigenin 7-O-beta-glucopyranoside, quercetin 3-O-beta-glucopyranoside, and quercetin 3-O-alpha-rhamnopyranosyl (1 --> 6)-betaglucopyranoside—were extracted and characterized from the flowers. Two sesquiterpene lactones, namely alantolatone and isoalantolactone, have been documented.
Fruits	Fruits contain flavonoids and alkaloids
Seeds	A galactomannan that dissolves in water has been extracted from the seeds that have -galactose and -mannose in a 2:3 molar ratio. The plant's seed oil provides cis 12, 13-epoxyoleic (vernolic) acid, 9, 10-methylene octadec-9-enoic (sterculic) acid, and 8, 9-methylene-heptadec-8-enoic (malvalic) acid. Seed oil showed a significant presence of unsaturated fatty acids. Stearic and palmitic acids, Raffinose was discovered in seeds. The amino acid composition of seed proteins (31%) includes threonine, glycine, serine, glutamine, lysine, methionine, isoleucine, proline, alanine, cysteine, tyrosine, phenylalanine, leucine, asparagine, histidine, valine, and arginine.

Traditional Uses:

Almost all the parts of *A. indicum* are of medicinal importance and traditionally used for the treatment of various ailments.

Table 3: Traditional Uses of *A. indicum* [4].

Parts	Traditional uses
Roots	Demulsant, diuretic, in chest infection and urethritis.
Infusion of the root	Prescribed in fevers as a cooling medicine and is considered useful in strngury, haematuria and in leprosy.
Leaves	Ulcer and as a fomentation to painful parts of body.
Decoction of the leaves	Toothache, tender gums and internally for inflammation of bladder.
Bark	Febrifuge, anthelmentic, alexeteric, astringent and diuretic.
Seeds	Piles, laxatives, expectorants, in chronic cysticis, gleet and gonorrhea

Ethanobotanical Uses:

India is home to more than 400 distinct tribal and ethnic groups. Every tribal community possesses its own traditions, vernaculars, beliefs, and knowledge regarding the use of natural resources as medicinal aids. Nearly all the components of this plant are recorded as beneficial in ethnobotanical studies carried out by ethnobotanists. Records indicate that indigenous people from India, Malaya, the Philippine Islands, and Indochina utilize its components for medicinal uses like fever reduction, worm expulsion, nausea prevention, inflammation reduction, urinary or uterine discharge issues, hemorrhoids, and lower back pain [4].

Table 4: Ethanobotanical Uses of *A. indicum*

Parts	Ethanobotanical uses
Leaf	1. The seeds and leaves are ground with water to create a paste that is applied to the penis to treat syphilis. 2. The leaves are utilized in eye rinse, mouth rinse, for cataracts, and diarrhea. 3. A paste made from leaves is consumed to treat hemorrhoids and alleviate leg pain. 4. The bread made from a blend of leaf powder and wheat flour is consumed each night for roughly a month to treat uterus displacement. 5. The juice of the leaf, when combined with jiggery, is employed in treating snakebites as an antidote [5].
Fruit	1. The fruit is utilized for treating piles, gonorrhea, and cough. 2. A mixture of fruit decoction and ammonium chloride is administered orally with water for the treatment of hemorrhagic septicaemia.[6].
Seed	Seed powder is used orally with water as aphrodisiac and laxative.
Root	1. The plant's root is used for treating gonorrhea and leprosy. 2. Root infusion is administered to treat fever, dry cough, and bronchitis [7].

Pharmacological activities:

Table 5: Pharmacological activities of *A. indicum*

S.No	Diseases	Activity
01	Hepatoprotective:	The water extract of *A. indicum* was evaluated for its hepatoprotective effects against hepatotoxicities caused by carbon tetrachloride and paracetamol in rats. The plant showed notable hepatoprotective effects by mitigating changes in biological parameters induced by carbon-tetrachloride and paracetamol, which was clear through enzymatic analysis. The extract from the plant might disrupt free radical production, potentially resulting in liver-protective effects. *A. indicum* demonstrated significant hepatoprotective effects against carbon tetrachloride and paracetamol, comparable to the standard silymarin [8].

02	Hypoglycemic activity:	The alcohol and water extracts of *A. indicum* leaves (400mg/kg, p.o.) demonstrate a notable hypoglycemic effect in normal rats four hours post-administration (23.10% and 26.95% respectively). The aqueous extract was also shown to be highly effective in lowering blood glucose levels. [9].
03	Immunomodulatory activity:	The entire powdered form of the plant at a dosage of 500mg/kg body weight indicated a statistically significant increase in modulatory behavior across all models when compared to the control group (9)
04	Analgesic activity:	Pet ether and benzene extracts demonstrated significant analgesic properties. The plant's fixed oil demonstrates strong analgesic properties when administered in doses of 400 and 600mg/kg. Eugenol (4-allyl-2-methoxyphenol) extracted from *A. indicum* has been shown to have considerable analgesic effects [10].
05	Antimicrobial activity:	Extracts from *A. indicum* (fruits, roots, and leaves) exhibit no notable inhibition against the microorganisms *Bacillus cereus var mycoids, Bacillus pumilus, Bacillus subtillis, Bordetella bronchiseptica, Micrococcus luteus, Staphylococcus aureus, Staphylococcus epidermis, Escherrchia coli, Klebsiella pneumonia, pseudomonas aeruginosa, Steptococcus faecalis, Candida albicans, Aspergillus niger, Saccharomyces cerevisia.* The lack of activity against the aforementioned strains indicates that the plant lacks antimicrobial properties. The examination of the seeds of *A. indicum* (L.) shows Mycelial inhibition (%) against *Absidia ramos* and *Aspergillus niger* by 6.97 and 37.25 respectively [11].
06	Antimalarial activity:	Beta-sitosterol isolated from the petrollium ether extract of leaf of *A. indicum* showed mosquito larvicidal activity [12].
07	Anti-diarrhoeal activity:	The research demonstrated that both the methanolic extract and the aqueous extract exhibited considerable anti-diarrheal effects in diarrhea induced by Castor oil and prostaglandin E2, in comparison to the control group [13].
08	Anti estrogenic activity	The methanolic extracts of *A. indicum* exhibit an anti-estrogenic impact on uterotropic and uterine peroxidase functions in ovariectomized rats. This extract was identified to result in considerable inhibition of enzyme activity and the uterotropic response triggered by estradiol, while in the group not exposed to estradiol, a slight increase in peroxidase activity was noted [14].
09	In vitro anti arthritic activity	An extract of *A. indicum (Linn.)* that is soluble in water was examined through three in vitro parameters: protein denaturation, membrane stabilization, and protease inhibition. A. indicumat dosages of 100 and 250 mcg/ml offered considerable protection from protein denaturation and damage to RBC membranes caused by hypotonic saline. It also showed notable anti-protease activity [16].
10	Diuretic activity	Seed extract of *A. indicum* (200 and 400 mg/kg) was assessed for its diuretic properties. The extract at dosages of 200 and 400 mg/kg resulted in a notable dose-dependent rise in urinary excretion and sodium loss, but it did not impact the intrinsic potassium-sparing effect [15].
11	Anticancer activity	Srikanth P et al selected medicinal plants, specifically A. indicumand Blumea mollis, to evaluate their potential anti-oxidant properties and cytotoxic effects. The extract was also evaluated for its antioxidant activity via FRAP, 1, 1-Diphenyl-2-picrylhydrazyl [DPPH] radical scavenging, and Nitric Oxide radical inhibition assessed through the Griess Illosvoy reaction with minor modifications. These extracts demonstrate antioxidant qualities and a suppressive effect on cancer cells with higher concentration and extended duration [13].

12	Anti convulsant activity	Golwala et al. investigated the anticonvulsant properties of *A. indicum* leaf extracts. The ethanolic extract was observed to enhance the onset of clonic convulsions while reducing the onset of tonic seizures, demonstrating a notable anticonvulsant effect. The water extracts demonstrated a notable protective effect by prolonging the onset of clonic convulsion time and reducing extensor time in comparison to the control group. The anticonvulsant effect was ascribed to linoleic acid and/or flavonoid components found in the extracts [17].
13	Larvicidal activity	The toxicity of crude hexane, ethyl acetate, petroleum ether, acetone, and methanolic extracts of *A. indicum* was evaluated for their larvicidal activity. All extracts demonstrated moderate effects on larvae. However, the greatest larval mortality was observed in the petroleum ether extract. Additionally, the identification of β-sitosterol as a potential novel mosquito larvicidal agent was verified through 1 H NMR, 13C NMR, and mass spectrometry data, showing an LC50 value of 26.67 ppm against C. quinquefasciatus [18].
14	Wound healing activity	[18] assessed the wound healing properties of *A. indicum* Linn. There was a notable rise in the rate of wound closure. All the extracts were collected for phytochemical analysis. The gradual alterations in the wound area were observed by outlining the wound edge daily. The findings indicate that the petroleum ether extract of "*A. indicum*" Linn exhibited more effective wound healing activity compared to the ethanol extract [19].
15	Anti asthmatic activity	This research highlighted the efficacy of powder from the dried aerial components of *A. indicum* in reducing the intensity of typical symptoms associated with bronchial asthma, such as dyspnoea, cough, chest tightness, and wheezing. It was also observed to notably enhance pulmonary function assessed by forced vital capacity (FVC), forced expiratory volume in 1 second (FEV1), and peak expiratory flow rate (PEFR) in individuals with mild to moderate bronchial asthma [20].

CONCLUSION

A. indicum possesses multiple pharmacological properties, including Hepatoprotective effects, Hypoglycemic effects, Immunomodulatory effects, Analgesic effects, Anti-microbial effects, Anti-malarial effects, Anti-Diarrhoeal effects, Anti-Estrogenic effects, Wound Healing effects, In Vitro Anti-Arthritic effects, Diuretic effects, Anti-Cancer effects, Anti-Convulsant effects, Larvicidal effects, and Anti-Asthmatic effects. The primary chemical components include carbohydrates, steroids, glycosides, flavonoids, tannins, and phenolic substances. This review article has aimed to gather and compile information on *A. indicum*, which will be beneficial for society to explore alternative medical systems.

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RESEARCH ARTICLE

GC-MS ANALYSIS OF BIOACTIVE COMPOUNDS, ANTIOXIDANT AND ANTIBACTERIAL ACTIVITY OF *ABUTILON INDICUM (L)* LEAVES

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Abstract

The present study explored the therapeutic potential of *A.indicum* leaves. In today's world, plant secondary metabolites are increasingly favored as therapeutic agents to address various diseases and disorders. This study aimed to analyze the bioactive secondary metabolite profile of *A.indicum* leaves by assessing the total alkaloid, phenolic, and flavonoid content, antioxidant capability, and properties of four aqueous and ethanolic extracts. Qualitative phytochemical analysis using different polarity solvents and established methods revealed the presence of alkaloids, flavonoids, phenols, steroids, tannins, saponins, phytosterols, terpenoids, and glycosides in the leaves. The antioxidant potential was evaluated using DPPH and ABTS radical scavenging assays, while spectrophotometric methods were employed to measure the total alkaloid, flavonoid, and phenolic contents in the leaf extracts. The ethanolic extract showed a higher yield, greater antioxidant potential, and elevated total phenolic and flavonoid contents compared to the aqueous extracts. Analysis of bioactive compounds using Gas Chromatography-Mass Spectrometry (GC-MS). Gas Chromatography-Mass Spectrometry (GC-MS) examination of ethanolic leaf extracts identified 36 chemical entities of both high and low molecular weight in different quantities. These bioactive chemical compounds have been shown to have physiological significance and are crucial from a pharmaceutical perspective. This study indicates that the leaves of *A.indicum* are rich in bioactive secondary metabolites that positively impact human health, possess strong antioxidant properties, and exhibit antibacterial activity against certain bacterial strains, highlighting their considerable therapeutic potential.

KEYWORDS

Abutilon indicum, phytochemical, Antioxidant, Anti-bacterial activity.

Introduction:

In India, ancient traditions such as Ayurveda, Unani, and Siddha have relied on herbal medicines to address a wide range of health issues and physiological conditions. Traditional medicine comprises the medicinal elements derived from the plant kingdom. The wealth of knowledge has historically been regarded as valid[1]. The World Health Organization (WHO) defines traditional medicine as the collective understanding of indigenous practices, beliefs, and their applications of plants for treating various ailments. According to WHO, the healthcare needs of many individuals in developing nations are primarily supported by traditional medicine, predominantly sourced from natural plant products[2]. The species *A. indicum*, commonly referred to as "Country mallow" in English, and known as "Thuthi" locally, can be found throughout the warmer regions of India[3]. Abutilon indicum (L.) Sweet is referred to as Atibala in Sanskrit and has been extensively utilized in Ayurvedic medicine[4]. *A.indicum* belongs to the economically significant Malvaceae family[5]. Primary plant metabolites consist of simple compounds like nucleic acids, proteins, amino acids, polysaccharides, and carbohydrates, while secondary metabolites encompass a wide array of chemical compounds produced via distinct metabolic pathways, diverging from primary metabolism, including alkaloids, phenols, flavonoids, glycosides, lipids, terpenes, tannins, steroids, anthraquinones, and saponins, which serve as essential elements for various effective medications[6]. Plants naturally resist oxidative damage due to their secondary metabolites, which, when consumed, contribute to a dietary source of antioxidants. The green extraction process is recognized as a vital technique in the extraction and identification of phytochemicals, which exhibit beneficial properties without toxic effects[7]. Microorganisms are a primary cause of both acute and chronic illnesses, leading to an increased reliance on plant extracts, which are abundant sources of antimicrobial agents and are recognized

as innovative treatments against antibiotic-resistant pathogens[8]. Plant extracts have found applications as preservatives, antibiotics, and antimicrobial agents across various sectors such as food, aquaculture, pharmaceuticals, and clinical settings[9]. Given the advantageous effects of plant bioactive compounds on human health, this research was conducted to evaluate the presence of secondary metabolites, free radical scavenging capability, and antibacterial activity in the leaves of *A.indicum*[10]. According to the findings of this study, these leaves possess a high concentration of bioactive constituents, including alkaloids, flavonoids, phenols, saponins, terpenoids, glycosides, steroids, carbohydrates, and amino acids[11]. Therefore, this research aims to examine the phytochemicals, antioxidants, and antimicrobial properties in order to explore the potential biological applications of the leaves of *A.indicum.*

2. Materials and Methods

2.1 Plant material

The plant specimens were authenticated as *Abutilon indicum (L)* Sweet subsp. Indicum (Malvaceae) by the Botanical Survey of India, Coimbatore (BSI/SRC/5/23/2024-25/ Tech./509). The aerial parts of the plant sample were washed in normal water and again rinsed in distilled water and was shade dried at room temperature for 15 days.

Source: Young *A. indicum* plants were collected from the vicinity of Pallipalayam, Namakkal district, Tamil Nadu, India in the flowering season.

Sample for Research: The above Cultivated *A. indicum* was used for the further research work.

2.2 Preparation of extract

The leaves of the *A.indicum* plant, which were dried in the shade, were chopped into pieces and then ground into a fine powder using a micro-crusher. The powder, weighing 10 g, was then placed in 100 ml of ethanol, aqueous solution, acetone, and chloroform for a maceration process lasting 48 hours. A magnetic stirrer was used to enhance the extraction process. Afterward, the solvent was removed, and the remaining residue was filtered through filter paper before drying with a Rotavapor. The ethanol, aqueous, acetone, and chloroform extracts of the plant were collected and stored at 4°C for future experiments. Subsequently, a phytochemical screening was conducted to identify the active phytoconstituents present in the leaves extracts of *A.indicum* in the aforementioned solvents.

2.3 Preliminary Phytochemical Analysis:

Qualitative tests were performed on different solvent extracts of *A.indicum* to identify various active compounds such as alkaloids, flavonoids, saponins, tannins, glycosides, phenols, carbohydrates, and proteins, among others[12].

2.4 Quantitative Determination of Phytochemicals

2.4.1 Determination of Total Alkaloids Contents:

To 1 ml of the test extract, 5 ml of phosphate buffer at pH 4.7 was added along with 5 ml of BCG solution, and the mixture was shaken with 4 ml of chloroform. The extracts were subsequently collected in a 10-ml volumetric flask and diluted with chloroform to reach the desired volume. The absorbance of the chloroform complex was measured at 470 nm, using a blank prepared in the same way but without the extract. Atropine was used as a standard for comparison against Atropine equivalents in the assay.

2.4.2 Determination of Total Flavonoid Contents:

To assess the total flavonoid content, 500 µL of each sample (at a concentration of 1 mg/mL) was combined with 100 µL of 10% (w/v) aluminum chloride and 100 µL of 1.0 M potassium acetate. Following this, 1.5 mL of ethanol and 2.8 mL of distilled water were added, and the mixture was blended. The resulting solution was kept in a dark environment for 1 hour, and its absorbance was subsequently measured at 415 nm using a SpectraMax M2e microplate reader. The total flavonoid content is expressed in terms of quercetin equivalents (mM QE/g).

2.4.3 Determination of Total Phenol Contents:

The total phenolic content in various solvent extracts was assessed using Folin-Ciocalteu's reagent (FCR). In this procedure, different concentrations of the extracts were combined with 0.4 ml of FCR (diluted 1:10 v/v). After allowing the mixture to stand for 5 minutes, 4 ml of sodium carbonate solution was added. The tubes were then filled to a final volume of 10 ml with distilled water and allowed to sit for 90 minutes at room temperature. The absorbance of the samples was measured at 750 nm against a blank using a spectrophotometer. A standard calibration curve was created using catechol solutions, and the total phenolic content of the extract was reported in milligrams of catechol per gram of dry weight based on the standard graph.

2.5 Antibacterial activity of ethanolic leaves extract of *A.indicum*

The antibacterial activity of the ethanolic leaves extract of *A.indicum* was evaluated using the disc diffusion method (Kirby-Bauer method). Select microorganisms, including Streptococcus, Staphylococcus aureus, Pseudomonas, and E. coli, were cultured on separate nutrient agar plates. A 20 ml portion of sterilized nutrient agar medium containing agar was poured into each Petri dish and allowed to solidify for 10-15 minutes. Following this, 100 µl of bacterial inoculum was evenly spread across the respective solidified Petri dishes using a cotton swab. Discs containing the extract were

placed on the surface of the agar plates and then incubated for 24 hours at 26-37°C in a bacterial incubator. After the incubation period, the antibacterial activity was assessed by measuring the diameter of the clear zone of inhibition in millimeters (mm).

2.6 Evaluation of Scavenging activity of ethanolic leaves extract of *A.indicum*

2.6.1 Determination of Antioxidant Activity Using the 2,2-Diphenyl-1-picrylhydrazyl (DPPH) Radical Scavenging Method:

The radical scavenging capability of the sample against DPPH was assessed spectrophotometrically in a dark environment using the DPPH method, which is a stable free radical that accepts an electron or hydrogen radical to achieve stability. The reaction mixture, with a total volume of 3 ml, consisted of 1 ml of DPPH, 0.5 ml of the sample, and was completed to 3 ml with distilled water. The tubes were incubated at 37°C for 10 minutes. A blue color chromophore developed, and its absorbance was measured at 517 nm.

Inhibition (%) = [(A control – A test)/ A control] × 100

2.6.2 Determination of Antioxidant Activity Using the ABTS Free Radical Scavenging Method:

The ABTS radical scavenging ability of the ethanolic leaf extract of *A.indicum* was evaluated following the method outlined by Dorman and Hiltunen (2004). A total of 10 ml of 7 mM ABTS was combined with 10 ml of 2.45 mM potassium persulphate solution and allowed to stand for 16 hours. Subsequently, the absorbance of the reaction solution was measured at 734 nm. After this, varying concentrations of ethanolic leaf extract of *A.indicum* (ranging from 50 to 250 µg/ml) were added to 1.48 ml of the ABTS solution. The absorbance of the reaction mixture along with the sample was recorded at 734 nm after incubating for 30 minutes at 37 degrees Celsius. Vitamin C (Ascorbic acid) was used as the positive control. The percentage of inhibition was determined by plotting the ABTS scavenging curve against the extract dosages.

2.7 Identification of components in GC-MS analysis:

GC-MS, or gas chromatography-mass spectrometry, is a crucial tool for analysing unknown plant-origin components. The ethanolic extract of *A. indicum* leaves were analysed using GC-MS. A 6890 N Agilent gas chromatograph and a JMS 600 H JEOL mass spectrometer were used for GC-MS. In a temperature program ranging from 50 to 256 °C at a rate of 4 °C/min with a 2-minute hold, the compound mixture was separated on a fused silica capillary SPBI column with dimensions of 30 m x 0.32 mm and a film thickness of 0.25 µm. The injector's temperature was 260 °C, and the carrier gas helium was flowing at a rate of 1 mL per minute. The ion source temperature was 250 °C, the analyser temperature was 250 °C, the electron emission was 100 µA, and the ionization voltage was 70 eV in the EI mode JMS 600 H JEOL mass spectrometer. Split mode was used to manually inject the sample. The sample ratio in split mode was 1:45 [13].

2.8 Statistical analysis

Three biological replicate extracts were analyzed for each assay described above. Results were expressed as the mean ± standard deviation of mean (SD).

3. Results and Discussion

3.1 Phytochemical screening of leaves extract of *A.indicum*

Phytochemicals are a notable source of bioactive compounds. During the current drug discovery process, the bioactivity of various phytochemicals is of great importance. **Table 1** presents the phytochemical profile results, showing that the leaf extract of *A.indicum* contains a range of phytocomponents, such as tannins, phenols, carbohydrates, proteins, and saponins. These phytoconstituents have been studied for their potential in treating numerous conditions, including diabetes, cancer, inflammation, and others. A variety of therapeutic, antibacterial, and antifungal properties, as well as treatments for various ailments that affect overall skin health, are attributed to these phytochemical compounds.

Table -1: Phytochemical screening of various solvent leaves extract of *A.indicum*

Phytochemicals	Aqueous	Ethanol	Acetone	Chloroform
Sugar	+	+	+	+
Glycosides	-	-	+	+

Phenols	+	+	+	+
Amino acids	+	+	-	-
Alkaloids	+	+	+	-
Flavnoids	+	+	+	-
Steroids	-	+	+	+
Saponins	+	+	-	+
Tannins	+	-	-	+
Terpenoids	+	+	-	-
Xanthoproteins	+	+	+	+

Note: +: Present, -: Absent

These plants are proving to be an increasingly valuable reservoir of bioactive compounds of significant therapeutic potential, according to the study's findings, which also suggest that the detected phytochemical substances may represent the bioactive elements.

3.2 Estimation of secondary metabolite in aqueous and ethanolic leaves extract of *A.indicum*

The presence of Alkaloid, Flavonoid and phenolic content was investigated in aqueous and ethanolic leaves extract of *A.indicum* extracts. The results of this investigation were observed in Table 2.

Table 2: Alkaloid, Flavonoid and phenolic content in aqueous and ethanolic leaves ethanolic leaves extract of *A.indicum*

S.No	Name of Secondary metabolite	Alkaloid	Flavonoid	Phenol
1	Aquoeus Extract	5.31±0.45	7.37±0.39	9.41±0.29
2	Ethanolic Extract	6.41±1.40	8.70±1.03	10.24±0.35

As a result, it shows that the highest levels of Alkaloid, Flavonoid, and phenolics are present in the ethanolic extract of *A.indicum* leaves. Nevertheless, Alkaloids and Flavonoids may contribute to hormonal regulation and immune response. The presence of these phytoconstituents enhances the antibacterial, anti-inflammatory, and anticancer properties of this extract. Compounds such as tannins and other polyphenols, along with phenolics, are beneficial in combating various diseases. Phenolic compounds exhibit anti-inflammatory, anticancer, and cardioprotective benefits. The apparent anticancer properties may stem from the antioxidant effectiveness of the phenolic substances isolated from the plant [14].

The potent antioxidant characteristics of the extracts were evidenced by their elevated phenolic content. They possess the capacity to neutralize free radicals and prevent cellular damage. Furthermore, the phenolic compounds showcased the pharmacological potential of this extract by displaying antibacterial activity against a wide range of pathogens [15].

3.3 Antibacterial activity of aqueous and ethanolic leaves extract of *A.indicum*

Secondary metabolites, including phenols, tannins, and saponins, contributed to the observed antibacterial effects. The aqueous and ethanolic extracts of *A.indicum* exhibit antibacterial properties due to their ability to inhibit the growth of various microbes, suggesting potential applications in food packaging, wound care, and personal hygiene products. When evaluated for antibacterial properties, the aqueous and ethanolic extracts of *A.indicum* demonstrated a noteworthy antibacterial profile against E. coli, Klebsiella pneumoniae, Staphylococcus aureus, and Enterococcus faecalis. Tables 3 and 4 & Figures 1 and 2 provide a summary of the antibacterial activities of the ethanolic and aqueous extracts, measured as the zone of inhibition (mm) [16].

Table -3: Antibacterial activity of ethanolic leaves extract of A. indicum. Average value = Mean ± standard

Name of the microorganism	ZONE OF INHIBITION (mm)				
	Sample extract (µl)			Control	
	50	100	200	Penicillin	Streptomycin
E.coli	1.2	1.8	2.8	3.2	4.4
Klebsiella pneumonia	1.8	2.3	3.2	4.2	4.5
Staphylococcus aureus	2	3.6	4.7	5.2	5.4
Enterococcus faecalis	1.7	2.2	3.5	3.3	3.3

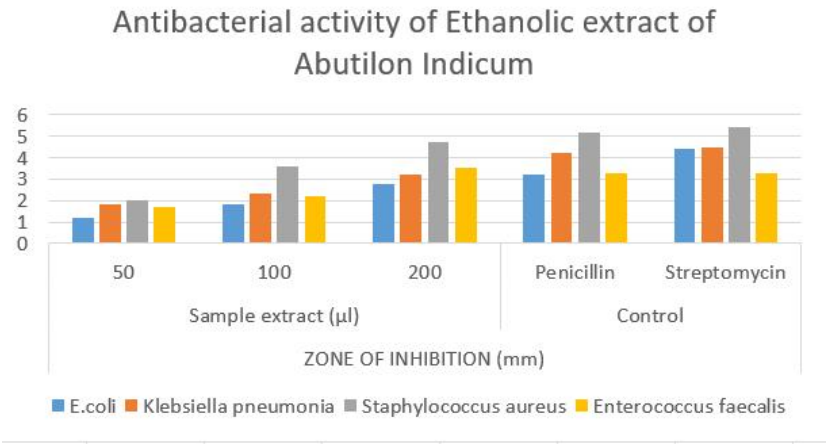

Fig: 1 Antibacterial activity of ethanolic leaves extract of *A. indicum*.

Table -4: Antibacterial activity of aqueous extract of A. indicum. Average value = Mean ± standard

Name of the microorganism	ZONE OF INHIBITION (mm)				
	Sample extract (µl)			Control	
	50	100	200	Penicillin	Streptomycin
E.coli	1.6	1.8	2.1	2.4	2.5
Klebsiella pneumonia	2	2.2	2.5	2.6	2.5
Staphylococcus aureus	2.2	2.4	2.5	2.8	2.9
Enterococcus faecalis	1.5	2.2	2.3	2.5	2.6

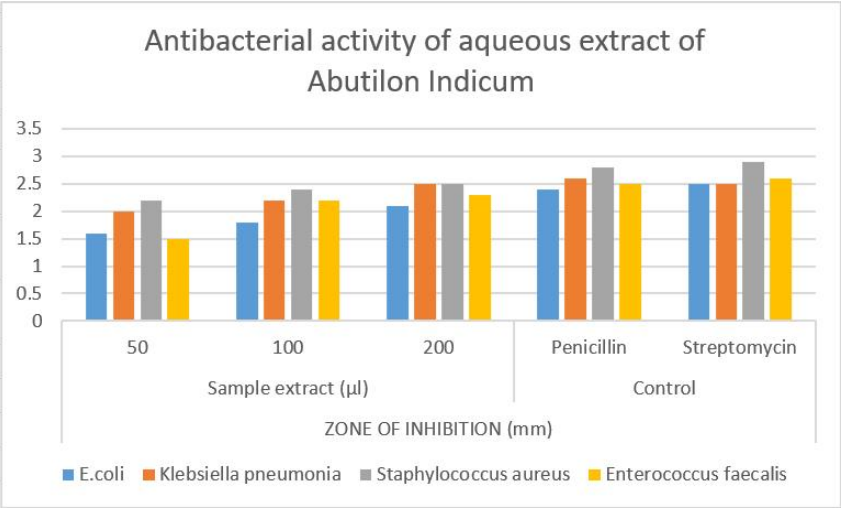

Fig: 2 Antibacterial activities of aqueous leaves extract of *A. indicum*.

Based on **Tables 3 and 4,** the *A.indicum* leaf extracts showed notable microbicidal efficacy against all tested pathogenic strains, with a range of inhibition zone widths between 1.5 to 10.0 mm. The microbicidal activity was lowest against E. coli and Enterococcus faecalis, while it was highest against Klebsiella pneumoniae and Staphylococcus aureus. From Tables 3 and 4, it is anticipated that these findings will prompt further research into *A.indicum* and its potential development into antibacterial medications.

3.4 Evaluation of scavenging activity:

3.4.1 Determination of Antioxidant Activity Using the 2,2-Diphenyl-1-picrylhydrazyl (DPPH) Radical Scavenging Method

DPPH is a stable free radical found in both aqueous and ethanol solutions. It becomes a stable diamagnetic molecule by accepting either a hydrogen or an electron radical. To enhance the antioxidant activity, DPPH is a common substrate used in experiments.

The antioxidant capacity of *A.indicum's* ethanolic leaf extract was evaluated using a DPPH radical scavenging assay, with results presented in **Table 5 and Figure 1**. The administration of varying doses of the aqueous and ethanolic leaf extracts revealed a significant ability to effectively neutralize DPPH free radicals. At concentrations ranging from 50-250 µg, the ethanolic leaf extract of *A.indicum* showed a marked reduction in DPPH radicals.

The highest dosage (250 mg) of the ethanolic leaf extract indicated a significant decrease in DPPH radical levels, as evidenced by absorbance measurements at 517 nm, confirming the extract's free radical scavenging capability. These findings affirm the antioxidant activity of the ethanolic leaf extract of *A.indicum* as a free radical scavenger, although its scavenging effect was less than that of standard vitamin C.

Table 5: DPPH antioxidant assay of ethanolic leaves extract of *A.indicum* (Average value = Mean ± standard)

Percentage of radical scavenging activity		
concentration of sample (µg /ml)	**control: Vitamin c**	**Ethanolic leaves extract of *A.indicum***
250	64.91±0.84	59.58±1.20
200	55.71±0.54	51.38±1.10
150	45.10±0.49	42.77±0.89
100	37.06±1.69	34.73±0.82
50	25.25±0.90	23.92±0.69

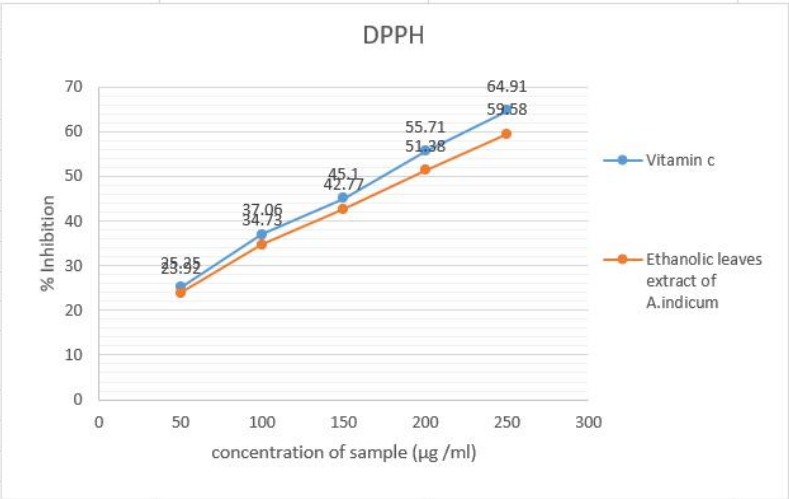

Figure 3: DPPH activity of ethanolic leaves extract of *A.indicum*

Tables 5 and Figure 3, showed that the ethanolic extract was able to neutralize the DPPH free radicals by 59.58%, 51.38%, 42.77%, 34.73%, and 23.92% at concentrations 250,200,150,100,50 µg/ml, and the control Ascorbic acid was able to do so by hydrogen donating activity by 64.91%, 55.71%, 45.10%, 37.06% and 25.25% at dosages of 250,200,150,100,50 µg/ml. Ethanolic extracts and control Ascorbic acid have their highest scavenging efficacy at doses of 250 µg/ml respectively, as shown in Figures 3 . In contrast to ascorbic acid, which served as the study's positive antioxidant control, it was demonstrated that DPPH scavenging increased in a concentration dependent way.

3.4.2 Determination of Antioxidant Activity Using the ABTS Free Radical Scavenging Method

The effectiveness of the ethanolic extract from the leaves of A. indicum in scavenging ABTS radicals was assessed, with the findings shown in table 6 and figure 4. The various concentrations of the ethanolic leaf extract of A. indicum demonstrated a significant ability to scavenge ABTS radicals efficiently. The ethanolic leaf extract of A. indicum at different doses ranging from 50 to 250 µg showed a notable decrease in the absorbance of the ABTS radical at 734 nm in a dose-dependent manner [17].

Table 6: ABTS antioxidant assay of ethanolic extract *of A.indicum*
(Average value = Mean ± standard)

Percentage of radical scavenging activity		
concentration of sample (µg /ml)	**control: Vitamin c**	**Ethanolic leaves extract of *A.indicum***
250	63.64±0.96	57.61 ±0.83
200	52.94±0.88	47.3±1.28
150	41.45±1.06	40.15±1.51
100	35.01±0.73	33.81±0.60
50	31.98±1.65	30.24±2.06

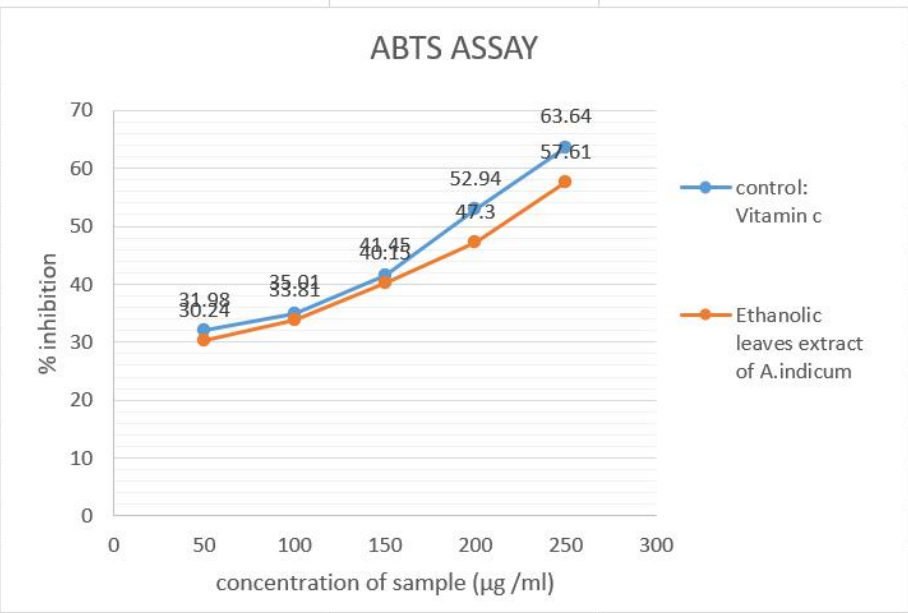

Figure 4: ABTS antioxidant assay of ethanolic extract *of A.indicum*

Tables 6 and Figure 4 showed that the ethanolic extract was able to neutralize the free radical activity by 57.61%, 47.3%, 40.15%, 33.81%, and 30.24% at concentrations of 250,200,150,100,50 µg/ml and compared with control Ascorbic acid. The ethanolic extracts have their highest scavenging efficacy at doses of 250 mg/ml, as shown in Figures 4. In order to neutralize the dangerous radical and shield cells from oxidative stress, The higher dosage (250 µg) of the ethanolic leaves extract showed a notable ability to scavenge ABTS radicals, hence indicating the in vitro free radical scavenging capability of it [14].

3.5 Identify biocomponents from leaves of *A. indicum* by GC-MS analysis:

Gas Chromatography-Mass Spectrometry (GC-MS) plays a key role in the analysis of unknown components of plant origin. The chemical composition of ethanolic extracts of leaves of *A. indicum* were subjected to GC-MS. A total of 13 compounds has been identified via GC-MS analysis considering retention time, molecular formula, molecular weight, and peak area. Table 7 displays the active compounds along with their molecular formula, molecular weight (MW), concentration (peak area %), and their biological applications. The main compounds found in the leaves included 2-Cyclopenten-1-one, N,N-Dimethylglycine, Butanedioic acid, monomethyl ester, Oxirane, hexyl-, 1,2-Benzenediol, O-(2-methoxyethoxycarbonyl)-O'-(cyclopropylcarbonyl)-, 4-Vinylphenol, 2-Methoxy-4-vinylphenol, Cyclohexasiloxane, dodecamethyl-, 4H-1,2,4-Triazol-4-amine, 2(4H)-Benzofuranone, 5,6,7,7a-tetrahydro-4,4,7a-trimethyl-, 4-Methoxybenzoic acid, 3-fluorophenyl ester, 1,2-Benzisothiazol-3(2H)-one, 2-methyl-, 1,1-dioxide, .gamma.-Elemene. The active substances found in the Ethanolic leaves extract of A. indicum through GC-MS analysis are displayed in Table 7 and Figure 5.

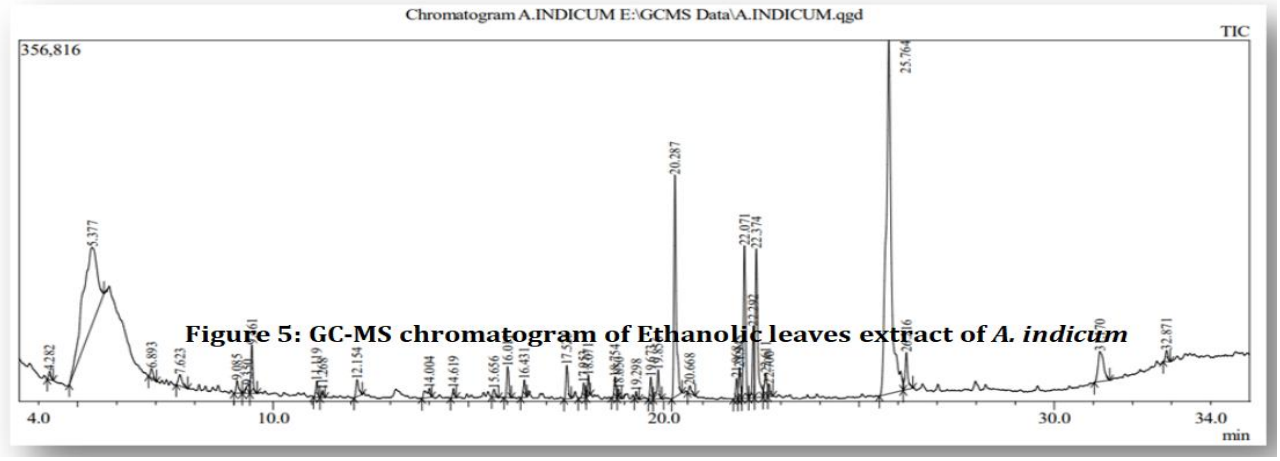

Figure 5: GC-MS chromatogram of Ethanolic leaves extract of *A. indicum*

Table 7: Identification of phytocomponents in ethanolic extract *of A.indicum* by GC-MS analysis:

Peak	Retention Time	Area %	Name of the compound	Molecular formula	Molecular Weight (g/mol)	Nature of the compound	Pharmacological activity
1	4.282	0.31	2-Cyclopenten-1-one, 2-hydroxy-	$C_5H_6O_2$	98.1	Enol and ketone	antiviral and cytoprotective effects [18]
2	5.377	20.3	N,N-Dimethylglycine	$C_4H_9NO_2$	103.12	Glycine derivative	anti-inflammatory, antioxidant, and immunomodulatory effect [19]
4	7.623	0.74	Butanedioic acid, monomethyl ester	$C_5H_8O_4$	132.11	free carboxylic acid group and a methyl ester group	No reported activity
5	9.085	0.6	Oxirane, hexyl-	$C_8H_{16}O$	128.21	epoxides	No reported activity
6	9.35	0.56	1,2-Benzenediol, O-(2-methoxyethoxycarbonyl)-O'-(cyclopropylcarbonyl)-	$C_{15}H_{16}O_6$	292.28	synthetic organic compound	No reported activity
7	9.461	1.71	4-Vinylphenol	C_8H_8O	120.15	phenolic styrene	Antioxidant, anti-angiogenic and Anti-cancer activity [20]
8	11.119	0.53	2-Methoxy-4-vinylphenol	$C_9H_{10}O_2$	150.17	aromaticphenolic compound	anti-inflammatory, anti-cancer, antimicrobial [21]
9	11.268	0.23	Cyclohexasiloxane, dodecamethyl-	$C_{12}H_{36}O_6Si_6$	444.92	organosilicon compound	No reported activity
10	12.154	0.82	4H-1,2,4-Triazol-4-amine	$C_2H_4N_4$	84.08	heterocyclic organic compound	No reported activity
12	14.619	0.31	2(4H)-Benzofuranone, 5,6,7,7a-tetrahydro-4,4,7a-trimethyl-	$C_{11}H_{16}O_2$		lactone or cyclic ester	antifungal, antibacterial, and anticancer activities [22]
13	15.656	0.3	4-Methoxybenzoic acid, 3-fluorophenyl ester	$C_8H_7FO_3$	264.2	ester	No reported activity
14	16.011	1.04	1,2-Benzisothiazol-3(2H)-one, 2-methyl-, 1,1-dioxide	$C_8H_7NO_3S$	197.211	Organic heterobicyclic compound	Antibacterial, antifungal, antiviral, analgesic [23]
15	16.431	0.58	.gamma.-Elemene	$C_{15}H$	204.35	monocyclic sesquiterpene	Anti-inflammatory, antileishmanial activity, immunomodulation [24]

4. Conclusion

A. indicum is traditionally utilized in medicine for addressing conditions such as respiratory issues, urinary problems, inflammation, and digestive disorders. The phytochemical constituents such as alkaloids, flavonoids, phenols, tannins, saponins, glycosides, terpenoids, sugars, amino acids, and steroids present in *A. indicum* leaf extract are thought to possess antibacterial properties. *A. indicum* is known for its antibacterial capabilities and is traditionally employed to manage bacterial infections and treat wounds.

Due to the presence of phytochemicals like tannins and polyphenols, *A. indicum* might help protect the skin from free radical-induced damage and could potentially support anti-aging, showcasing its antioxidant activity. Numerous medicinal, antibacterial, and therapeutic attributes are linked to these phytochemical compounds. Products derived from pure and diverse phytochemical sources, such as the leaves of *A. indicum*, should be considered as alternatives to expensive medications that often have considerable side effects. Therefore, the leaves of *A. indicum* could be regarded as a promising candidate for drug development due to their significant medicinal potential. Phytoconstituents like alkaloids, flavonoids, saponins, and glycosides have been noted for their variety of biological effects, including anticancer, anti-inflammatory, and antimicrobial properties. Phenolic compounds, commonly found in both edible and non-edible plants, are acknowledged for their diverse biological effects, such as their antioxidant activity and promotion of health benefits. The findings from this study could enhance the understanding of the various medicinal properties of *A. indicum* leaves. This research implies that the ethanolic extract serves as a potent therapeutic agent. With these insights, it appears that the leaves of *A. indicum* represent a prudent choice regarding human health. Further investigations are required to isolate and identify these bioactive compounds.

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RESEARCH ARTICLE

DEVELOPMENT OF THINFILM FOR TRANSDERMAL DELIVERY OF HERBAL OILS

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Abstract

Wound healing is a complex biological process, results in the restoration of tissue integrity. Allopathy uses drugs and sometimes surgery to treat ailments related to bone and joint disorders. To overcome the drawbacks associated with current treatment methodologies herbal therapies such as herbal oils, tablets, yoga, meditation, special diets, etc are followed. To enhance the herbal delivery several nanomaterials are used. In the current study Poly (vinyl alcohol)/Chitosan (PVA/CTS) thin films of approximately 4 mm in thickness were synthesized by stirring using acetic acid and Glutaraldehyde. The prepared thin film with a high crosslinking density and a dense inter-porous structure were utilized with oil for the formation of herbal oil thin film. The composite films were characterized by Fourier-transform infrared spectroscopy (FTIR), and biocompatibility assays. The results confirmed that highly stable and uniformly distributed herbal thin film obtained over the entire thin film networks. The tensile test revealed that the effective incorporation of herbal oil within the hydrogel networks rendered the composite films more elastic. Due to its inter-porous structure, uniform distribution of oil and biocompatibility, the herbal oil-loaded PVA/CTS thin film may be utilized as a biomaterial in medical applications.

keywords

Thin films, nanomaterial, herbal oil, PVA, Chitosan

Introduction:

Wound healing is a complex biological process, results in the restoration of tissue integrity. General medicines are concentrating on the symptoms of a disease and not on the causes of those symptoms (Bennadi, D. 2013, Alonso-Castro *et al*., 2018). Herbal medicine has a long history of evolution in styles and practice worldwide (Srivastava, J. K *et al*., 2010). In its early stage, herbal or animal medicines were widely utilized over many different countries, including Greece, as allopathic medicine, Ayurvedic medicine in India (Han, G and Ceilley R., 2017, Zhang, J., *et al* 2012). In today's time, nanotechnology is being utilized to develop efficient products in the cosmetic and pharmaceutical industries (Pandey, A., & Pandey, G. 2013). The application of nanotechnology in transforming bioactive material into nanoscale products substantially improves their biocompatibility and enhances their effectiveness, even when used in lower quantities (Ansari, S. H. *et al*., 2012, Bonifacio, B. V *et al*., 2014). There is a significant global market potential for these nanoparticles because of which research teams around the world are interested in the advancements in nanotechnology. (Abdullah, O. G, *et al*., 2015).

Wounds can be categorized into acute and chronic types Acute wounds are the outcome of traumatic or surgical events that heal predictably following a regular healing process (Ellis, S., *et al*., 2018, Young, A., & McNaught, C. E. 2011). Burn wounds are another class of wounds that are caused by heat, chemicals, electricity, sunlight, radiation or friction Burns can be classified into superficial, partial-thickness and full-thickness burns. The materials used in the treatment of chronic wounds are used for two different purposes scaffolding materials that can host the endogenous cells and facilitate their growth and wound closure; temporary dressings that cover the wound area and maintain a suitable condition supporting the healing process. The ideal wound dressings are supposed to cover the wound, preserve the body water content, be oxygen permeable to allow oxygen access to growing tissue, and prevent the growth of environmental pathogens without interfering with the wound healing (Harper, D., *et al.,* 2014, Guo, S. A., & DiPietro, L. A. 2010). The utilized materials should be immunocompatible, non-degradable, and should not support cell ingrowth and cellular adhesion so to avoid complications during their removal. Dressing delivering drugs and biological factors

should preserve the activity of the drugs and should be able to release the drugs at the desired rate. Scaffolding materials used for the treatment of chronic wounds, should facilitate the tissue regeneration, restore the tissue function, and promote a rapid healing process preventing chronic wounds. The material should possess a degradation rate that matches the rate of tissue growth. In addition, neither the material nor the by-products of the degradation process should induce immunogenicity and toxicity. The scaffolding material should adhere properly to the surrounding tissues and its mechanical properties should match those of native skin to avoid the detachment and breakage over the course of healing (Saghazadeh *et.al*., 2018). They should have a limited swelling capacity and maintain their shape over time. These scaffolding materials can also be used as a depot of growth factors and the drug that are directly being delivered to the healing tissue (Murphy, P. S., & Evans, G. R. 2012).

Polyvinyl alcohol (PVA) was created about 90 years ago as the first synthetic colloid and it has been used for various applications since then. PVA is prepared in two steps due to the unstable form (readily tautomerized into acetaldehyde) of vinyl alcohol as monomeric units he free-radical polymerization of vinyl acetate in an alcoholic solution and partial hydrolysis of poly vinyl acetate (Noushini, A *et al*., 2013) By controlling hydrolysis step, different grades as degree of hydrolysis of PVA polymer can be prepared and finally affect the behaviour of polymer material, solubility, crystallinity, and chemical properties (Thong *et al*., 2016). Chitosan is a deacetylated product of chitin, which is an abundant natural resource that features less storage than cellulose (Aranaz, I., *et al*., 2021) Chitosan is a renewable natural alkaline polysaccharide that has no toxicity and no side effects, and it features good moisturizing and adsorption properties (El Hadrami, A *et al*., 2010). The United States Food and Drug Administration (FDA) has approved that chitosan is safe in the use of foods and drugs (Wang *et.al*., 2020). The current study aims to develop thinfilm for herbal oil delivery.

1. MATERIALS AND METHODS

1.1. Materials

Chitosan, PVA, acetic acid, glutaraldehyde, Dulbecco's modified Eagle's medium (DMEM), Fetal Bovine Serum (FBS), sodium chloride, sodium bicarbonate, di-sodium hydrogen phosphate dihy drate, 3-(4,5-dimethyl thiazolyl-2)-2,5-diphenyl tetra zolium bromide (MTT) and other chemicals were obtained from Himedia, Mumbai, India. All the chemicals used were of analytical grade without any further purification.

1.2. Cell culture

The cultures were maintained in the medium containing DMEM, FBS (10% v/v), penicillin (100 units/ml), and streptomycin (100 mg/ml). The cells were incubated at 37 °C with 5% CO2 throughout the study. The cells were detached after the plates reached 100% confluency using trypsin and seeded at a density of 1 9 103 cells/well (Park, S *et al*., 2017).

2.3. Thin film preparation

0.25 g of chitosan is dissolved in 25 ml of acetic acid, and an equal volume of pva solution is mix which contains 0.25 g of pva and 25 ml of distilled water. The two mixtures are mixed for one hour in a magnetic stirrer at 1000 rpm at 60 degrees Celsius. 1ml of 2% Glutaraldehyde solution in water was added to the solution, and the chitosan-pva blend mixture was immediately transferred to an aluminium covert glass plate and air dried for 4 hours in an oven at 80 ℃. (Jiang, S *et* al., 2011, Hu, Y *et al.*, 2020)

2.4. Oil incorporation in thin film preparation

0.25 g of chitosan is dissolved in 25 ml of acetic acid, and an equal volume of pva solution is mix, which contains 0.25 g of pva and 25 ml of distilled water. The two mixtures are mixed for one hour in a magnetic stirrer at 1000 rpm at 60 degrees Celsius. 1 mL of 2% Glutaraldehyde solution in water has been added to the solution, along with 2 mL of murivenna herbal oil. The chitosan-pva-oil mixture was immediately transferred to an aluminium covert glass plate and air dried for 8 hours in an oven at 80 ℃ (Kudaibergenov, S. E *et* al., 2012, Kumar, H. N. *et al*., 2010).

2.5. Fourier transform infrared (FTIR) spectroscopy:

The vibrational structural characteristics analysis of the chemical functional group in the thin films was done using Fourier transform infrared (FTIR) spectroscopy (Ng, Y.C *et al*., 2013). FT-IR spectrophotometer was used to record the IR spectra of between 500–4000 cm−1(Transmittance range).

2.6. Skin irritacy assay – Pig skin protocol:

Ex-viva pig skin irritation study:

Fresh porcine skin was purchased from a local slaughterhouse within 6 hours of animal slaughter. Initially the skin is washed thoroughly with tap water and then with distilled water. The skin was shaved carefully to remove hair and subcutaneous fat using scalpel, then washed with sterile phosphate-buffered saline (PBS, pH 7.4). The tissue was cut into uniform pieces of roughly 2 × 2 cm were mounted on Petri dishes with the epidermal surface facing upward (Moniz T *et al*., 2021).

Control films containing PVA and Chitosan, and test films containing PVA, Chitosan and Murivenna herbal oil were gently placed on the skin surface and covered with thin parafilm to ensure uniform

contact. The skin samples were incubated at 37 °C for 24 hours in a humidified chamber.

After incubation, the thin films were carefully removed, and each skin sample was examined visually for signs of redness, swelling, or any other allergic irritation. The tissues were then fixed in 10% neutral buffered formalin, processed through graded alcohols to remove water, embedded in paraffin. The tissue is cut to a thickness of 5 µm slice. The sectioned slice was stained with hematoxylin and eosin (H & E) and examined microscopically to assess the condition of the epidermis and dermis layer of skin for erythema (Lakshmi, C. 2014, Mojumdar, E.H *et al*., 2021).

2.7. Cytotoxicity assay:

In a 96-well plate, the cells were seeded on the thin films with a density of 1000 cells/well and incubated for 24 h in a 5% CO2 incubator. The sample with media solution was removed after 24 h incubation and the cells were washed with phosphate-buffered saline (PBS) before the cell culture assays (Seah, M.Q *et al*., 2020). Further cell proliferation and viability referred to as MTT (3-(4,5- dimethylthiazol-2-yl)-2,5-diphenyltetrazolium bromide) assay was carried out.

2. RESULTS AND DISCUSSION

3.1. Preparation of Thin Film

The thin film was successfully developed using polyvinyl alcohol (PVA) and chitosan in a 1:1 ratio, with the incorporation of selected herbal oils. The film developed (Fig. 1) was smooth, flexible, transparent, and non-sticky, indicating good miscibility between the polymers and uniform distribution of the oil. The developed thin film was assessed further for studying the thin film properties.

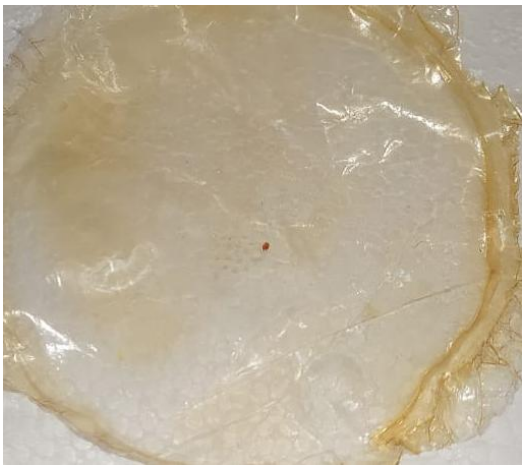
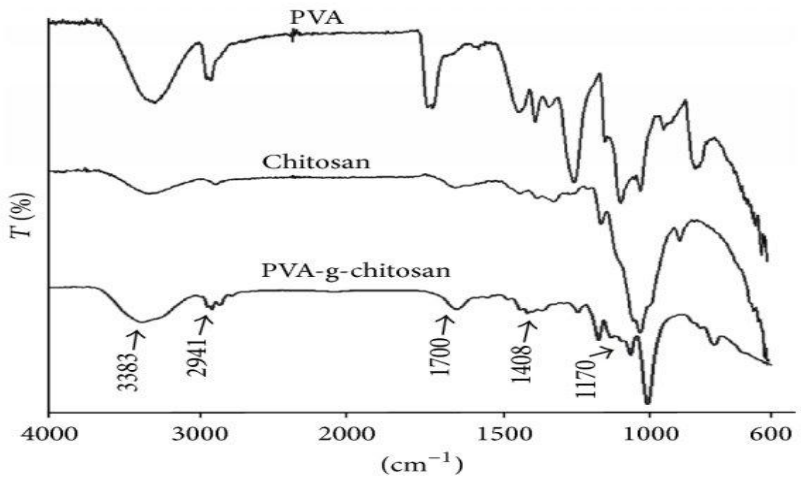


Fig 1: Developed thin film incorporated with herbal oil

3.2. FTIR (Fourier Transform Infrared Radiation)

Fourier transform infrared spectroscopy also known as FTIR analysis is an analytical technique used to identify organic, polymeric, and inorganic materials. FTIR analysis method used infrared light to scan test sample and observe chemical properties

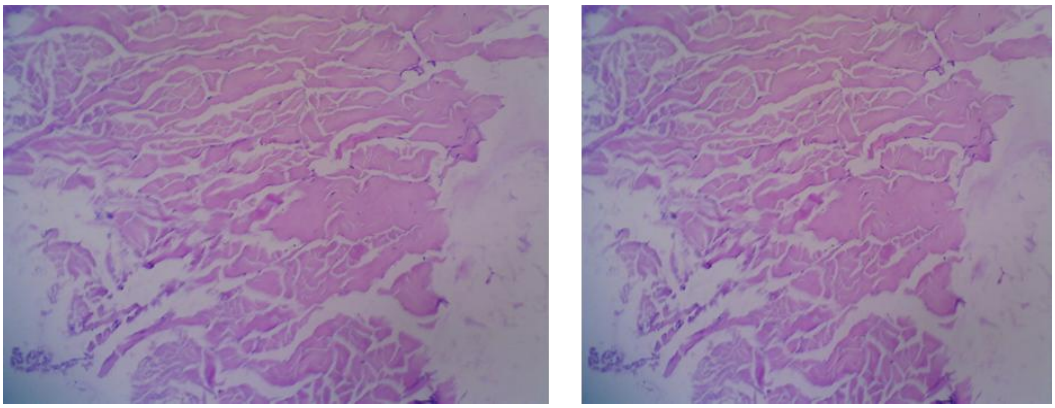
The identification of oil and polymers molecules in the combined solution of pva, chitosan was studied at the range 4500-500 cm-1 using FTIR spectroscopy by thin film. FTIR is the most powerful tools for identifying the types of chemical bonds (functional groups) present in the compounds.



The peak of 3383 and 2941 cm-1 in the spectra correspond to O-H stretching vibration indicating the presence of Alchol. The peak at 1700 cm-1 was assigned as C=O stretching indicates the presence of Conjugated aldehyde. The peak at 1408cm-1was assigned S=O stretching indicates the presence of Sulfonyl chloride. The peak of 1170cm-1 was assigned as C-O stretching indicates the presence of Ester.

3.3. Skin irritacy test – pig skin

The skin irritancy test was performed using pig skin, which closely resembles human skin in histological structure. The control film (without herbal oil) and herbal oil-incorporated film were applied to the pig skin and observed for any signs allergic irritation or inflammation.



Control thin film Thin film with oil

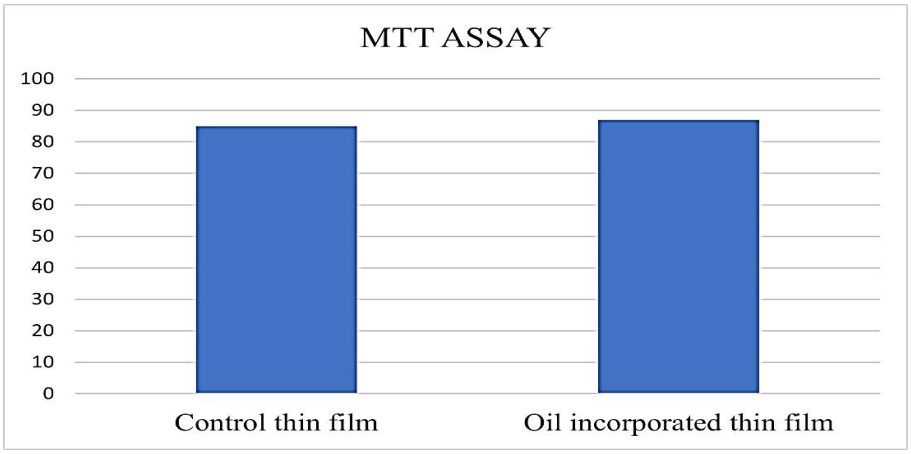
Fig 3: Skin Irritacy test

Samples	Observation
Control film	Normal appearance of epidermis and dermis, no signs of inflammation and allergic irritations
Film with herbal oil	Mild skin reaction observed in the muscle and adipose tissue, indicating minimal irritation

The invitro study shows (wound healing) no irritation and allergy; thin film 10 x muscle bundle, thin film shinned out epidermis with dermis shows normal, thin film 10 x shoes deep adipose tissue of animal tissue by using this thin film. In the incorporation thin film with oil there is a slit skin irritation in the muscle, and adipose tissue

3.4. Cytotoxicity Assay – MTT

The MTT assay was carried out to assess the cytotoxic effect of the developed thin film on living cells. The result indicated that the film extract showed no significant cytotoxicity when compared to the control (untreated) cells. The cell viability remained above 85%, indicating that the polymer-oil matrix is non-toxic and did not interfere with normal cellular metabolism. The result confirmed that the formulated film is non-toxic and suitable for biomedical applications such as wound healing or transdermal drug delivery.



3. CONCLUTION

In this study thin film was formulated and developed using polyvinyl alcohol (PVA) and chitosan in equal proportions for the incorporation and delivery of herbal oil (Murivenna) which has significance in pain relief. The FTIR analysis was performed and determine the drug in thin film which indicate the successful blending of polymers and herbal components. The MTT assay showed cell viability greater than 85%, indicating the film is non-toxic and biocompatible. Furthermore, the ex vivo pig skin irritation assay showed no significant tissue damage, confirming its dermal safety and compatibility. The thin film may allow potential to be used as biomaterials for medical applications, like wound dressing, pain-relief patch etc. In previous work PVA and chitosan were used for the preparation of hydrogel, in this study these polymers were successfully employed as "Thin Film" with the incorporation of herbal oils.

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RESEARCH ARTICLE

A REVIEW ON THERAPEUTIC POTENTIAL OF BRAHMMAMUNI KARPAM IN SIDDHA MEDICINE

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Abstract

Brahmmamuni Karpam is a premier *Kayakarpam* formulation and a popular polyherbal restorative within the Siddha system of Bharatiya medicine. Attributed to the esteemed Sage Brahmmamuni who is one of the 18 Prime Siddhars, this preparation is very similar to *Kaya Kalpa Chikitsa*, the science of longevity and rejuvenation. This review investigates the therapeutic significance, historical lineage, and pharmacological basis of this remedy, traditionally used for chronic dermatological, respiratory, and rheumatic disorders. It alongside enhances mental acuity and vitality. This formulation contains seven distinct botanicals such as Licorice, Black Cumin, Cumin, Clove, Ironwood flower, Dill, and Coriander seeds. These possess potent antimicrobial, anti-inflammatory, and gastroprotective potentials. A critical aspect of its manufacture is the rigorous *Suddhi* (purification) protocol, essential for detoxifying components and optimizing bioavailability. Contemporary research validates these ancient applications, identifying bioactive constituents like Thymoquinone in Black Cumin and Eugenol in Clove as key agents in immunomodulation and oxidative stress reduction. Brahmmamuni Karpam regulate metabolic and digestive health, treate conditions of the head and sensory organs, and resolve musculoskeletal complaints such as edema. Ultimately, it embodies a holistic strategy, harmonizing the three humors (*Vatham, Pitham, Kapham*) to ensure sustained physical resilience and youthful vigor.

keywords

Kaya Karpam, Rishi Brahmmamuni, Suddhi, Tridosha, Vatham, Pitham, and Kapham.

1. INTRODUCTION

Brahmmamuni Karpam stands as a preeminent formulation within the Siddha system of medicine, one of the world's oldest traditional healing lineages rooted in Dravidian culture. This traditional polyherbal preparation is attributed to Rishi Brahmmamuni, a luminary among the eighteen primordial *Siddhars* (spiritual scientists) who laid the foundations of Tamil medical literature. As a foundational element of *Kaya Kalpa Chikitsa* the specialized branch of Siddha science dedicated to rejuvenation and longevity Brahmmamuni Karpam is designed to transcend the limitations of conventional disease treatment. Its primary objective is not merely the improvement of symptoms but the fundamental transformation of the body's resistance to degeneration. The term *Kayakarpam* is derived from the Tamil words *Kaya* (body) and *Karpam* (stone-like durability). In this context, the formulation acts as a biological shield, and aim to arrest the natural process of agin. [1]

It prevents premature signs of senescence such as *Narai* (graying of hair), *Thirai* (wrinkling of the skin), and general frailty. It also strengthens the innate immunity. Achieving a precise equilibrium of the *tridhosam.* The efficacy of Brahmmamuni Karpam is due to synergistic blend of seven distinct herbals. However, the raw potency of these botanicals is refined through a rigorous and elaborate purification process known as Suddhi. In Siddha pharmaceutics, *Suddhi* is critical; it is a detoxification protocol designed to eliminate

impurities, mitigate toxicity, and enhance the bioavailability of the bioactive compounds. This ensures that the final product is potent and safe for human consumption. Brahmmamuni Karpam is indicated for a wide spectrum of chronic ailments. It has been employed in the management of refractory skin diseases (dermatopathies), chronic respiratory conditions, and rheumatic disorders involving inflammation and pain [2]. Beyond its somatic applications, the formulation is prominent for its psychosomatic benefits, believed to enhance mental clarity, cognitive function, and kindle internal spiritual energy. However, the administration of such potent *Kalpa* medicines requires a disciplined approach. It demands strict observance to Pathiyam (dietary and lifestyle restrictions) to facilitate proper adaptation. The guidance of a qualified medical practitioner, specifically a Bachelor of Siddha Medicine and Surgery (BSMS), is necessary to determine the proper dosage and duration, ensuring the therapy yields its promised vitality without adverse effects. [3]

2. BRAHMMAMUNI SIDDHAR

Brammahmuni Siddhar stands as a seminal figure within the ancient Tamil Siddha lineage, celebrated for his profound contributions to spiritual philosophy, alchemy, and medicine. As one of the eighteen principal Siddhars, he represented the tradition's core such as Yoga, medicine, and alchemy. Brahmmamuni's philosophy emphasizes on the transmutation of the human physique into a divine instrument, advocating for physical longevity and holistic well-being as essential prerequisites for spiritual liberation. Brahmmamuni made pivotal advancements in the development of complex Herbo-mineral formulations. He advocated meticulous *Suddhi* (purification) protocols and critical processes devised to eliminate toxicity from potent metals and minerals to detoxify. His medical doctrine is strongly rooted in the restoration of humoral homeostasis, aiming to balance the *Mukkutram* (*Vatham, Pitham,* and *Kapham*) to prevent disease and arrest degeneration. These advanced medical insights were traditionally encoded in cryptic and symbolic Tamil verses, a stylistic method intended to preserve the secrecy and integrity of this knowledge for future generations. [4]

2.1. Siddha Medicine

The classical texts provide a comprehensive framework incorporating the botanical identification and taxonomy of medicinal flora, the confer significant immunomodulatory benefits and a broad spectrum of therapeutic effects. These ingredients are recognized for their anti-ulcer, gastroprotective, anti-inflammatory, and anti-complex pharmaceutical processing of herbo-mineral formulations, and specific detoxification protocols. Furthermore, they delineate precise guidelines for posology and therapeutic application. This literature posits that the pharmacological efficacy of the medicine is intrinsically linked to the ethical integrity and spiritual discipline of the practitioner during the preparation process. [5]

2.2. Rasavatham (Alchemy)

A substantial portion of Rishi Brahmmamuni's literary corpus is dedicated to the intricate science of alchemy (Rasavada). His treatises provide detailed expositions on the purification (Suddhi) and stabilization of mercury, the pharmacological application of sulfur and minerals, and the precise regulation of thermal cycles. However, this alchemical discourse transcends mere material transmutation; it is articulated as a profound allegory for inner spiritual refinement, where the chemical purification of matter serves as a symbolic representation of the soul's evolution [6]

2.3. Kayakalpa, Longevity and Scientific Convergence

Brahmmamuni posited that physical longevity is a fundamental prerequisite for spiritual progression and self-realization. Despite originating in a pre-modern era, Brahmmamuni's methodologies exhibit a profound convergence with contemporary biomedical principles [7] Preventive Medicine and Public Health: His holistic health framework prioritizes disease prevention over symptomatic treatment. His recommendations regarding dietary discipline, sleep hygiene, and breath regulation align closely with modern preventative medicine strategies and lifestyle management protocols. From a modern pharmacological perspective, this reflects an early, empirical awareness of toxicity management and the necessity of safety profiling in drug development. Modern science acknowledges the critical role of trace minerals in enzymatic and metabolic regulation. The herbo-mineral formulations attributed to Brahmmamuni demonstrate an advanced understanding of pharmacokinetics, where minerals are processed to enhance bioavailability and therapeutic efficacy while mitigating potential cytotoxicity [1]

3. COMPOSITION OF BRAHMMAMUNI KARPAM

As per the classical literature available in Tamil, Brahmmamuni Karpam is a polyherbal formulation composed of a specific blend of seven medicinal herbs. This synergistic combination is reported to microbial properties, while also playing a vital role in maintaining oral hygiene and optimizing digestive function. [4]

Table-1 List of Herbal Ingredients used in Brahmmamuni Karpam

S.No	Herbs used in Karpam	Parts used
1	Glycyrrhiza glabra	Roots
2	Nigella sativa	Seeds
3	Syzygium aromaticum	Flower
4	Cuminum cyminum	Seeds
5	Mesua Ferre	Flower
6	Anethum graveolans	Seeds
7	Coriandrum sativum	Seeds

3.1. Glycyrrhiza glabra L (Athimathuram)

Glycyrrhiza glabra L is known as as Licorice and traditionally revered as Athimathuram in Tamil medicine, and represents one of the most pharmacologically significant species within the Fabaceae family. For several years, this perennial herbaceous legume has served as a cornerstone of ethnopharmacology, spanning the ancient medical systems of Egypt, Greece, Rome, and China. Its medicinal value is concentrated in its extensive rhizome and root system, which serves as a biological factory for a diverse array of bioactive secondary metabolites. The most prominent among these is Glycyrrhizin that provides the root with its characteristic sweetness. The pharmacological profile of G. Glabra is remarkably broad, characterized by potent anti-inflammatory, antioxidant, antimicrobial, and immunomodulatory activities. Clinical and laboratory investigations have validated its efficacy in treating various systemic disorders. In respiratory medicine, it acts as a powerful demulcent and expectorant, providing relief for throat infections, persistent coughs, and even adjunct support for tuberculosis management. In the gastrointestinal tract, licorice extracts are utilized for their anti-ulcer properties, effectively coating the stomach lining and regulating acid secretion. Furthermore, its hepatoprotective nature makes it a vital agent in managing liver diseases, including hepatitis, by mitigating oxidative stress and inhibiting viral replication. Recent oncological research has also begun to explore its potential in inducing apoptosis in specific malignant cell lines, while its cardiovascular benefits include the regulation of lipid metabolism and plaque stabilization [8]. Thus, modern research continues to refine delivery systems and dosage protocols to harness the profound healing potential of this ancient botanical while ensuring systemic safety. [9]

3.2. Nigella sativa (Karuncheeragam)

Nigella Sativa L., commonly known as Black Cumin or Karuncheeragam in Tamil tradition, is an annual flowering herb of the Ranunculaceae family. Renowned globally as the "miracle herb," its seeds have been utilized for millennia in Unani, Siddha, and Ayurvedic systems. The plant's profound medicinal value is primarily attributed to its complex chemical profile, which includes fixed oils, proteins, alkaloids, and saponins. However, its most significant bioactive constituent is thymoquinone (TQ), a volatile oil component that has been the subject of extensive contemporary research.

The therapeutic spectrum of Nigella sativa is remarkably diverse. Scientific investigations have validated its potent antioxidant, anti-inflammatory, and immunomodulatory properties, which serve as the foundation for its multi-organ protective effects. In the cardiovascular system, it assists in the management of hypertension and hyperlipidemia. Its metabolic benefits are equally significant; it enhances insulin sensitivity and glycemic control, making it a critical functional food for type 2 diabetes management. Furthermore, N. Sativa exhibits strong nephroprotective and hepatoprotective activities, shielding vital organs from drug-induced toxicities and oxidative damage. Emerging oncological studies also highlight its potential to inhibit tumor growth and induce apoptosis in various cancer cell lines, while its bronchodilatory effects offer relief in chronic respiratory conditions like asthma [10]. As clinical integration evolves, N. sativa remains a primary candidate for drug discovery, bridging the gap between ancient herbal wisdom and modern evidence-based medicine. [11]

3.3. Cuminum cyminum (Seeragam)

Cuminum cyminum is known as Seeragam in Tamil tradition and Cumin in English. It is a significant aromatic herb belonging to the Apiaceae (Umbelliferae) family. It has gained substantial scientific interest for its role as a functional food. The plant's medicinal efficacy is largely attributed to its volatile oils and secondary metabolites, most notably cuminaldehyde, which serves as the primary bioactive marker for its therapeutic potential. The pharmacological spectrum of C. cyminum is broad, characterized by potent antioxidant, anti-inflammatory, and antimicrobial properties. In metabolic health, cumin has demonstrated remarkable clinical efficacy in weight management and obesity control. Clinical trials have exhibited that cumin extract can significantly reduce Body

Mass Index (BMI), waist circumference, and fat mass in overweight individuals. Its anti-diabetic potential is evidenced by its ability to improve insulin sensitivity and regulate blood glucose levels in Type 2 diabetes patients. The herb also exhibits profound organ-protective effects, particularly nephroprotective and hepatoprotective activities, which help mitigate oxidative damage in the kidneys and improve liver function markers in patients with non-alcoholic fatty liver disease (NAFLD). Additionally, its carminative properties make it a staple for treating various gastrointestinal disorders [12]. Geographically, Cuminum cyminum is native to the East Mediterranean region and Upper Egypt, though it is now cultivated extensively across the globe. [13]

3.4. Syzygium aromaticum (Ilavangapoo)

Syzygium aromaticum, known as Ilavangapoo in Tamil tradition and Clove globally, is a premier aromatic spice belonging to the Myrtaceae family. Historically native to the Maluku Islands of Indonesia, it has evolved into a globally significant botanical resource. The medicinal value of clove is exceptionally high, primarily residing in its dried flower buds, which yield a potent essential oil. The pharmacological cornerstone of the plant is Eugenol, a phenolic compound that constitutes up to 70–90% of its essential oil, alongside eugenol acetate and gallic acid. [14]. The therapeutic spectrum of S. aromaticum is distinguished by its superior antioxidant and antimicrobial capabilities, which often surpass those of many common fruits and vegetables. In clinical and traditional settings, it is revered for its Anti-inflammatory and Antiseptic Actions: It effectively inhibits cyclooxygenase-2 (COX-2) and possesses broad-spectrum activity against bacterial and fungal pathogens. Emerging studies suggest its role in regulating blood glucose levels and providing hepatoprotective benefits against oxidative stress [15]. Its resilience and high phenolic content ensure its continued dominance as a critical raw material for the pharmaceutical, cosmetic, and food preservation industries. [16]

3.5. Mesua Ferre (Sirunagapoo)

Mesua ferrea L., traditionally recognized as Sirunagapoo in Tamil medicine and Nagakesara in Ayurveda, is a majestic evergreen tree belonging to the Calophyllaceae family. Often referred to as Sri Lankan Ironwood or Indian Rose Chestnut, it is celebrated for its heavy timber and aromatic blossoms. In the context of the Brahmmamuni Karpam formulation, the dried flowers and stamens are the primary focus of pharmacological interest, serving as a rich reservoir of bioactive secondary metabolites, including phenylcoumarins, xanthones (such as euxanthone and mesuaxanthone), triterpenoids, and flavonoids [17]. Antimicrobial Activity: Recent studies highlight its efficacy against various pathogenic strains, supporting its use in treating skin infections and promoting wound healing [18]. While often found growing wild in protected forest reserves, it is frequently cultivated as an ornamental tree in parks and temple gardens due to its elegant form, distinctive drooping pink-to-red young foliage, and highly fragrant white flowers [19]

3.6. Anethum graveolans (Sadhakuppai)

Anethum Graveolens L., recognized as Sadhakuppai in Tamil tradition and Dill globally, is an annual aromatic herb belonging to the Apiaceae family. Historically integrated into Ayurvedic and Siddha medicine, it serves as a multifaceted botanical resource valued for both its culinary utility and its essential oil production. The medicinal efficacy of the plant is primarily concentrated in its dried fruits (commonly referred to as seeds), which house a complex essential oil matrix dominated by Carvone, alongside limonene, dillapiole, and various phellandrenes [20]. The pharmacological spectrum of A. graveolens seeds is largely defined by its gastrointestinal and metabolic benefits. Dill seeds are a premier remedy for flatulence, dyspepsia, and intestinal spasms. The essential oil stimulates gastric mucosal secretion and improves overall digestion. Antidiabetic and Hypolipidemic Effects: Contemporary studies indicate that dill extracts can significantly lower blood glucose levels and improve lipid profiles, making it a valuable adjunct for managing metabolic syndrome and Type 2 diabetes. The presence of flavonoids and phenolic acids provides a robust defense against oxidative stress and exhibits broad-spectrum activity against various food-borne pathogens. It is utilized to promote urine flow and enhance milk secretion in lactating mothers, supported by its ability to modulate hormonal pathways [21]. The Indian subcontinent remains one of the largest producers, where the specific climatic conditions of the semi-arid regions contribute to the high carvone content required for pharmaceutical-grade essential oils. [22]

3.7. Coriandrum sativum (Malli)

Coriandrum sativum, commonly known as coriander or cilantro, is a versatile annual herb belonging to the Apiaceae family. It is highly valued in both traditional systems like Ayurveda and modern pharmacology for its diverse bioactive profile, which includes essential oils (primarily linalool), flavonoids, and phenolic acids. Its applications are broad-spectrum; it is widely utilized as a digestive stimulant and carminative to treat dyspepsia, flatulence, and diarrhea. Modern research has further validated its antidiabetic potential, as it stimulates insulin secretion and enhances glucose uptake. Additionally, the plant

exhibits significant antioxidant, anti-inflammatory, and antimicrobial properties, making it effective against foodborne pathogens and chronic inflammatory conditions like arthritis. Emerging studies also highlight its neuroprotective effects, suggesting a role in managing anxiety and preventing neurodegenerative diseases such as Alzheimer's by reducing oxidative stress in brain tissues [23]. It is a truly global crop, extensively distributed across temperate and subtropical biomes. Major producing regions include India (the world's largest producer), Morocco, Canada, Pakistan, and various countries in Central Europe and North Africa. The plant is highly adaptable but thrives best in well-drained loamy soils and cool-to-moderate climates; however, it is known for "bolting" when exposed to high temperatures. While primarily a cultivated species, it has naturalized in several parts of North America and Europe, frequently appearing in anthropogenic habitats such as roadsides and fields. This wide distribution underscores its economic and cultural importance as both a staple culinary spice and a cornerstone of herbal medicine [24]

4. CONCLUSION

Brahmmmuni Karpam must be explored in both the polyherbal formulation and individually. This is regarded as the boon of the Indian Knowledge system pertaining to Tamil Culture and Tamil Tradition. It is right to explore all the polyherbal formulation and karpam with modern research tools. This review suggests that systematic research can be carried out in Brahmmmuni Karpam.

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RESEARCH ARTICLE

ENHANCING FIRE AND SMOKE DETECTION THROUGH COMPUTER VISION AND OPENCV-BASED ANALYSIS IN HSV COLOR SPACE

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Abstract

Advances in computer vision, particularly with tools like OpenCV, are transforming fire and smoke detection by overcoming the limitations of traditional smoke detectors, which are often ineffective in large, open spaces with high ceilings or ventilation. Traditional detectors rely on particle or heat changes, leading to delayed alerts in ventilated areas. Computer vision-based systems, however, enable real-time analysis of video streams to identify early visual indicators of fire and smoke. Fire detection factors include analyzing unique flame characteristics such as color intensity in the RGB or HSV color space, shape irregularities using contour analysis, and flickering patterns through motion detection. Smoke detection involves techniques such as edge blurring, optical flow analysis, and texture variance to identify diffused, moving patterns indicative of smoke. By integrating OpenCV functions like color thresholding, contour detection, and background subtraction, these systems provide faster and more reliable alerts, enhancing safety in residential and commercial environments by mitigating risks associated with delayed responses.

Keywords: Computer vision, Smoke Detection, Fire Detection, Open CV.

1. INTRODUCTION

Advances in computer vision open up new ways to over- come the disadvantages of smoke detectors, such as diffusing smoke particles before they come into contact with sensor- based alarms in large, open areas. The traditional smoke de- tectors rely on either particle or heat change detection, which proves sluggish and inadequate under high ceiling or ventilated spaces. The computer vision can provide the possibility of early warning signs of smoke and fire by analyzing color, shape, and motion patterns in video sequences through visual analysis. For quick indication of probably fire/smoke areas, the proposed system utilizes real-time processing of images, such as color thresholding, contour analysis, and so on. By providing an early warning system that identifies not only fire dangers, this technology could enhance residential and commercial environments' ability to identify fires. Advances in computer vision are now able to design novel methods of fire detection that avoid the conventional drawbacks of smoke detectors, especially in large or open rooms where high ceilings or airflow may cause a delay or prevent smoke concentration. In conventional systems, smoke detectors are based on the sensing of changes in heat or smoke particles, which may take some time to be detected in ventilated rooms and result in possible hazardous delays. The restrictions may be lessened with computer vision allowing for rapid identification of visual signs of smoke and fire in video streams by unique color, shape, and motion patterns.

2. Literature Survey

Detection explores various methodologies and technologies in fire detection, emphasizing the significance of wireless sensor networks (WSN) for monitoring environmental factors like temperature and smoke, which are crucial for early fire detection. It highlights the integration of multiple sensors, including gas and flame sensors, to enhance detection accuracy and reduce false alarms. The paper also discusses the advantages of using ZigBee technology for its low power consumption [1] and ease of integration, making it a popular choice in fire detection systems. Furthermore, it addresses the challenges faced by current systems, such as the need for reliable solutions that minimize false alerts, and suggests that future research should focus on developing cost-effective and lightweight sensors to improve the overall effectiveness of fire detection technologies .Overall, the survey provides a comprehensive overview of existing fire detection methods and identifies areas for future advancements in the field.

Microcontrollers and GSM modules with smoke sensors and cameras to identify smokers, while later

work by Panjang et al. (2018) [2] used IoT components like the MQ2 sensor and NodeMCU to send alerts when smoke was detected. Face recognition, particularly on low-cost platforms like the Rasp- berry Pi, has been applied widely in IoT security settings and serves here to identify smokers. Additionally, smoke sensors have seen varied use beyond cigarette detection, such as in smart homes, health monitoring, and environmental safety, providing a foundation for IoT-based monitoring. This study integrates GPS and a mobile notification system, following trends in real-time response systems, to create a location-aware solution for detecting and identifying smoking violations in non-smoking areas.

The advancements in automated fire detection systems, focusing on their necessity due to the increasing frequency of forest fires caused by climate change and human activity. Previous studies have shown that early detection can mitigate the devastating effects on ecosystems. Various technologies are employed in forest fire detection, including sensors, cameras, and image processing algorithms [3], which are integrated into IoT frameworks to detect fires at early stages and enable quick responses. Notably, this paper uses an Arduino as the central controller, processing data from smoke detectors, flame detectors, and cameras to determine fire presence accurately and minimize false positives. The literature emphasizes combining sensor data and AI to enhance detection accuracy, reduce response times, and protect biodiversity and local communities.

The literature surrounding the scheduling of Web Jobs within Azure App Service reveals several key themes and findings that contribute to understanding best practices and methodologies in this area: Efficient Resource Utilization: Research emphasizes the importance of optimizing resource [4] usage when scheduling tasks in Azure App Service. the advantages of leveraging serverless computing through Azure Functions and Logic Apps. This approach reduces operational overhead by allowing developers to focus on writing code. DevOps integration, and automation, all of which should be enhanced operational efficiency and reliability in cloud- based applications Traditional fire detection methods, such as satellite monitoring [5] and optical cameras, offer broad cover- age but struggle with limitations like high installation costs, signal interference, and false alarms due to environmental conditions. Recent developments in Wireless Sensor Networks (WSN) and IoT have improved fire detection systems by integrating temperature, smoke, and CO sensors with data analysis to enable real-time monitoring and rapid response. These networks, often supported by drones, GPS, and cloud- based analytics, enhance precision and reduce the time needed to detect and address fire incidents. Researchers are also investigating machine learning algorithms [6] to analyse visual data, enhancing accuracy by reducing false positives from non- fire-related elements. The study proposes an Arduino-based system integrating various sensors and alarm mechanisms to monitor forest conditions continually, offering an efficient and cost-effective solution to mitigate fire-related risks.

Importance of fire [7] and smoke detection in ensuring the security and well-being of students and staff, referencing previous works on IoT-enabled monitoring systems. Key studies include the use of IoT for identifying cigarette consumption in confined spaces and the detection of smoke and hazardous gases to prevent fires. The integration of technologies [8] such as Arduino microcontrollers, Wi-Fi modules, and smoke sensors is highlighted for real-time data transmission and notification. Previous research has demonstrated that smart systems can effectively detect and respond to smoke and fire threats, contributing to safer environments. These systems often in- corporate additional features such as mobile app notifications for authorized personnel, exemplified by platforms like Blynk and communication tools like Telegram.

The advancements in fire and smoke detection technologies emphasize the integration of IoT, Wireless Sensor Networks (WSN), and [9] AI for early and accurate detection. Studies high- light the use of microcontrollers like Arduino, sensors (smoke, flame, and gas), and ZigBee for low-power, real-time monitoring with reduced false alarms. IoT-enabled systems, supported by mobile notifications and GPS, enhance response times, making them suitable for smart homes, health monitoring, and environmental safety. Machine learning and image processing algorithms further improve accuracy by analyzing visual [10] data and reducing false positives. Applications extend to forest fire detection, smoking violation identification, and educational institutions, showcasing cost-effective, reliable solutions that prioritize safety and environmental protection

3. Proposed Work

To develop a fire and smoke detection system based on Open CV and Python which can monitor the video stream for fires or smoke and alert its users whenever fires or smoke are visible. Taking into account that lighting conditions may change, the system must employ changeable thresholds of the HSV values so that the correct identification can be made whilst cutting down on false alarms. This aspires to increase safety measures by preventing fire or smoke from being unnoticed during instances when it is critical to detect fire or smoke.

A. Objective

The main objectives of the project are:

- To detect smoke by identifying grayish hues

with low saturation levels, typical of smoke.

- To detect fire in a video feed based on specific color characteristics associated with flames.
- To enable dynamic threshold adjustment for both fire and smoke detection using HSV color space filtering.
- To reduce false detections by requiring fire or smoke regions to be consistently detected over multiple frames before triggering an alert.

B. Novelty of Proposed work

The proposed fire and smoke detection system demonstrates novelty through its integration of fire and smoke detection in a unified framework, leveraging HSV color space for precise thresholding tailored to each phenomenon. It introduces real-time dynamic threshold adjustment using OpenCV trackbars, enabling adaptability to diverse environments and lighting conditions. By incorporating temporal consistency checks, the system significantly reduces false positives caused by transient noise. Additionally, contour-based area filtering refines detection by isolating meaningful regions while ignoring irrelevant noise. Its lightweight design, modular structure, and open-source implementation enhance its practicality and accessibility, making it a versatile, cost-effective solution for real-time hazard monitoring in various applications

4. Experimental Methodology

The Steps involved in Implementing and Evaluating a Fire and Smoke Detection System Using Python and Open CV are:

- Set Up the Open CV Development Environment.
- Capture and Preprocess Video Frames.
- Implement HSV-Based Fire Detection.
- Integrate Dynamic HSV Threshold Adjustment.
- Evaluate Performance Metrics.
- Analyze and Document Results.

C. HSV Color Space and Thresholding

HSV, in this case, is employed since it can distinguish be- tween hue and brightness, thus providing a better accuracy of detection associated with color and flames, and smoke. Unlike RGB, HSV allows for thresholding, which is adjustable. In this way, colors associated with flames and smoke are quite possible to segregate. For example, the color of flames are bright colors like red, yellow and orange; smoke usually ap- pears with low saturation, and with mixed brightness, looking mainly gray. The system could differentiate these two creating some HSV ranges. It detects areas with colors between 0 and 50; that is, colors like red and yellow, high saturation between 150 and 255, and high brightness through HSV filtering for fire recognition.

D. Contour Detection and Area Filtering

In the study, contours retrieved from the binary masks formulated from HSV thresholds are considered for evaluating the shape and size of regions detected. By removing tiny or very irregularly shaped areas-the majority of which are noise not actually fire or smoke it has been indicated that the contour analysis will enable focusing of the system on the meaningful places. Area thresholds applied on contours ensure meaningful areas only are highlighted. For example, it sets the contour area threshold for fire areas to at least 1000 pixels; therefore, the system can easily identify larger, more stable fire patches while excluding smaller changes or anomalies in the video stream. It would ensure that only significant and persistent regions are marked as potential fire or smoke regions, thus making this thresholding process increase the reliability of detection and reduce.

E. Real-time Threshold Adjustment

OpenCV track bars are able to be employed inside the project so that threshold can be changed dynamically, and HSV values can be customized in real time in case of testing. This flexibility is very important because it would permit hue and brightness thresholds to be set for different lighting conditions, settings, and sources of fire and smoke. Operators can fine- tune the detection settings by dynamically changing the HSV ranges for particular situations, such as artificial lighting, natural sunshine, or shadows that may otherwise interfere with accuracy. With this real-time adaptation ability, the change in the visual features of fire and smoke may vary with whether the situation is indoors or outdoors or daytime against night time, ensuring the system would be flexible and effective under any condition. In addition, dynamic threshold customisation also reduces false positives as threshold values.

F. Alert Mechanism

The fire or smoke alarm will be activated only when there is a probable fire or smoke region detected reliably for a number of consecutive frames. This method reduces the chance of false positives due to isolated noise, momentary illumination changes, or slight color shifts in the video stream. Transient visual artifacts, such as those that could be mistaken for fire or smoke, can be distinguished by the system from occurrence of real fire or smoke by requiring persistence in the detection. This way, this persistence check, acting like a filter, will make sure warnings are issued only in response to continuing, consistent visual patterns, coherent with smoke or fire and not necessarily in response to brief interruptions.

G. Tool used

Visual Studio Code is a streamlined code editor with support for development operations like debugging, task running, and version control. It aims to provide just the tools a developer needs for a quick code-build-debug cycle and leaves more complex workflows to fuller featured IDEs, such as Visual Studio IDE.

H. Flowchart

The flowchart illustrates the sequential process of a fire and smoke detection system using HSV color space. It includes initialization, frame capture, detection logic for fire and smoke, temporal consistency checks, alert generation and termination.

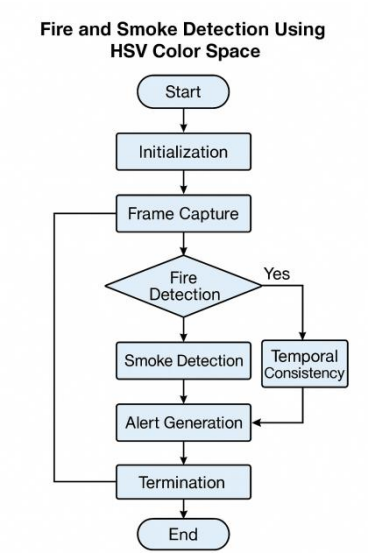

Figure 1: Process Flowchart

5. Result and Analysis

The proposed Fire and Smoke Detection System using HSV Color Space was successfully implemented and tested on video sequences captured under different lighting and environmental conditions. The system processes real-time frames and detects fire and smoke regions based on their color and motion characteristics.

A. Result

- ✓ The HSV color model effectively distinguished fire and smoke from the background due to its separation of chromatic content (hue and saturation) from intensity (value).
- ✓ Fire regions were identified using hue and saturation thresholds, while smoke detection relied on low-saturation and high-value pixel ranges.
- ✓ Temporal consistency checks reduced false positives caused by momentary color fluctuations or lighting variations.

Figure 2: Smoke Detection

Figure 3: Fire Detection

Figure 4: No smoke or Fire Detected

5. Conclusion

The HSV-based detection approach proved efficient for real-time fire and smoke monitoring. The fire and Smoke detection System offers a possible and reasonably proficient Python-and-OpenCV-based real-time hazard detection solution. It adapts to a variety of backgrounds and light situations through active thresh- old variations and color-space modifications using the Hue, Saturation, and Value (HSV) technique. The implementation minimizes false alarms and emphasizes an association with reliability through continual detection checks and noise- reduction strategies. The project creates a handy tool for fire and smoke detection in time to be put to good use in preventing possible disasters, strongly emphasizing the need for real-time monitoring for safety applications.

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RESEARCH ARTICLE

ETHNO MEDICINAL PLANTS USED BY MALAYALI TRIBALS IN YERCAUD HILLS, SALEM DISTRICT, TAMIL NADU, INDIA.

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Abstract

The present study highlights the importance of some medicinal plants in the health care system of Malayali tribals community of Yercaud Hills, Salem district, Tamil Nadu, India. Ethnomedicinal information was collected from malayali tribes through personal interviews and group discussions with 8 randomly selected informants. Use value (UV), fidelity level (FL) and Informant Consensus factor (ICF) were determined. During the data collection 20 species distributed in 16 families for treating 44 different ailments. Ethnomedicinal plants like *Abrus pulchellus*, Wall, *Andrographis paniculata*, Wall.ex.Nees, *Asclepias curassavica*, L, *Asparagus racemosus*, Wild, *Azadirachta indica*, A. Juss, *Cassia fistula*, Linn, *Centella asiatica*, Urb, *Corallocarpus epigaeus*, Hook.f, *Curculigo orchioides*, Gaertn, *Emblica officinalis*, Gaerth,*Enicostemma littirale*, Blume, *Hemidesmus indicus*, R. Br, *Holarrhena pubescens* (Buch.Ham.) Wall.ex.G.Don, *Leucas aspera*, Spreng, *Mimosa pudica*, Linn, *Myrica esculenta*, Buch. Ham, *Pergularia daemia* (Forsk.) chiov,*Terminalia bellerica*, Roxb, *Terminalia chebula*, Retz and *Toddalia asiatica*, Lamk were documented during the study. UV of the encountered plant species ranged from 0.38 to 1.13. The uppermost FCI value is reported for Ejaculation of semen and Bone fracture. In the present investigation, the FL varied from 50 to 100%.

Keywords: Ethnomedicinal plants, Malayali tribals, Yercaud Hills Use value (UV), Fidelity level (FL) and Informant Consensus factor (ICF).

1. Introduction

India is one of the 17th mega biodiversity countries of the world which resides a gargantuan diversity of plants, animals and microbes. When peoples were appearing on this earth has been crucial with the plant kingdom for their day today needs such as food, medicine, clothing, shelter and other requirements. Now days in many developing countries peoples are take modern medicine for their illnesses, but in many rural areas indigenous medicine based folk remedies has been played an important role in the health care system. In India the indigenous people are exercise a divergence of herbals for impressive curing of various diseases (1,-2) and it is known that India has the second largest tribal population in the world after Africa (3). Today traditional medicine and ethnobotanical information play an important role in scientific research and conservation programs in different parts of the world (4).

Eastern Ghats ecosystem contains more than 2500 species of angiosperms which compose about 13 % of the flowering plants in India (5). Yercaud hills is the major point in the Eastern Ghats, located in the forest types range from evergreen to moist deciduous with the altitude of 1515 meters (4970 Ft). The temperature ranges from 13^0 C to 29^0 C on the peaks and 25^0 C to 40^0 C at the foot hills. The average annual rainfall is around 1500 mm – 1750 mm (6). The soil is deep and non-calcareoces (7). Malayali tribals are typically hill tribals present in the foot hills of Yercaud hills. The main aim of the present study is highlights the importance of some medicinal plants in the health care system of Malayali tribals community of Yercaud Hills.

2. Material and Methods

Frequent field surveys were carried out in Yercaud hills in different seasons during 2014 - 2016. Interview and data gathering methods were followed by Schultes (1962)[(8)] and Jain (1989)[(9)];

Jain and Rao (1977)[10]. The voucher specimens were collected and identified by referring to standard floras (11-12).

2.1. Data analysis

2.1.1. Use Value (UV)

The relative importance of each species used in the study area was quantitatively evaluated following the method developed by Phillips and Gentry (1993a, 1993 b) [13-14].

UV = ∑U/ N, Where, UV is the use value of species; U is the number of use reports cited for a particular species and n is the total number of informants interviewed. In general, UV is high, if there are more use report citations (When there are more uses and all the informants agree with it) for a given species and low when there are few reports.

2.1.2. Informant consensus factor (ICF)

Informant consensus factor (ICF) was calculated to evaluate if there was a consensus in the knowledge of plants used in the ailment group between healers in the study area. The ICF was calculated using the following formula (15)

ICF = Nur - Nt/Nur-1 where Nur refers to the number of use reports for a particular ailment category and Nt refers for a particular ailment category by all informants.

2.1.3. Fidelity level (FL)

The fidelity level (FL), the percentage of informants claiming the use of a certain plants for the same major purpose, was calculated according to the following formula (16)

FL (%) = Np / N × 100. Where Np is the number of informants that calming a use of a plant species to treat particular diseases and N is the number of informants that use the plants as a medicine to treat any given disease.

3. Results and Observations

3.1. Utilization of plant species as traditional medicine by Malayali tribes in Yercaud Hills

The investigation revealed that the traditional healers of Yercaud hills used 20 species of plants encompassing to 16 families to treat 44 different types of ailments. Most of the recorded medicinal herbs are harvested from natural environment in the different location of the yercaud hills by traditional healers. The day before they collect the plants, they pray to the plant and tie a thread that has been dipped in turmeric around the plant. The next day, they hymn a mantra before harvesting. The reported twenty important medicinal herbs in the present survey were arranged in alphabetical order according to their botanical name. The botanical name of each plant is followed by the local name, family and ethnomedicinal uses are listed in the table 1.

During the survey we noted single plant may use for curing many ailments such as *Abrus pulchellus* is used to treat female infertility, easy delivery and rashes, *Andrographis paniculata* is used to treat centipede bite, scorpion sting, snake bite, diabetes, fever, small pox and cure blister. *Asclepias curassavia* used for curing migraine pain, cycosis, normal delivery, lumbago, dysentery and excessive bleeding after delivery. *Asparagus racemous* used for increase the sperms count, epididymitis and diabetes. *Azadirachta indica* recommended for female infertility, snake bite, mosaic and small pox, *Cassia fistula* used for curing snake bite, chest pain, diabetes and blister, *Centella asiatica* used for body pain, diabetes, menstrual disorder, increase sexual capacity and sperm count, female infertility, hemorrhoids, *Corallocarpus epigaeus* is used for treating antidote for beetle bite, centipede bite, scorpion sting and snake bite, *Curculigo orchioides* oral administration of rhizome powder can used for curing diabetes, neurotic problems, ejaculation of semen, epididymitis, increase sperm count, erysipelas and kidney stone, *Emblica officinalis* used to cure dental ache, whoop cough, diabetes, liver problem and reduces the weight, *Enicostemma littorale* to treat the body pain, fever, beetle bite, centipede bite, snake bite, chest pain, dymenorrhoea and blister, *Hemidesmus indicus* is consumed for curing constipation, abdominal pain, kidney stone, chest pain and snake bite, bark of *Holarrhena pubescens* administer orally to cure hemorrhoids, trismus and bone fracture, *Leucas aspera* Oral administration to cure paralysis, migraine pain, rashes, chest pain ear ache. *Mimosa pudica* consumed to cure wound, beetle bite, female infertility, epididymitis and hemorrhoids. *Myrica esculenta* Oral administration of bark powder good for bone fracture, diabetes, female infertility and over bleeding during menstruation period. Consumption of leaves of *Pergularia daemia* to cure body pain, snake bite, irregular menstruation, normal delivery and lumbago. Fruit powder of *Terminalia bellerica* administers orally to cure diabetes, dysentery, colitis and reduce the Weight. Oral administration of fruit powder of *Terminalia chebula* used to treat diabetes, colitis, dysentery, hemorrhoids, dental ache, chest pain, whoop cough and reduce weight and *Toddalia asiatica* is used to cure snake bite, centipede bite, chest pain, cold, erysipelas leprosy.

3.2. Data analysis:

The present work was the first ever study to record quantitative data of the medicinal flora of the region, including Use Value, Informant Consensus Factor and Fidelity Level.

3.2.1. Use Value (UV):

As indicated in table 2, UV of the encountered plant species ranged from 0.38 to 1.13. The highest UV was found for *Centella asiatica* (1.13) while

lowest was for Abrus pulchellus, Asparagas racemous and Holarrhena pubescens (0.38). Other important plant species with high use value were Curculigo orchioides (1), Enicostemma littorale (1), Terminalia chebula, Andrographis paniculata (0.88), Asclepias curassavia (0.75), Leucas aspera (0.75), Toddalia asiatica (0.75), Emblica officinalis (0.63), Hemidesmus indica (0.63), Terminalia bellerica (0.5), Myrica esculenta (0.5), Mimosa pudica (0.5), Corallocarpus epigaeus (0.5) and Cassia fistula (0.5). It was also observed that the highest use values were due to the high number of use reports in the study area.

3.2.2. Informant Consensus Factor:

The inhabitants used medicinal plants in the treatment of 44 different types of ailments. The important disorders were Ejaculation of semen, Bone fracture, snake bite, Chest pain, Female infertility, skin diseases, diabetes, Menstrual disorder, Hemorrhoids, Body pain and sperm count. To determine the informant consensus factor (FCI), all the reported ailments were first grouped into 11 different disease categories on the basis of their use reports (Table 3). The uppermost FCI value is reported for Ejaculation of semen and Bone fracture (1), followed by Snake bite (0.86), chest pain (0.8), female infertility and skin diseases (0.75), Diabetes (0.71), Menstrual disorder and Hemorrhoids (0.66), Body pain and sperm count (0.5). These results show that Ejaculation of semen and Bone fracture were especially common in the study area.

3.2.3. Fidelity level (FL):

Fidelity level highlights the medicinal flora, Medicinal plants with maximum curative properties have the highest fidelity level, i.e., 100%. In the present investigation, the FL varied from 50 to 100%. The plant species most commonly utilized in the research area with 100% fidelity levels were Abrus pulchellus, Andrographis paniculata, Corallocarpus epigaeus, Asparagus racemous, , Curculigo orchioides, which were used to treat Female infertility, snake bite, increase sperm count and ejaculation of semen respectively. The FL determined for *Enicostemma littorale* (Body pain), *Centella asiatica* (Menstrual disorder), *Emblica officinalis* (Whoop cough and diabetes), *Myrica esculenta* (Bone fracture and diabetes), *Toddalia asiatica* (Snake bite), *Holarrhena pubescens* (hemorrhoids), *Pergularia daemia* (Snake bite) and *Leucas aspera* (Rashes) were 93, 88, 75, 75, 71, 60, 60 and 50% respectively (Table: 4).

Table 1 List of Ethnomedicinal plants used by Malayali tribes in Yercaud Hills

S. No	Botanical Name	Local Name	Family	Ethnomedicinal uses
1	*Abrus pulchellus* Wall.	Vellaikuntumani	Fabaceae	Oral administration of seed powder along with the honey to cure the female infertility, Seed paste with a glass of milk it causes easy delivery and Both seeds and leaves paste with hot water administered orally to cure rashes.
2	*Andrographis paniculata* Wall. Ex. Nees.	Siriyananagai	Acanthaceae	Oral administration of whole plant parts powder along with the hot water to cure centipede bite, whole plant parts powder administrated orally to cure scorpion sting, consumption of leaves powder to cure snake bite, Oral administration of leaves powder to reduced the diabetes, Oral administration of leaves decoction to cure fever, consumption of leaves infusion to cure small pox and whole plant parts powder mixed with castor oil applied externally to cure blister.
3	*Asclepias curassavia* L.	Mokkutipoodu	Asclepidaceae	Leaves juice extracts poured in the noise to relief the migraine pain, fresh leaves are added to the boiling water while taking bath to cure cycosis, oral administration of leaves juice to causes normal delivery, crushed leaves along with milk administered orally to cure lumbago, leaves paste administered orally to arrest dysentery and seed paste along with the hot water administered orally to cure excessive bleeding after delivery.
4	*Asparagus racemous* Willd.	Thanerivittankilangu	Liliaceae	Rhizome powder along with milk to increase the sperms count, oral administration of rhizome powder along with pepper and garlic to cure

				epididymitis and consumption of rhizome powder is reduced the diabetes.
5	*Azadirachta indica* A. Juss.	Vembu	Meliaceae	Oral administration of bark powder along with jiggery to cure female infertility, consumption of bark powder to cure snake bite, leaves paste mixed with common salt apply whole body while taking bath; this process continues for one month to cure mosaic and leaves paste administered externally to cure small pox.
6	*Cassia fistula* Linn.	Konnei	Caesalpiniaceae	Oral administration of bark powder along with pepper and garlic with hot water to cure snake bite, infusion of bark is consumed orally to cure chest pain, oral administration of bark powder to reduced diabetes and root powder mixed with castor oil administered externally to cure blister.
7	*Centella asiatica* Urb.	Vallarai	Apiaceae	Leaves are added to the boiling water and the vapor is inhaled to relief the body pain, oral administration of leaves powder can reduce the diabetes, oral administration of leaves powder is used to cure menstrual disorder, oral administration of leaves powder with milk used to cure the lacking in manly sexual capacity, oral administration of whole plant parts powder with cow milk to increase the sperm count, oral administration of whole plant parts powder is used to cure female infertility, consumption of whole plant parts powder with curd to cure burning sensation during urination, oral administration of whole plant parts powder is used to cure hemorrhoids and whole plant parts paste with milk administered orally to cure ejaculation of semen.
8	*Corallocarpus epigaeus* Hook.f.	Keradankilangu	Cucurbitaceae	Oral administration of rhizome powder with hot water to cure beetle bite, consumption of rhizome powder with hot water to cure centipede bite, rhizome powder administered orally to cure scorpion sting and rhizome powder with hot water administered orally to cure snake bite.
9	*Curculigo orchioides* Gaertn.	Nilapanaikilangu	Amaryllidaceae	Oral administration of rhizome powder can reduce diabetes, rhizome powder administered orally to cure neurotic problems, oral administration of rhizome powder with milk to cure ejaculation of semen, Oral administration of rhizome paste is used to cure epididymitis, rhizome powder with milk to administered orally to cure the lacking in manly sexual capacity, oral administration of rhizome powder with cow milk to increase the sperm count, rhizome paste administered externally to cure erysipelas and oral administration of rhizome powder with hot water to cure kidney stone.
10	*Emblica officinalis* Gaertn.	Nelli	Euphorbiaceae	Fruit paste keep inside the mouth to cure whoop cough, fresh fruit placed on the painful teeth to cure dental ache, oral administration of fruit powder can reduce diabetes, bark powder administered orally to cure liver problems and fruit powder with hot water administered orally; it reduces the weight.

11	*Enicostemma littorale* Blume.	Vellaragu	Gentianaceae	Leaves are added to the boiling water and the vapor is inhaled to relief the body pain, oral administration of leaves decoction to cure fever, whole plant parts powder with hot water to administer orally to cure beetle bite, oral administration of whole plant parts powder with hot water to cure centipede bite, whole plant parts powder administered orally to cure snake bite, oral administration of whole plant parts powder with hot water to cure chest pain, whole plant part powder along with pepper and nigella to administered orally to cure dymenorrhoea and oral administration of leaves powder is used to cure blister.
12	*Hemidesmus indicus* R. Br.	Nannari	Asclepidaceae	Oral administration of leaves powder used to cure constipation, entire aerial parts powder administered orally to cure abdominal pain, oral administration of whole plant parts powder with hot water to cure kidney stone, whole plant parts powder with hot water administered orally to cure chest pain and root powder administered orally to cure snake bite.
13	*Holarrhena pubescens* (Buch.Ham.) Wall.ex.G.Don.	Kudasapali	Apocynaceae	Bark powder along with the seeds of cumin and garlic with hot water to administer orally to cure hemorrhoids, consumption of bark paste with mother milk to cure trismus and oral administration of bark powder to cure bone fracture.
14	*Leucas aspera* Spreng	Thumbai	Mimosaceae	Oral administration of whole plant parts powder to cure paralysis, leaves juice poured into the noise to relief the migraine pain, leaves are added to the boiling water and the vapor is inhaled to relief the body pain, leaves paste administered externally to cure rashes, leaves powder with hot water administered orally to cure chest pain and leaves juice extract poured into the ear to cure ear ache.
15	*Mimosa pudica* Linn.	Thottalsurungi	Mimosaceae	Leaves paste is applied over wound, whole plant parts powder along with the turmeric mixed with coconut oil to applied beetle bitten area, oral administration of leaves paste is used to cure female infertility, whole plant parts consumed in the form of pill to cure epididymitis and leaves paste with milk administered orally to cure hemorrhoids.
16	*Myrica esculenta* Buch.Ham.	Kudumaruthamaram	Combretaceae	Oral administration of bark powder with cow milk is good for bone fracture, bark powder with hot water administered orally can reduce the diabetes, bark powder with hot water administered orally to cure female infertility and oral administration of bark powder with hot water is used to cure over bleeding during menstruation period.
17	*Pergularia daemia* (Forsk.) chiov.	Velliparuthi	Asclepidaceae	Leaves are added to the boiling water and the vapor is inhaled to relief the body pain, whole plant parts powder administered orally to cure snake bite, leaves powder administered orally to cure irregular menstruation, leaves juice mixed with castor oil administered orally; it causes normal delivery and

				consumption of leaves juice with milk to cure lumbago.
18	*Terminalia bellerica* Roxb.	Thanrikkai	Combretaceae	Oral administration of fruit powder can reduce diabetes, fruit powder with cow milk to administer orally to arrest dysentery, fruit powder with hot water to administer orally to cure colitis and oral administration of fruit powder is used to reduce the Weight.
19	*Terminalia chebula* Retz.	Kadukkai	Combertaceae	Oral administration of fruit powder can reduce diabetes, fruit powder with hot water to administer orally to cure colitis, fruit powder with cow milk taken orally; it arrest dysentery, fruit powder along with cumin seeds administered orally to cure hemorrhoids, fresh fruit placed on the painful teeth it reduced the dental ache, bark powder administered orally to cure chest pain, fruit paste keep inside the mouth cure whoop cough and fruit powder with hot water is administered orally to reduce weight.
20	*Toddalia asiatica* Lamk.	Mulaikaradanmullu/ Milagaranai	Rutaceae	Oral administration of root powder with hot water is used to cure snake bite, root powder with hot water to administered orally to cure centipede bite, infusion of bark is taken orally good for chest pain, roasted seed paste administered orally for cold, bark paste applied externally for erysipelas and root powder mixed with oil applied externally for leprosy.

Table: 2 Use Value (UV) of ethnomendicinal plants used by Malayali Tribes in Yercaud Hills

S. No	Botanical Name	Vernacular Name	Family	Ailment category	UV value
1	*Abrus pulchellus* Wall.	Vellaikuntumani	Fabaceae	Female infertility, easy delivery and rashes	0.38
2	*Andrographis paniculata* Wall. Ex. Nees.	Siriyananagai	Acanthaceae	Centipede bite, scorpion sting, snake bite, diabetes, fever, small pox and blister	0.88
3	*Asparagus racemous* Willd.	Thanerivittankilangu	Liliaceae	Increase sperm count, epididymitis and diabetes	0.38
4	*Centella asiatica* Urb.	Vallarai	Apiaceae	Body pain, diabetes, menstrual disorder, sexual capacity, sperm count, female infertility, burning sensation during urination, hemorrhoids and ejaculation of semen	1.13
5	*Corallocarpus epigaeus* Hook.f.	Keradankilangu	Cucurbitaceae	Beetle bite, centipede bite, scorpion sting and snake bite	0.5
6	*Curculigo orchioides* Gaertn.	Nilapanaikilangu	Amaryllidaceae	Diabetes, neurotic problem, ejaculation of semen, epididymitis, sexual capacity, increase sperm count, erysipelas and kidney stone	1
7	*Emblica officinalis* Gaertn.	Nelli	Euphorbiaceae	Whoop cough, dental ache, diabetes, liver problem and weight loss	0.63
8	*Enicostemma littorale* Blume.	Vellaragu	Gentianaceae	Body pain, fever, beetle bite, centipede bite, snake bite, chest pain, dymenorrhoea and blister	1

9	*Holarrhena pubescens* (Buch.Ham.) Wall.ex.G.Don.	Kudasapali	Apocynaceae	Hemorrhoids, trismus and bone fracture	0.38
10	*Leucas aspera* Spreng	Thumbai	Mimosaceae	Paralysis, migraine pain, body pain, rashes, chest pain and ear ache.	0.75
11	*Myrica esculenta* Buch.Ham.	Kudumaruthamaram	Combretaceae	Bone fracture, diabetes, female infertility and over bleeding during menstruation	0.5
12	*Pergularia daemia* (Forsk.) chiov.	Velliparuthi	Asclepidaceae	Body pain, snake bite, irregular menstruation, normal delivery and lumbago	0.63
13	*Toddalia asiatica* Lamk.	Mulaikaradanmullu/ Milagaranai	Rutaceae	Snake bite, centipede bite, chest pain, cold, erysipelas and leprosy	0.75

Table:3 Informant Consensus Factor value of Major ailments

S. No	Major ailment	ICF
1	Ejaculation of semen	1
2	Bone fracture	1
3	Snake bite	0.86
4	Chest pain	0.8
5	Female infertility	0.75
6	Skin diseases (Rashes, blister, erysipelas and leprosy)	0.75
7	Diabetes	0.71
8	Menstrual disorder	0.66
9	Hemorrhoids	0.66
10	Body pain	0.5
11	Sperm count	0.50

Table : 4 Most commonly used medicinal plants and their major uses with their fidelity level

S. No	Botanical Name	Major ailment	Fidelity level (%)
1	*Abrus pulchellus* Wall.	Female infertility	100
2	*Andrographis paniculata* Wall. Ex. Nees.	Snake bite	100
3	*Asparagus racemous* Willd.	Increase the sperm count	100
4	*Centella asiatica* Urb.	Menstrual disorder	88
5	*Corallocarpus epigaeus* Hook.f.	Snake bite	100
6	*Curculigo orchioides* Gaertn.	Ejaculation of semen	100
7	*Emblica officinalis* Gaertn.	Whoop cough and Diabetes	75
8	*Enicostemma littorale* Blume.	Body pain	93
9	*Holarrhena pubescens* (Buch.Ham.) Wall.ex.G.Don.	Hemorrhoids and blister	60
10	*Leucas aspera* Spreng	Rashes	50
11	*Myrica esculenta* Buch.Ham.	Bone fracture and diabetes	75
12	*Pergularia daemia* (Forsk.) chiov.	Snake bite	60
13	*Toddalia asiatica* Lamk.	Snake bite, erysipelas and leprosy	71

4. Conclusion

The study depicts Salem district of Tamil Nadu revealed in the field of folk medicine. The survey of the report includes both common and serious health issues such as Diabetes, Body pain, snake bite, Skin diseases and Mensural disorders Therefore, documentation of traditional knowledge is the only way out to preserve the knowledge base protect the medicinal plants resources endemic to this area. Clinical study to prove the validity of the recorded treatments could spread indigenous herbal knowledge worldwide; hence, action should be

taken to conserve herbal knowledge, as well as the medicinal plants.

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RESEARCH ARTICLE

TRADITIONAL USE OF MEDICINAL PLANTS BY MALAYALI TRIBES IN YERCAUD HILLS, EASTERN GHATS, SALEM DISTRICT, TAMIL NADU, INDIA.

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Abstract

An ethnobotanical survey was conducted in 10 villages of Yercaud Hills, Salem district, Tamil Nadu among the Malayali tribals by personal interviews and field visits along with the informants during November 2012 – May 2014. Informants were selected based on their experience and knowledge on medicinal plants. From each village one person was selected. Present study focused on local inhabitants who used traditional resources for self-medication. A total number of 30 plant species belongs to 30 genera and 22 families have been reported for their use in treat ailments such as leprosy, snake bite, beetle bite, apoplexy, body pain, stomach, rashes, swelling, cataract, worm infection, trismus, mental disorders, menorrhea, dysentery, tumor and sprain. Botanical name, vernacular name, parts used, name of diseases against which the plants used, mode of preparation and administration for each recipes are discussed. The result of this study showed that local people in this study area still depend on medicinal plants and these plants play decisive role in primary health care system.

Keywords: Eastern Ghats, Yercaud hills, Malayali tribes, Ethnomedicinal plants.

1. Introduction

Plants are the basis of life on earth, supplying fresh oxygen and play an important role to people's livelihood. Worldwide 2, 48, 000 seed plants are reported and more than 50,000 of them are used for medicinal purposes. The use of plants from different plant parts performs a great role particularly in the places where they lack modern health facilities/clinics/hospitals. India is the largest country, have the richest arrays of registered and relatively well known medicinal plants [(1)]. Eastern Ghats are discontinuous range of mountain set along Eastern coast, starting at West Bangal, and pass through states like Orissa, Andhra Pradesh and Tamil Nadu. Eastern Ghats holds the rich floral system with more medicinal plants. The land is also inhabited by quite a few tribes which include Savara, Jatapa, Dora, Gadapa, Khond, Manne Dora and Mukha Dora. These indigenous people have their own unique cultural heritage. These people follow the age old customs and traditions. They are still dependent on the forest produce and hunting for their livelihood. These tribes have good knowledge about geography of the region and its produce and thereby make a good use of its medicinal plants.

The study area Yercaud hills is the major point in the Eastern Ghats, located with the forest types range from evergreen to moist deciduous. Malayali tribals are typically hill tribals present in the foot hills of Yercaud hills. Malayali simply means a hill person an appellation distinguishing them from the people of plains. In physical appearance they scarcely differ from the people of plains. They speak Tamil dialect of their own. They are supposed to be descendants of Kanchipuram vellalar. They appear to have migrated from Kanchipuram (a town near Chennai, Tamil Nadu) between seventh and eleventh centuries. The tribals are mostly working as casual laborers in coffee estates. They are also cultivating the food grains, fruits and vegetable [(2)].

2. Materials and Methods

2.1. Study Area:

The study was conducted at Yercaud Hills range of the Eastern Ghats situated in Salem district of Tamil Nadu. The Hill range is situated at an altitude of 1515 meters (4970 ft) above. The most popular Servarayan temple is situated at 5,236 feet in Yercaud Hills. The geographical position of the study area is 11^0C 45′ 56" N latitude and 78^0C 17′ 55" E longitude. The temperature ranges from 13^0 C to 29^0 C on the peaks and 25^0 C to 40^0 C at the foot hills. The average annual rainfall is around 1500 mm – 1750 mm.

2.2. Study Pattern and Period:

Study was conducted during November 2012 – May 2014 to design the importance of traditional medicine from plants for curing various ailments.

2.3. Method of data collection:

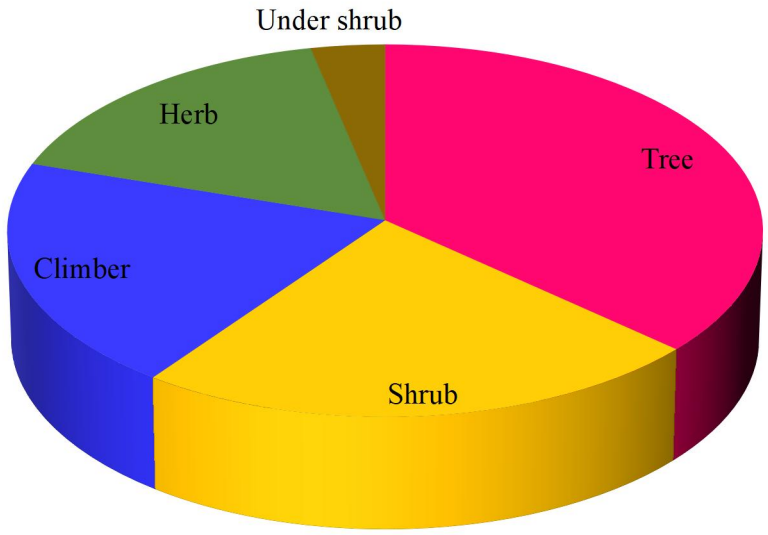
Ethnomedicinal data were collected through general conversations with the informants. Personal interviews were used to obtain the information of medicinal plants with their local names, parts used, mode of preparation (i.e., decoction, paste, powder and juice) and form of usage either fresh or dried and mixtures of other plants used as ingredients. The recipes on the mode of preparation of ethno-herbal products along with dosage, application and duration were also gathered. The data gathered were cross verified by repeated queries with different local herbalists in different seasons [3]. A total number of 10 traditional healers comprising of 6 males and 4 females were identified between the ages of 35 and 80. They were selected based on their knowledge of medicinal plants. Informants were asked to come to field and show the plants with local names. The species mentioned by the informants were identified taxonomically for which the voucher specimens were referred with standard floras [4, 5].

3. Results and Discussion

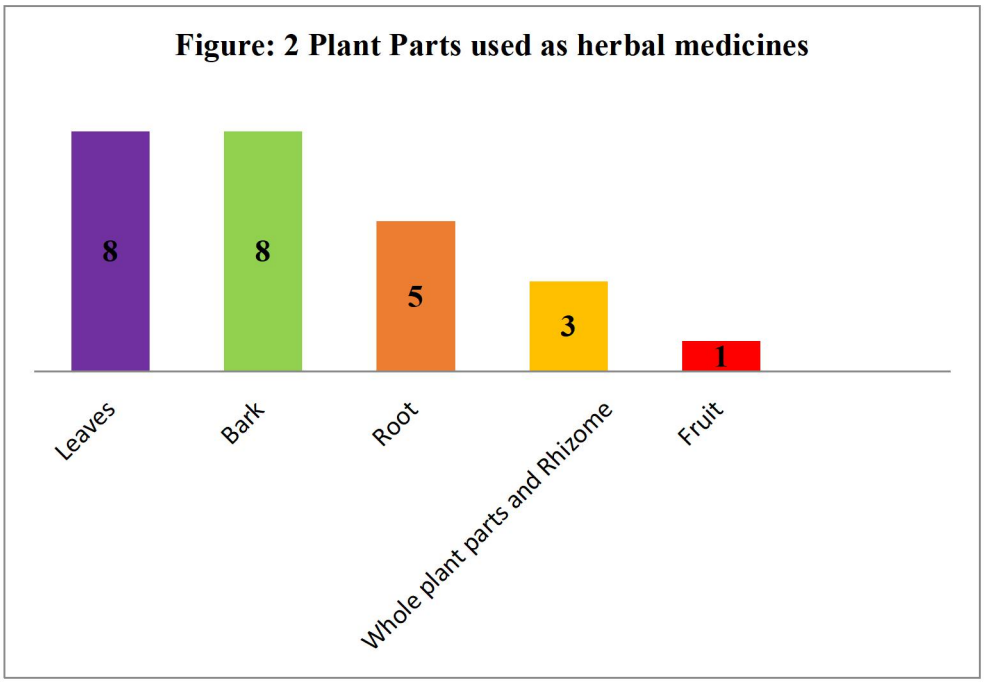
During the course of investigation, 10 villages viz., Mundakampadi, Muluvi, Karadiyur, Pattipadi, Velur, Jernakaadu, Taalur, Vellakadai, Puliyur and Periakadu were visited. More reliable informants who had rich experience and practical knowledge of the plants used in the traditional system of medicine were selected. These informants were considered as collaborators in ethnobotanical research thus giving equal participation in collection of information.

During the investigation 30 ethnomedicinal plant species distributed in 30genera and 22 families were recorded. These plants were used to cure different ailments such as leprosy, snake bite, beetle bite, apoplexy, body pain, stomach, rashes, swelling, cataract, worm infection, trismus, mental disorders,menorrhea, dysentery, tumor and sprain (Table. 1). Among 30 plant species Tree forms (11 species) were found to be commonly used followed by shrub (7 species), climber (6 species), herb (5 species) and undershrub species (1 species each) (Figure 1). Malayali tribes seldom try to collect parasite from other trees for their medicinal requirement, because they have so many herbal drugs available around their shelters.

Figure: 1Calssification of Medicinal Plants based on habit



The most dominant plant parts used were bark and leave (8 species each), root (5 species), whole plant parts and rhizome (3 species each), seeds (2 species) and fruit (1 species) were documented (Figure 2). Many indigenous communities throughout the world also mostly utilize leaves for the preparation of herbal medicines [5, 6,7,8,9,10]. The reason why leaves are used mostly is that they are collected very easily than underground parts, flowers, fruits etc. [11].



Medicines were prepared in the form of powder, paste and juice. Some plants were used as individuals and also combination with other plants. Internal uses (62.5%) were predomination over external uses (31.25%). Internal consumption was done for body pain, menorrhoea, dysentery, rashes, snake bite, stomach pain, swelling, trismus and worm infection and external applications are done for apoplexy, beetle bite, leprosy, sprain and tumor. For external use, the most important methods used direct application of paste or with oil. Most of the medicines were given orally which were also suggested by some other researchers in the world [12,13,14,15,16].

In our present research we mainly want to highlight the newly documented plants species of medicinal uses that were collected from Malayali tribes in Yercaud Hills. The previous researcher who all worked in Yercaud Hills and various part of Tamil Nadu in Eastern Ghats not enumerate the uses of *Dioscorea oppositifolia*, *Mangifera indica*, *Premna tomentosa, Ruta graveolens* and *Terminalia bellerica* for apoplexy, *Premna tomentosa* for mental disorders, *Combretum ovalifolium*, *Plumbago zeylanica*, and *Toddalia asiatica* for leprosy, *Alangium salvifolium* for snake bite, *Asclepias curassavia* for dysentery, *Coccina indica* for stomach pain, *Artocarpus hirsutus* and *Evolvulas alsinoids* for tumor, *Carica papaya* for beetle bite and *Abrus pulchellus* for rases. Local tribal people of kerala [17] used *Dendrophoe falcate* for treating rheumatic complaints. In our findings whole plant part of *Dendrophoe falcate* is used to cure body pain. Therefore, new medicinal uses of encountered species are suggested to be evaluated for in depth screening of bioactive compounds and related pharmacological activities.

According to some studies, we found similarity with many species of plants which cure various types of ailments that were recognized by some other tribal community and Malayali tribes in Tamil Nadu. *Rhinacanthus nasuta* [7], *Azadirachta indica* [18, 19], *Alangium salvifolium* [20] and *Corallocarpus epigaeus* [21, 22] were repute as a remedy for snakebite and we also get the similar result in our data collection. Plants which are used in repetitive manner in any ailment could be more likely to have biologically active compound [13]. Few of the plants reported in this study are good evidence of effectiveness and were scientifically validated as significant pharmacological agent. For example, the phytochemical analysis of leaves extract of *Rhinacanthus nasuta* revealed the presence of various components such as alkaloids, anthraquinones, Triterpenoids, carbohydrates, flavonoids, saponins, phytosterols and Poly-phenols. The GCMS analysis also showed the presence of two major components such as alkaloid and poly-phenolic compound [23] isolated from *Rhinacanthus nasuta* may responsible for its pharmacological activities, *Corallocarpus epigaeus* plant extract is capable of inhibiting the elevation of blood glucose level [24] and Ethanol Extract of *Alangium salviflouim* exhibited significant antidiabetic, anti-inflammatory, anticonvulsant and analgesic activities which might be due to the bioactive compounds [25].

Conclusion

The present investigation revealed that medicinal plants till play a vital role in the primary health care of the people. Many people in the studied part of Yercaud hills is till continue to depend on medicinal plants, at least for the treatment of apoplexy, beetle bite, body pain, cataract, dysentery,

leprosy, menorrhea, mental disorders, rashes, snake bite, sprain, stomach pain, swelling, trismus, tumor and worm infection.The information gathered from tribals is useful for the further research in the field of ethnobotany, taxonomy. This study offers a model for studying the relationship between plants and people and traditional remedies of great therapeutic importance. The value of using ethnobotanical information is to initiate drug discovery efforts. This study also gathered a broad spectrum of information concerning medicinal plants used by tribals.

Table: 1 List of Ethnomedicinal plants used by Malayali tribals in Yercaud Hills, Salem district, Tamil Nadu, India.

S. No	Ailments	Botanical Name	Vernacular Name	Family	Parts used	Mode of Preparation and administration
1	Apoplexy	*Dioscorea oppositifolia*, L.	Malaikilangu	Dioscoreaceae	Rhizome	Mentioned plants parts are made into powder and the powder is added to the neem oil and made into chrism and applied externally to cure apoplexy.
		Mangifera indica, L.	Mamaram	Anacaradiaceae	Fruit	
		Premna tomantosa, Willd.	Pidangunari	Verbenaceae	Bark	
		Ruta graveolens, L.	Agaravagaram	Rutaceae	Leaves	
2	Beetle bite	*Carica papaya*, Linn.	Ppali	Caricaceae	Leaves	Leaves paste administration externally to cure beetle bite.
		Stachytarpheta urticaefolia, D & G.	Kurangaivaalchedi	Verbenaceae	Leaves	Crushed leaves are applied externally to cure beetle bite.
		Tephorosia pumila, Baker.	Sirukolingi	Fabaceae	Leaves	Leaves paste applied externally to cure beetle bite.
3	Body pain	*Gyrocarpus americanus*, Jacq.	Thanakkumaram	Gyrocarpeaceae	Bark	Bark powder consumption orally for 3 days to relief the body pain.
		Caesalpinia crista, L.	Kalachikaai	Caesalpiniaceae	Seeds	Mentioned plants parts are made into powder and the powder is mixed with hot water administration orally for 3-4 days to relief the body pain.
		Calotropis procera, R.Br.	Vellerukkan	Asclepidaceae	Root	
		Dendrophoe falcate, L.	Maraottu	Loranthaceae	Whole plant parts	
4	Cataract	*Ipomoea Pes-caprae*, Sweet.	Adappukodi	Convolvulaceae	Leaves	Leaves juice is poured into eye to cure cataract.
5	Dysentery	*Asclepias curassavia*, L.	Mokkuthipoodu/ Muthumani	Asclepidaceae	Leaves	Consumption of leaves paste can arrest dysentery.
6	Leprosy	*Combretum ovalifolium*, Roxb.	Vennangukodi	Combretaceae	Whole plant parts	Mentioned plants parts are made into powder and the powder is mixed with oil
		Plumbago zeylanica, L.	Chitramullam	Plumbaginaceae	Bark	

		Toddalia asiatica, Lamk.	Mulaikaradan mullu/Milagaranai	Rutaceae	Root	made into chrism and applied externally to cure leprosy.
7	**Menorrhoea**	*Polyathia cerasoides* (Roxb) Bedd.	Senthalamaram	Annonaceae	Bark	Oral administration of bark powder is good for menorrhoea.
8	**Mental disorders**	*Premna tomantosa*, Willd.	Pidangunari	Verbenaceae	Bark	Oral administration of bark paste along with milk is good for mental disorders.
9	**Rashes**	*Abrus pulchellus,* Wall.	Vellaikuntumani	Fabaceae	Seeds and Leaves	Both Seeds and leaves paste along withhot water to administration orally for 3 days to cure rashes.
10	**Snake bite**	*Rhinacanthus nasuta*, Nees.	Nagamalle	Acanthaceae	Leaves and Root	Both leaves and roots pills administration orally. It used to get rid from snake poisonous.
		Alangium salvifolium, Linn.	Alangal	Alangiaceae	Bark	Mentioned plants parts are made into powder and the powder is mixed with hot water and given orally to cure snake bite.
		Azadirachta indica, A.Juss.	Vembu	Meliaceae	Bark	
		Corallocarpus epigaeus, Hook.f.	Keradankilangu	Cucurbitaceae	Rhizome	
11	**Sprain**	*Capparis rotundifolius*, Rottl.	Naakkulinjan	Capparidaceae	Root	Roots are crushed and applied externally for sprin.
12	**Stomach pain**	*Coccinia indica*, W & A.	Kovay	Cucurbitaceae	Rhizome	Rhizome is made into powder along with the seeds of Pepper and bulb of garlic and the powder is mixed with hot water to give orally for 7 days for stomach pain.
13	**Swelling**	*Euphorbia antiquorum*, L.	Sadhurakalli	Euphorbiaceae	Leaves	Oral administration of leaves paste is used to cure swelling.
14	**Trismus**	*Chloroxylon swietenia*, DC.	Purusa maram	Rutaceae	Bark	Bark is made into paste along with the seeds of Pepper and bulb of garlic; this

						preparation is mixed with mother milk and given orally for trismus.
15	**Tumor**	*Artocarpus hirsutus*, Lam.	Kattuppala	Moraceae	Bark	Mentioned plant parts are made into paste along with the turmeric and apply externally for tumor.
		Evolvulus alsinoides, Linn.	Vishnukirandhi	Convolvulaceae	Whole plant parts	

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RESEARCH ARTICLE

ETHANOMEDICINAL PLANTS USED BY THE PANIYA TRIBES IN GURUSIMALAI HILLS, PANDALUR, NILIGIRI DISTRICT

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Abstract

In the present report an attempt has been made to document the available ethno-medicinal plants and their application among Paniya tribes in Gurusimalai Hills, Pandalur, Niligiri district. Regular field trips were conducted during the months of July-November 2022. The information about the plants was recorded by means of discussion using standard questionnaire with the informers along with the field visits during the collection hours. According to the report of study, a total about 70 plant species belonging to 62 genera and 35 families for treating various kinds of ailments such as Fever, bronchitis, piles, ulcer, abdominal disorders, skin diseases, urinary discharges, snake bite, asthma, diabetes, heart diseases and weight loss. Among the parts, Root, leaves, fruits and Seeds were mainly utilised by the informants. A detailed analysis concluded that, Leaves (46 species) were the most frequently used part of a plant followed by the Fruit (15 species), Root (10 species), Seed (9 species), Whole plant parts, Flower and Bark (each 4 species), Stem (2 species) and Tuber (1 species). The most commonly used medicinal plants fell under shrub forms (25 species) followed by Herb (19 species), tree (13 species), Climber (12 species) and succulent herb (1 species). The mode of formulation preparation or administration was observed to be in the form of juice (27 species) followed by past (15 species), decoction (14 species), Powder (11 species), and vapour (3 species). The present study concluded that the native people in the study area have their unique way of utilising medicinal plants to treat different kinds of ailments. This might pave the path for developing a scientifically validated botanical or lead to semi-synthetic derivatives intended for modern medicine.

Keywords: Ethnomedicinal Plants, Paniya Tribes, Gurusimalai Hills and Pandalur.

1. INTRODUCTION

India is having a rich diversity of medicinal plants. The supply base of 90% of herbal plants is used in the mass production of Ayurveda, Siddha, Unani, and Homoeopathy systems of medicines. It was mainly collected from the forest. This wild source is gradually reduced day by day. Therefore, there is a necessity for the conservation and sustainable use of medicinal plants. In the future, ethnobotany may play an important role in sustainable development and biodiversity conservation [(1)]. Plants and their derivatives are used for the treatment of diseases, such plants are known as herbal medicine, which is considered part of folk or traditional medicine. For many centuries, treatment with medicinal plants was the only resource available for numerous ethnic groups, and nowadays, plants are still used in traditional medicine to treat and prevent many diseases [(2-3)]. These medicinal plants lie in some chemical substances that produce a definite physiological action on the human body [(4)].

Ethnobotany is defined as the study of the relationship between people and plants and most commonly refers to the study of ancient uses of plants. By the way of explanations, a study that explores the role of plants as medicine, sustenance, and natural resources is a gateway to God. India is having rich vegetation with a wide variety of plants, because of the furthermost variations in geographical and climatic conditions prevailing in the country [(5)]. Medicinal plants have obtained global importance in the alternative healthcare system, for their proven and effective curative properties. Certain plant antidotes used in modern medicine have an ethnobotanical background [(6-7)]. The tribals have developed their traditional knowledge related to plant.

Ethnobotanical study in Gurusimalai hills, Pandalur in Nilgiri District is bound especially by the traditional knowledge of tribes. The people who

used many plants are unknown to us and the tribal residents only know it. Hence understanding the established knowledge through tribal participative research is necessary to carry on the knowledge to the next generations. To objective of the study traditional knowledge of tribes and villagers of pandalur, Nilgiri district, and Tamil Nadu through an ethnobotanical survey.

2. MATERIALS AND METHODS

2.1. Study Area

The present study were conducted in the Gurusimalai hills range located near Pandalur of Nilgiris district in Tamil Nadu. The Gurusimali hills are situated at 11°29' 0" N.76°20' 0" E. at an altitude of 1100 meters. The average annual temperature in pandalur is 22°C. The average annual rainfall is 3086mm. Pandalur forest is a part of Western Ghats covered with mixed deciduous vegetation.

2.2. Tribes of Gurusimali Hills

Paniyas is an ethnic group of India. They inhabit the area of the Nilgiris, in the states of Tami Nadu. The paniyas also known as paniyas. A scheduled tribe, they have a population of around 94.000 individuals in Tamil Nadu 10.134. Following the abolishment of the slave - holding system, the paniyas were resettled in different areas established by the government. Paniyas were also historically reputed for their boldness. The paniyas today are a scheduled tribe. Paniyas spoken both at home and during religious ceremonies. Some paniyas also use other languages such as Malayalam, Tamil, while the paniyas in Tamilnadu use the Tamil script. They are concentrated mainly in the gudalur and pandalur taluk of the Nilgiris district. of Tamil Nadu. Most of the paniyas tribes have a great knowledge of medicinal plants that are used for first aid remedies to treat cough, cold, fever. headache. poisonous bites and some other ailments.

2.3. Methods of Data Collection

The present investigation was undertaken a view to study the Ethnomedicine of Paniyas from Gurusimalai hills, Western Ghats, Nilgiris district, Tamil Nadu. A good number of aboriginal tribals inhabiting at the foot hills of Western Ghats. Field work in tribal areas is the most important part of all ethnobotanical research. Before starting with field work, preliminary information about the geographical area of study, its physiographical features, climate etc., were collected. A general idea about the tribal community was acquired from earlier publication of Paniyas tribes. Ethnomedicinal reports from the present study area were also screened.

Mainly two methods were adopted in collecting ethnobotanical information from tribal people. In the first method, the herbal practitioners and other knowledgeable persons well-acquainted with plants and their properties of that area were taken on the field. Uses of plants as given by them were recorded and voucher specimens were also collected simultaneously, for authentication of information and future record through herbaria.

In second method, plants near to the tribal hamlets were collected and brought to the tribal physician's house. During the initial survey one person had been introduced by the villagers became the key person, who led the way to introduce to other knowledgeable informants. The person from each area of the study accompanied to the field showed the plants and information as to which health conditions the plants were used and the method of preparation and administration of remedies. At that end of each interview, specimens of the plants were collected for scientific identification and herbarium preparation following standard procedures [8]. Specimen number, local name, location and identification points were remarked on each herbarium sheet. Each of the plant material was assigned field book number and documented as to family, scientific name, vernacular name (Tamil), part used medicinal uses, plant parts that were identified as having use in ethnobotany were collected and compressed. Plants species collected were identified with the help of flora books [9-10].

3. RESULT AND DISCUSSION

3.1. DOCUMENTATION OF ETHNOBOTANICAL KNOWLEDGE

The present study was carried out in the Gurusimalai hills of pandalur , the Western Ghats in the Nilgiri district. Systematic field trips were conducted throughout the paniyas tribe colony of Gurusimalai hills, during the period of July to November 2022. The work is the outcome of intensive field studies undertaken in hamlet inhabited by tribal community. Explorative field trips were regularly made twice in a month to study area for all habitants to elicit information on medicinal plant used to treat various ailments. Field work is the most significant aspect in this type of study. Extensive field trips were conducted to remote rural settlements. The interviews were conducted in the local language (Tamil), information that includes local names, plant parts used, and method of utilization was gathered from for each medicinal plants. The species mentioned by the informants were taxonomically classified. The voucher specimens were collected and identified by referring to standard floras [9-10].

In data obtained from the held survey are presented and the result of this study has revealed a total number of 70 plant species of ethnomedicinal importance belonging to 35 families of the plant kingdom and represented by 62 genera have been documented to be used by the paniyas tribe traditional healer (Table -1). Traditional healers were using these plants to cure the fever, stomach ache and respiratory disorders, skin disease, joint

pains, hair loss, snakebite more number of medication were used for complicated problems such as heart diseases. Kidney disorder and skin diseases, cancer the medicinal knowledge information were taken to the field and information on medicinal plants were recorded the information were asked to explain therapies of the diseases and to list plants.

Among all families Fabaceae are the most dominant families with 7 species each followed by Solanaceae with 6 species each, Rutaceae with 5 species each, Cucurbitaceae and Malvaceae with 4 species each, Amaranthaceae. Lamiaceae and Rubiaceae with 3 species each. Acanthaceae, Areceae, Aristolochiaceae, Caesalpiniacese, Euphorbiaceae, Piperaceae, Poaceae. Sapindaceae and Umbellifers with 2 species each. Asclepiadaceae, Asphodelaceae, Asteraceae, Capparaceae, Caricaceae, Legumes, Lythraceae, Meliaceae, Menispermaceae, Moraceae, Myrtaceae, Passifloraceae. Phyllanthaceae, Rosaceae, Sapotaceae,Verbanaceae and Vitaceae with 1 species each (Table-2 ; Figure - 2). Many plant species belonging to families to Solanaceae, Fabaceae, Malvaceae, then formation collected from this study are in agreement with the previous reports.

From Life form analysis, the most commonly used medicinal plants fell under shrub forms (25 species) followed by Herb (19 species), tree (13 species), Climber (12 species) and succulent herb (1 species) (Table – 3; Figure-3). The frequent use among the indigenous communities is a result of wealth of herbaceous plants in their own environment and Gurusimalai hills harbours more number of shrubs as compared to herb, trees and climbers.

Among the different plant parts used Leaves (46 species) were the most frequently used part of a plant followed by the Fruit (15 species), Root (10 species), Seed (9 species), Whole plant parts, Flower and Bark (each 4 species), Stem (2 species) and Tuber (1 species) (Table-4; Figure-4). Many indigenous communities throughout the world also mostly utilize leaves for the preparation of herbal medicines [11]. The reason why leaves are used mostly is that they are collected very easily than underground parts, flowers, fruits etc. [12].

Paniyas tribes adopted various mode of preparation of medicine for curing various ailments. Various parts from different plants in the form of paste, decoction, powder, juice, infusion, pill, chrism and raw material were used. The paste was prepared by grinding the fresh or dried plant parts with oil or water. The powder was prepared by grinding of shade dried plant parts. The decoction was obtained by boiling plant parts in water and volume was reduced to one fourth (optional). Inhalation was done by burning of plant parts and inhaling the smoke through nose or mouth [13]. The preparation and utilization of plant parts were grouped in to eight categories. The mode of formulation preparation or administration was observed to be in the form of juice (27 species) followed by past (15 species), decoction (14 species), Powder (11 species), and vapour (3 species) Table-5; Figure – 5.

The knowledge of plants has been accumulated in the course of many centuries based on different medicinal systems such as Ayurvedha, unani and siddha. In India it is reported that ,traditional healers use 2500 plant species and 100 species of plants serve as regular source of medicine [14] since the interest in traditional medicine has been increasing ,the study of plants have gained prominence to explore the traditional knowledge particularly in developing countries [15]. India is one the most medico- culturally diverse country in the world where the medicinal plants sector is part of a time honoured tradition that is respected even today [16].

The exploitation of natural resources by the local population has resulted in depletion of the biodiversity of forest communities. Forest degradation is usually accompanied by species extinction, reduction in biodiversity and decrease in primary productivity. Consequently, there is a growing interest in quantifying habitat characteristics like forest structure, floristic composition and species richness in India forest. The most important aspect of the tribal medicinal is that fresh plant material is used for the preparation of medicine. Alternatively, if the fresh plant parts are not available, dried plant materials are used. For this reason, several plants served as edible food and alternative remedy to cure a more than single diseases. From this study it is clear that tribals possess innate ability the character of plants and exploit the plants resources to meet their health care needs.

Table 1: List of Ethnomedicinal Plants Used By Paniya Tribes, Gurusimalai Hills, Nilgiri District

S.No	BOTANICAL NAME	FAMILY	VERNACULAR NAME	HABIT	PARTS USES	MODE OF ADMINISTRATION
1	*Abrus precatorius* L.	Fabaceae	Kuntrin mani	Shrub	Root	Decoction of roots it used to cure fever, bronchitis, hepatitis.

2	*Abutilon indicum* (L.) Sweet	Malvaceae	Thuthi	Shrub	Leaves	The leaf paste are used for piles, ulcer
3	*Achyranthus aspera* L.	Amaranthaceae	Nayuruvi	Herb	Leaf, root	Decoction prepared from the leaf and root of this plant is given for inflammatory condition of the body. Decoction of the roots in helpful to cure abdominal disorders.
4	*Aglaia elaeagnoidea* (A.Juss.) Benth.	Meliaceae	Chokkali	Tree	Fruit	Fruit edible to fever, skin diseases.
5	*Aloe vera (*L)Burm.	Liliaceae	Katrazhai	Succulent	Stem	This plant as used as proven to skin healer – cuts & insect bites, itching and skin swelling succulent plants.
6	*Amaranthus tricolor* L.	Amaranthaceae	Thandukeerai	Shrub	Whole Plant	Juice taken from the entire plant and drink cure urinary discharges.
7	*Aristolochia bracteolate* Lam.	Aristolochiaceae	Aduthinnappalai	Herb	Root	Decoction of roots is used to cure stomach pain.
8	*Aristolochia indica* L.	Aristolochiaceae	Garudakoli	Climber	Leaf	The leaf decoction applies on the snake bite swelling and drink cure the vomiting.
9	*Artocarpus heterophyllus* Lam.	Moraceae	Pala	Tree	Root, leaves	Root, leaves juice is used skin diseases, ulcer, asthma.
10	*Borreria verticillate* L.	Rubiacecae	Nathaisoori	Herb	Root	Root paste are used leucorrhoea.
11	*Calamus rotang* L.	Arecaceae	Pirambu	Climbing	Tuber	It used to cold, cough and fever.
12	*Capparis divaricate* Lam.	Capparidaceae	Thorrati	Shrub	Bark, leaves	This paste is used in dysentery, stomach problems.
13	*Capsicum frutescens* L.	Capparidaceae	Ganmillakai	Shrub	Fruit	The juice obtained from fruit are used for side effects of hay fever and common cold.
14	*Carica papaya* L.	Caricaceae	Pappali	Tree	Leaf, fruit	Leaf decoction cure fever, fruit juice cure cancer, diabetes, heart disease.
15	*Cassia auriculata* L.	Caesalpiniaceae	Aavarai	Climber	Fruit	Fruit used for fibre nutrition, less cholesterol and weight loss. Juice used avoid mental stress.
16	*Cassia fistula* L.	Caesalpiniaceae	Konrai	Tree	Young leaves	Foetid smell of mouth.
17	*Cassia sophera* L.	Caesalpiniaceae	Pannavarai	Shrub	Leaf flower	The dried flower and flower buds are used as substitute for tea in for diabetic patients.
18	*Cassia tora* L.	Caesalpiniaceae	Ustithagarai	Herb	Seed	Seed is mixed with water

						and ground into paste and applied to cure skin disease.
19	*Centella asiatica* (L.) Schrader	Apiaceae	Vallarai	Herb	whole plant	The leaf powder used for increasing the haemoglobin count. The whole plant boiled with water is used for memory power increase.
20	*Cissampelos pareria* L.	Menispermaceae	Ponmusuttai	Herb	Root, leaves	Juice is used for fistula, antidote, blood purification.
21	*Cissus quandrangularis* L.	Vitaceae	Pirantai	Climber	Leaf	Leaves are grinded with pepper and garlic for stomach disorders. Decoction used for fever.
22	*Citrullus colocynthis* (L.) Schrader	Cucurbitaceae	Varikurumathai	Shrub	Root	Root is ground with water and the decoction used to cure cough.
23	*Citrus limon* (L.) Burm.	Rutaceae	Lemon	Tree	Fruit	Fruit juice used for not having enough vitamins C.
24	*Clausena dentata* (Wild.) Roem.	Rutaceae	Aana	Small tree	Fruit	Rarely edible, used to cure wounds and burns
25	*Coccinia grandis* (L.) Voight	Cucurbitaceae	Kovai	Climbing	Whole plant	Leaves juice taken internally for ulcer.
26	*Coffea arabica* L.	Rubiaceae	Coffee	Shrub	Seed	Dried seeds are used as a stimulant, acting on central nervous system.
27	*Colacassia esculenta* (L.) Schott in Schott & Endl.	Araceae	Saembu	Herb	Leaf	Used for headaches, control blood pressure, treats cold, cough, asthma.
28	*Cardiospermum halicacabum* L.	Sapindaceae	Mudakaruthan	Climber	Leaves Roots, Seeds.	Leaves, roots &seeds are boiled with water and this water is used fox both to cure arthritis.
29	*Coriandrum sativum* L.	Apiaceae	Kothumalli	Herb	Leaf	The leaf juice used for digestion problem and gas problem as well as infection caused by bacterial.
30	*Cyanodaon dactylon* (L.) Pers.	Poaceae	Arugam pull	Herb	Leaf	Leaf juice used as drink empty stomach in the morning is good in normalizing the sugar level.
31	*Cyphomandra betacea* (Cav.) sendt.	Solanaceae	Marathakkali	Tree	Fruit	Fruit is boiled with water and drink it removed the poisonous.
32	*Dendrocalamus strictus* (Roxb.) Nees	Poaceae	Kalmungil	Tree	Fruit	Roasted fruits are given once day to treat dysentery and cough until cure.
33	*Dodonaea viscosa* (L.) jacq.	Sapindaceae	Virali	Shrub	Leaves	Leaf paste cure the swelling.
34	*Durio zibethinus murray*	Malavaceae	Durian	Tree	Leaf, fruit	Leaf decoction used reduce swelling. Fruit

						juice used in high blood pressure.
35	*Elephantopus scaber* L.	Asteraceae	Aanaichuvadi	Herb	Leaf, root	Juice used for cough, fever, stomach pain. Root juice prescribed to prevent vomiting.
36	*Euphorbia hirta* L.	Euphorbiaceae	Ammanpacharsi	Herb	Flower	It can used as a first aid fox insect bite. The leaf juice used for wart removal.
37	*Hibiscus cannabinus* L.	Malvaceae	Pulichakeerai	Shrub	Leaf, Flower Seed.	Leaf, flower and seed paste used for warmth balance. Flower juice and seed are consumed for biliousness and bruises.
38	*Indigofera tinctoria* L.	Fabaceae	Neeli	Shrub	Leaves	Used in bronchitis, dry cough, tuberculosis.
39	*Ixora brachiata* Roxb. ex DC.	Rubiaceae	Thetti	Shrub	Root bark	Root bark paste with coconut pulp applied for inflammation.
40	*Adathoda vasica* L.	Acanthaceae	Adathoda	Shrub	Leaf	Leaf juice is used for asthma and fever, bleeding piles, the boiled leaves was used rheumatic pain.
41	*Justicia glauca* Rottl.	Acanthaceae	Thavasimurungai	Shrub	Leaf	Leaf mixed with salt and honey and consumed it will cure cold and stomach disorder.
42	*Lawsonia inermis* L.	Lythraceae	Maruthani	Shrub	Leaf	The juice prepared from the heated leaves of the plant is applied to knee, this paste used for hairy dyes and hair care products.
43	*Limonia acidissima* L.	Rutaceae	Vila	Shrub	Bark	Insect bites, dysentery, snake bite.
44	*Leucas aspera* (Wild.)Link.	Lamiaceae	Thumbai	Herb	Leaf	The juice of leaves and the plant are used to reduce fever and also used as insecticide.
45	*Melothria maderaspatana* L.	Cucurbitaceae	Musummusukai	Climber	Leaves	Used for asthma.
46	*Mentha arvensis* L.	Lamiaceae	Pudhina	Herb	Leaf	Speed and easy digestion and which may also support healthy cholesterol levels.
47	*Mimosa pudica* L.	Mimosaceae	Thottal surungi	Herb	Leaf	The paste of mimosa pudica leaves alone is applied on injuries and snake bite.
48	*Momordica charantia* L.	Cucurbitaceae	Pavakkai	Climber	Fruit	Juice obtained from fruit used for immune system, improves respiratory health.
49	*Mucuna puriens* L.	Fabaceae	Poonaicali	Shrub	Seed	Seed juice are used nervous diseases.

50	*Murraya koenigii* (L.)Spreng.	Rutaceae	Kariverpilai	Tree	Leaves	Curry leaves are used for antimicrobial capability to protect the liver from damage.
51	*Ocimum sanctum* L.	Lamiaceae	Thulasi	Herb	Leaf	Leaf decoction used in fever, cold, cough.
52	*Ormocarpum cochinchinense* (Lour.) Merr.	Fabaceae	Elumbotti	Shrub	Leaf	Leaf decoction used for anti- oxidant
53	*Passiflora edulis* Sims	Passifloraceae	Koodithodai	Climber	Fruit, seed	The juice obtained from fruit are used prevent blood sugar. The seed raw eat regulating cure thyroid activity.
54	*Pergularia daemia* (Forssk.) Chiov	Asclepiadaceae	Uthamani	Herb	Leaves	Leaves juice used for urinary problems, fever, asthma and gas trouble.
55	*Phyllanthus amarus* Schum.& Thonn	Phyllanthaceae	Kizhanelli	Herb	Leaf	The leaf juice is used for jaundice.
56	*Physalis angulate* L.	Solanaceae	Sodakkuthakkali	Shrub	Seed, Leaf	Seed juice is mixed with leaf juice used in locally eye disease.
57	*Piper betle* L.	Piperaceae	Vetrilai	Climber	Leaves	It is used for digestive.
58	*Piper nigrum* L.	Piperaceae	Milagu	Climber	Fruit, Leaf	Leaves are boiled with water and this water is used for bath to cure arthritis. Fruit juice improves digestive.
59	*Pouteria campechiana* (Kunth) Baehni	Sapotaceae	[Egg fruit] Muttapazham	Tree	Fruit	Fruit used for heart disease to helping with blood sugar control and weight loss.
60	*Ricinus communis* L.	Euphorbiaceae	Amanukku	Herb	Leaf	Antioxidant activity, antitumour activity, bone regeneration activity.
61	*Rosa banksiae* R. Br .ex Aiton	Rosaceae	Rosa	Tree	Petals	Petals are boiled with water and it is used to prevent blockage of arteries.
62	*Ruta graveolens* L.	Rutaceae	Aruvatham pachai	Herb	Leaf	Crushed leaves and oil boiled and used for sinus problem.
63	*Sida cardifolia* L.	Malvaceae	Sitramuti	Climber	Leaves	Leaves juice are used for stomatitis, nervous disorder.
64	*Solanum nigrum* L.	Solanaceae	Manathakkali	Shrub	Leaf, root	Leaf juice of the plant is used on ulcers and other skin disease. Root juice from it is roots used against asthma.
65	*Solanum torvum* Sw.	Solanaceae	Chundai	Shrub	Leaf, fruit	Fruit was used for control the fever; leaf juice controls the microbial activities.
66	*Solanum virginianum* L.	Solanaceae	Kandankathiri	Shrub	Leaf, fruit	Fruit used for fever cough cold, leaves boiled with water van cure arthritic

						pain.
67	*Spinacia oleracea* L.	Amaranthaceae	Pasalai keerai	Shrub	Stem, leaves	The juice obtains from the stem that drinks cure the anaemia.
68	*Syzygium cumini* (L.) Skeels	Myrtaceae	Naval	Tree	Bark, seed, leaf	All are used for dysentery, diabetics, fever.
69	*Tephrosia purpurea* (L.) Pers.	Fabaceae	Kolinchi	Shrub	Whole plant	Decoction are used for kidney, liver disease.
70	*Vitex negundo* L.	Verbenaceae	Notchi	Tree	Leaf	Leaf paste is used as anti-dote for joint pain. Leaf juice is used for treatment of sinus problem.

Table: 2 Classification of species identified with respect to family

S. No	Family	Number of Species
1	Fabaceae	7
2	Solanaceae	6
3	Rutaceae	5
4	Cucurbitaceae and Malvaceae	4
5	Amaranthaceae. Lamiaceae and Rubiaceae	3

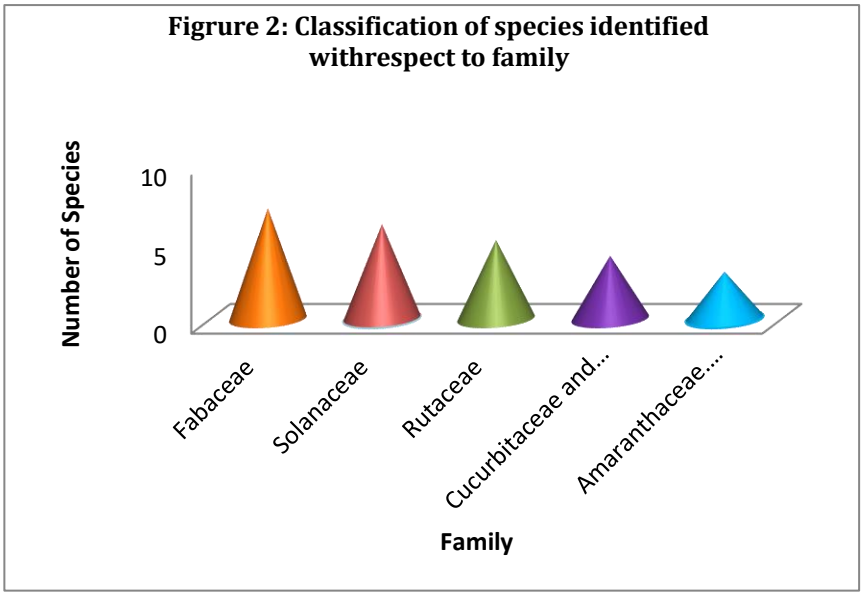


Table: 3 Classification of medicinal plants based on habit

S. No	Habit	Number of Species
1	Shrub	25
2	Herb	19
3	Tree	13
4	Climber	12
5	succulent herb	1

Figure 3: Classification of medicinal plants based on habit

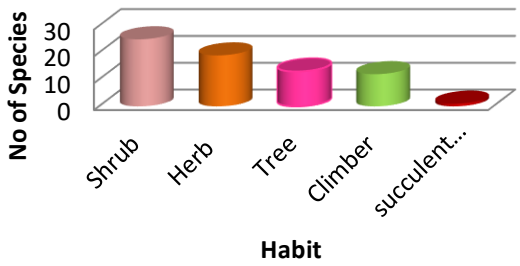


Table: 4 Plant parts used as herbal medicines

S. No	Parts used	Number of Species
1	Leaves	46
2	Fruit	15
3	Root	10
4	Seed	9
5	Flower and Bark	4
6	Stem	2
7	Tuber	1

Figure 4: Plant parts used as herbal medicines

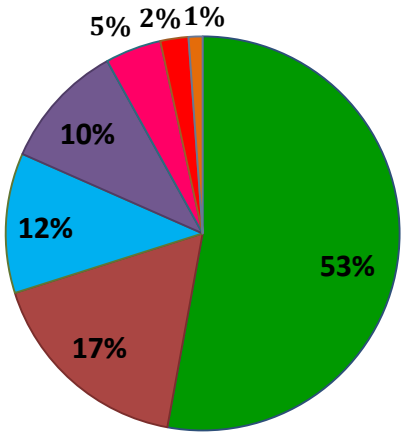
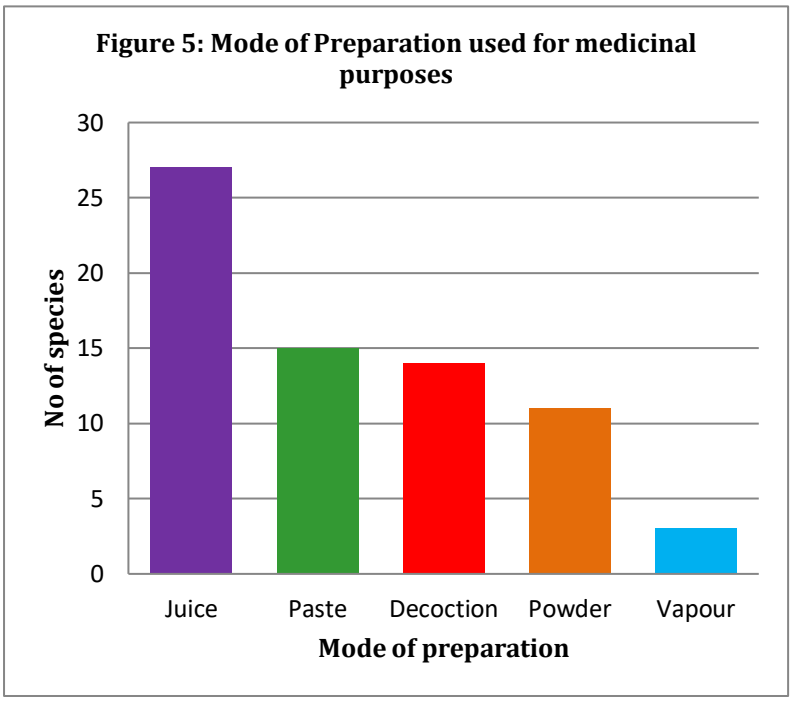


Table: 5 Mode of Preparation used for medicinal purposes

S. No	Mode of preparation	No of Species
1	Juice	27
2	Paste	15
3	Decoction	14
4	Powder	11
5	Vapour	3



4. CONCLUSION

Medicinal plants in Gurusimalai hills play an important role in the health care of the tribal people. Herbal medicines are comparably secure to synthetic drugs. The tribal people are more knowledgeable and experienced in conventional medicinal practices because it comes from thousands of years of trial and error. In the present study, 70 plants were documented, and among these 19 plants were herbs, 25 were shrubs, 12 were climbers and 13 were trees. They are using the plants for diuretics, snakebites, skin diseases, diabetics, cough & cold, body pain, and diarrhea as antiinflammatory and anti-cancerous diseases. Besides, the plants need to be evaluated through phytochemical analysis to discover the possibility of drugs.

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RESEARCH ARTICLE

A STUDY ON INVITRO ANTIOXIDANT ACTIVITY OF AQUEOUS SEED EXTRACT OF SESBANIA SESBAN (L) MERR.

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Abstract

The present study was done to investigate the *invitro* antioxidant activity of aqueous extract of *Sesbania sesban* seeds. The assays such as DPPH, Chelation, ferrous ion, ABTS, Superoxide radical, hydroxyl radical assay, FRAP assay and total antioxidant activity were done to assess the antioxidant potential of the seed extract. The extract was tested at a concentration range of 100 – 500 µg/ml for all the assays and the values were compared with a standard. The results obtained showed that the radical scavenging activity was in a dose dependent manner and found to increase with increase in concentration of the extract. The IC50 value was calculated for the assays and tabulated for inference. Different assays revealed different levels of radical scavenging potential of the extract and exhibited as a better antioxidant source for therapeutic applications.

Keywords: *Sesbania Sesban*, Antioxidant, Aqueous Extract, Radical Scavenging, Dose Dependent.

1. INTRODUCTION

The traditional medicine all over the world is nowaday revealed by an extensive activity of researches on different plant species and their therapeutic principles. Plants contain phytochemicals with various bioactivities including antioxidant, anti-inflammatory and anticancer activities. Currently, about 25% of the active component was identified from plants that are used as prescribed medicines [1].

Free radicals and reactive oxygen species (ROS) such as superoxide, hydroxyl and peroxyl radicals are normal by-products of aerobic metabolism produced *in vivo* during oxidation. These ROS are generated in the mitochondria and microsome organelles under normal physiological conditions. They can also be produced externally by exposure to radiation, toxic chemicals, cigarette smoking and alcohol consumption, and by eating oxidized polyunsaturated fats. Overproduction of ROS can result in oxidative damage to various biomolecules including lipids, proteins, DNA and cell membranes. They also lead to the development of a variety of diseases such as coronary heart diseases, cancer, diabetes, hypertension and neurodegeneration. While compounds capable of scavenging free radicals possess great potential in ameliorating these diseases, most of the ROS are scavenged by endogenous defense enzymes such as catalase, superoxide dismutase and peroxidase-glutathione system. However, the activities of these endogenous defense systems may not be sufficient to mop up the free radicals [2].

Antioxidants can protect the human body from free radicals and Reactive Oxygen Species (ROS) effects. Antioxidant agents are well known to retard the progress of many chronic diseases as well as lipid peroxidation [3].

Currently, there is a great interest in the study of antioxidant substances mainly due to the findings concerning the effects of free radicals' in the organism. Phenolic plant compounds have attracted considerable attention for being the main sources of antioxidant activity, in spite of not being the only ones. The antioxidant activity of phenolics is mainly due to their redox properties, which allow them to act as reducing agents, hydrogen donors, and singlet oxygen quenchers. In addition, they have a metal chelation potential. The antioxidant activities of phenolics play an important role in the adsorption or neutralization of free radicals. Several synthetic antioxidants are commercially accessible but have been reported to be toxic. Plants have been reported to exhibit antioxidant activity due to the presence of antioxidant compounds such as phenolics, proanthocyanidins and flavonoids [4].

Commonly used synthetic antioxidants include butylated Hydroxyanisole (BHA), Butylated Hydroxytoluene (BHT), Propylgallate (PG) and Tertbutylhydroxyltoluene (TBHQ). Though

important, they are known to constitute potential health risks and toxic effects. Their applications are, therefore, strongly restricted. Hence, the need to search, develop and utilize more effective antioxidant from natural origin. Inspite of our dependence on modern medicine and the tremendous advances in synthetic drugs, a large number of the world populations (80% of people) cannot afford the products of the western pharmaceutical industry and have to rely upon the use of traditional medicines, which are mainly derived from plant material [5].

Fabaceae, which is the third largest family among the angiosperms after Orchidaceae (orchid family) and Asteraceae (aster family), consists of more than 700 genera and about 20,000 species of trees, shrubs, vines, and herbs and is worldwide in distribution. *Sesbania sesban* (L) Merr belongs to fabaceae family has a long history of use in India, grows in a wide range of soils from loose sands to heavy clays. Root and bark used as bitter tonic used in debility nervous disorders and act as a CNS stimulant. Root of plant used as dysuria, retention of urine, hepatoprotective activity. Leaves are used as anthelmintic activity [6].

Therefore, this study has been designed to evaluate the *invitro* antioxidant activity of the aqueous seed extract of *Sesbania sesban.*

2. MATERIALS AND METHODS

2.1. Plant material and Preparation of extract

The plant was authenticated with Botanical Survey of India, Southern Regional Centre, Coimbatore. Seeds of *Sesbania sesban* were shade dried and healthy seeds were selected and grinded well to a coarse powder. Aqueous extract was prepared with 10g of the powdered sample in 300 ml of water. The extract that was obtained was condensed in an oven and was preserved in an air tight container and stored at 4^0C for further use.

2.2. *Invitro* antioxidant activity of aqueous extract of seeds of *Sesbania sesban*

2.2.1. Superoxide Radical Scavenging Assay [7]

Superoxide radical O_2^- scavenging capacity of aqueous extract was examined by a pyrogallol autooxidation system. The reaction mixture contained 70µl 10mM pyrogallol, 4.5ml 50mM Tris Hcl (pH 8.2) and 0.5ml various concentrations of samples. The absorbance at 325nm was recorded immediately at 30 seconds and then recorded once every minute. The scavenging rate was obtained according to the formula: O_2^-, scavenging rate (%) = $[1-(A_1-A_2)/A_0]$ X 100, where A_0 was the absorbance of the control (without extract), A_1 was the absorbance in the presence of the extract; A_2 was the absorbance of without pyrogallol.

2.2.2. Hydroxyl Radical Scavenging Assay [8]

Two sets were prepared for the hydroxyl radical scavenging effect, one with extract and sodium salicylate and the other with extract but without sodium salicylate. One set of the tubes containing the mixture 0.5ml of $FeSO_4$, 0.35 ml of H_2O_2, 0.5 ml of the extract and 0.15 ml of sodium salicylate and the other set of tubes containing all the components except sodium salicylate were incubated at 37^0 C for 1 hr. The absorbance was read at 562nm.

2.2.3. DPPH Radical Scavenging Activity [9]

Various concentrations of the extract (1.0 ml) were mixed with 1.0ml of methanolic solution containing DPPH radicals, resulting in the final concentration of DPPH being 0.135 mM. The mixture were shaken vigorously and left to stand for 30 min in dark, and the absorbance was measured at 517 nm. BHA was used as control. The percentage of DPPH decolorization of the sample was calculated according to the equation**:**

$$\% \text{ decolorization} = [1-(ABS_{sample}/ABS_{control}] \times 100$$

2.2.4. Reducing Power Assay [10]

The reaction mixture contained 2.5 ml of various concentrations of methanol extract of the sample, 2.5 ml of 1% potassium ferricyanide and 2.5 ml of 0.2 M sodium phosphate buffer. The control contained all the reagents except the sample. The mixture was incubated at 50°C for 20 min and were terminated by the addition of 2.5 ml of 10% (w/v) of trichloroacetic acid, followed by centrifugation at 3000 rpm for 10 min. 5.0 ml of the supernatant upper layer was mixed with 5.0 ml of deionized water and 1.0 ml of 0.1% ferric chloride. The absorbance was measured at 700 nm against blanks that contained distilled water and phosphate buffer. Increased absorbance indicates increased reducing power of the sample.

2.2.5. Ferrous Ion Chelating Assay [11]

The reaction mixture contained 1.0 ml of various concentrations of the extract, 0.1 ml of 2 mM $FeCl_2$ and 3.7 ml methanol. The control contained all the reaction reagents except sample. The reaction was initiated by the addition of 0.2 ml of 5 mM ferrozine. After 10 min at room temperature, the absorbance of the mixture was determined at 562 nm against a blank. A lower absorbance of the reaction mixture indicated a higher Fe^{2+} chelating ability. The capacity to chelate the ferrous ion was calculated by

$$\% \text{ chelation} = [1-(ABS_{sample}/ABS_{control}] \times 100.$$

2.2.6. ABTS Radical Scavenging Activity [12]

Samples were diluted to produce 0.2 to 1.0 mg/ml. The reaction was initiated by the addition of

1.0 ml of diluted ABTS to10 µl of different concentration of the sample or 10 µl of methanol as control. The absorbance was read at 734 nm and the percentage inhibition was calculated. The inhibition was calculated according to the equation .

$I = A_o - A_1/A_o \times 100$, where A_o is the absorbance of control reaction, A_1 is the absorbance of test compound.

2.2.7. Ferric reducing antioxidant power (FRAP) assay [13]

A solution of 20 mM $FeCl_3 \cdot 6H_2O$, 300 mM acetate buffer (3.1 g $C_2H_3NaO_2 \cdot 3H_2O$ in 16 ml $C_2H_4O_2$, pH 3.6) and 10 mM 2,4,6-tripyridyl-s-triazine (TPTZ) in 40 mM HCl) was prepared. At the time of establishing the assay, 25 ml acetate buffer, 2.5 ml TPTZ, and 2.5 ml $FeCl_3 \cdot 6H_2O$ was mixed to prepare the FRAP solution. Plant extract (150 µl) was mixed with 2850 µl of FRAP solution and incubated at room temperature in the dark for 30 min. Absorbance of the intense blue-coloured product (ferrous tripyridyltriazine complex) was measured at 593 nm. The observed absorbance of the sample was calculated by putting the values on a linear standard curve plotted between 200 µM to 1000 µM $FeSO_4$.

2.2.8. Total Antioxidant Capacity Assay [14]

This assay is based on the reduction of Mo (VI) to Mo (V) by the sample analyte and the subsequent formation of a green phosphate/Mo (V) complex at acidic pH. The reagent solution consists of 0.6 M H_2SO_4, 28.0 mM sodium phosphate and 4.0 mM ammonium molybdate. An aliquot of 0.1 ml of sample was combined with 1 ml of reagent solution. The tubes were capped and incubated in a thermal block at 95°C for 90 min. After the samples had cooled to room temperature, the absorbance of the aqueous solution of each was measured at 695 nm against a blank. The blank solution contained 1 ml of reagent solution and the solvent used for the sample, and it was incubated under the same conditions as the rest of the samples.

3. RESULTS AND DISCUSSION

The *invitro* antioxidant activity of aqueous seed extract of *Sesbania sesban* was done using different assays and the results are tabulated and discussed as follows.

Table: 1 Percentage inhibition activity of aqueous extract of seeds of *Sesbania sesban*

Sample concentration (µg/ml)	DPPH	Chelation	ABTS	Superoxide radical	Hydroxyl radical
100	21.70 ± 0.92	13.27 ± 0.85	12.39 ± 1.02	28.16 ± 0.69	16.60 ± 0.52
200	39.06 ± 1.25	22.24 ± 1.43	35.68 ± 1.50	39.43± 1.72	29.31± 1.37
300	56.43 ± 1.54	58.44± 2.70	55.66 ± 2.84	54.92± 1.50	43.19± 1.94
400	70.09 ± 1.86	66.67 ± 3.52	71.18 ± 3.98	67.60± 2.01	76.32 ± 2.25
500	79.09 ± 2.48	81.72 ± 4.87	81.71± 4.37	78.87± 0.74	83.88± 4.68

Value expressed as mean ± SD (n = 3)

In the DPPH test, the stable, nitrogen centered, coloured, DPPH free radical is reduced either by hydrogen donor or antioxidant to a non-radical DPPH-H and the decrease in colour of DPPH radical is monitored over a time period. The seed extract exhibited stronger radical scavenging ability and its 50% inhibition reached at 265 ± 12.5 µg/ml which indicates its good antioxidant potential. The percentage inhibition ranged from 21.70 ± 0.92 to 79.09 ± 2.48 % corresponding to 100-500 µg/ml of the extract.

Metal chelating activity is significant since it reduces the concentration of the catalyzing transition metal in lipid peroxidation [15]. It has been reported that the chelating agents, which forms σ bonds with the metal are effective as secondary antioxidants, because they reduce the redox potential, thereby stabilizing the oxidized form of the metal ion [16]. The EC_{50} value was found to be 275 ± 12.75 µg/ml.

ABTS is a compound frequently used in phytomedicine research to measure the antioxidant properties of plants for better elucidation of their biological properties. The radical is generated through the oxidation of ABTS to an intensely coloured nitrogen centered cation by reacting with potassium persulfate for 12-14 h. The IC_{50} values of the plant extracts were also determined for $ABTS^+$ which ranges at 275 ± 20.5 µg/ml.

Superoxide anion radical is one of the strongest reactive oxygen species among the free radicals that are generated. The scavenging activity of this radical by the plant extract compared favourably with the standard reagents such as gallic acid suggesting that the plant is also a potent scavenger of superoxide radical [4]. The extract was found to have the property to scavenge the superoxide radical at various concentrations ranging from 100-500 µg/ml. The activity increased with increase in concentration of the extract and reached its EC_{50} value of 275 ± 17.06 µg/ml.

The hydroxyl radical (OH) is said to be detrimental and initiates auto-oxidation,

polymerization and fragmentation of biological molecules. The identification of compounds that have excellent hydroxyl scavenging activity would be significant for some diseases caused by oxidative stress. It has been demonstrated that plants contain extract are significant. The percentage inhibition extract. The 50% percentage inhibition was at 340 ± many natural antioxidants compounds which have been identified as hydroxyl radical scavengers. Therefore, OH scavenging effects of *S.sesban* aqueous extract were assessed in the present study. The result shows that the scavenging activity of seed was at rise with increase in concentration of the 15.2 µg/ml.

Table: 2 EC_{50} (µg/ml) values of aqueous extracts of *Sesbania sesban*

DPPH	Chelation	ABTS	Superoxide radical	Hydroxyl radical	Reducing Power	FRAP
265 ± 12.5	275 ± 12.75	275 ± 20.5	276 ± 17.06	340 ± 15.2	300 ± 15.15	250 ± 14.01

EC_{50} value represents scavenging efficiency at 50% concentration of the extract on DPPH, ABTS radical, OH radical, chelation of ferrousions, superoxide radical, hydroxy radical, and by reducing power and FRAP assay Value expressed as mean ± SD (n = 3).

Table: 3 Total antioxidant activity of the aqueous extracts of *Sesbania sesban* by phosphomolybdenum assay

	mg/g (GAE)	mg/g (AAE)
Total antioxidant activity	5.84 ± 0.05	16.90 ± 0.13

Total Antioxidant Capacity (TAC) assay by phosphomolybdenum method that based on the reduction of Mo (VI) to Mo (V) by the sample analyte and subsequent formation of a green phosphate/Mo (V) complex at acidic pH, usually detects antioxidants such as some phenolics, ascorbic acid, α-tocopherol and carotenoids [14]. The total antioxidant activity of the aqueous seed extract of *Sesbania sesban* was determined and was found to be 5.84 ± 0.05 mg/g of gallic acid equivalent (GAE) and 16.90 ± 0.13 mg/g of ascorbic acid equivalent (AAE). The values represent a significant antioxidant potential of the extract.

Value expressed as mean ± SD (n = 3).

Table.4. Scavenging capacity of the aqueous extracts of *Sesbania sesban*

Sample concentration (µg/ml)	Reducing Power (A_{700nm})	FRAP (A_{540nm})
100	0.153± 0.008	0.282± 0.01
200	0.241± 0.01	0.415± 0.02
300	0.512± 0.03	0.627± 0.02
400	0.685± 0.03	0.795± 0.04
500	0.889± 0.04	0.971± 0.05

Value expressed as mean ± SD (n = 3).

The table.4 shows the scavenging capacity of the aqueous extracts of *Sesbania sesban* assessed by Reducing Power and FRAP assay. The reducing capacity of the extract, another significant indicator of antioxidant activity was also found to be appreciable. In the reducing power assay, the presence of antioxidants in the sample would result in the reduction of Fe^{3+} to Fe^{2+} by donating an electron. Increasing absorbance indicates an increase in reductive ability. The 50% inhibition was found at 300 ± 15.15 µg/ml. The extract was found to be effective at all concentrations. The results show that there was increase in reducing power of the plant extract as the extract concentration increases [4].

In FRAP assay, reduction of the ferric-tripyridyltriazine to the ferrous complex forms an intense blue colour which can be measured at a wavelength of 593 nm. The intensity of the colour is related to the amount of antioxidant reductants in the samples [17]. Since FRAP assay is easily reproducible and linearly related to molar concentration of the antioxidant present, thus it can be reported that extract of *S.sesban* may act as a free radical scavenger, capable of transforming reactive free radical species into stable non radical products. The antioxidant potentials of the extract of seeds of *S.sesban* were estimated from their ability to reduce TPRZ-Fe (III) complex to TPTZ-Fe (II) at 593 nm and its antioxidant activity increased proportionally with the polyphenol content [18]. The 50% inhibition was found at 250 ± 14.01µg/ml and the scavenging activity was a dose dependent manner.

4. CONCLUSION

The present study demonstrates the *invitro* antioxidant activity of aqueous seed extract of *Sesbania sesban.* Various assays supported the free radical scavenging potential and antioxidant potential of the extract at various concentrations. As per the literature available and the results of the present study, the *Sesbania sesban* seed extract can serve as a potent antioxidant source. A validation of the purified compounds from the extract need to be done for making it to be used for pharmaceutical and therapeutic applications.

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RESEARCH ARTICLE

WEARABLE E-TEXTILE INTEGRATED SENSORS FOR DETECTING HYPERKALEMIA AND HYPOKALEMIA

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Abstract

Recent evolutions in wearable and personalized healthcare devices have led to the emergence of real-time monitoring of the physiological and metabolic status of human beings. Detection of disorders related to potassium levels including hyperkalemia and hypokalemia is very much challenging in the current scenario. Potassium imbalance leads to massive change in electrical activity of the body especially disturbs the function of the brain, heart, nerves, bone and muscles in hospitalized patients. Potassium loss is a major concern in disorders such as hyperhidrosis and Cystic Fibrosis. Hence the real-time monitoring of potassium levels in the hospitalized patients may provide information related to latent cardiac problems and also assist in the diagnosis of apparent life-threatening diseases. Comprehensively, the real-time monitoring of potassium concentrations may shed light on the electrolyte loss, dehydration status and also the other associated diseases. In this study, the correlation between the Electrocardiogram (ECG) signals and the potassium levels can diagnose the potassium imbalance in a non-invasive manner. The novelty of our work is to develop a wearable E-textile integrated sensor for the detection of hyperkalemia and hypokalemia through ECG signal. The main advantage of this product is wearable and portable, and also ensures the patient safety and user friendly particularly for elderly and disabled patients and also for children.

Keywords: Hyperkalemia, Hypokalemia, ECG.

1. INTRODUCTION

Unexpected cardiac deaths have been raised due to the impact of hyperkalemia and hypokalemia in clinical sectors (C. S. Lin et al., 2020). This dyskalemias has been occurred during the correction of potassium (K^+) ions. To track these ions, point-of-care blood tests have been recommended for quick analysis of electrolyte levels in blood and plasma (Dylewski & Linas, 2018; Gavala & Myrianthefs, 2017). Potassium is one of the pivotal electrolytes like sodium, chlorine and plays a significant role in the generation of bio-potential signals of our body which helps to maintain the function of brain, heart, nerves, bone and muscles (Aburto et al., 2013). Potassium is the third most abundant minerals in the body and also regulates the water balance and the acid-base balance in the blood and tissues (Stone, Martyn, & Weaver, 2016). Potassium is highly reactive in water which produces the positive charged ion (K+) and assists in the maintenance of intracellular fluids and trans-membrane electrochemical gradient. Potassium has no effective way to be conserved like sodium in our body for future uses. Even when a potassium shortage exists, the kidneys continue to excrete it. Because the human body relies on potassium balance for a regularly functioning of the heart and nervous system, it is essential to strive for potassium's balance. Insufficient potassium causes a change in electrical activity of the body (Kuntjoro, Teo, & Poh, 2012).

Bioelectric potential or bio-potential are produced as a result of the electrochemical activity of the excitable cells, which are components of the nervous, muscular or glandular tissues. It is mainly occurred due to trans-membrane electrochemical exchange with the action of sodium, potassium and chlorine. A typical potassium level for adult falls between 3.5 and 5.0 milli equivalent per liter (mEq/L). Hyperkalemia is a condition due to high potassium minerals in human blood usually greater than 5.0 mEq/L and 5.5 mEq/L; the range in infants and children respectively. Levels higher than 7 mEq/L can lead to significant hemodynamic and neurologic consequences, whereas potassium levels exceeding 8.5 mEq/L can cause respiratory paralysis, arrhythmias or cardiac arrest (Alfonzo, Isles, Geddes, & Deighan, 2006). For example,

hypokalemia and hyperkalemia are paucisymptomatic, and generally found in cardiac or renal disease patients. Therefore, in this study, we developed the emerging non-invasive and blood-free potassium tracking method for the advance clinical purposes.

2. MATERIALS AND METHODS

2.1. Basic components

The basic components including Node Micro-Controller Unit (NODE-MCU), Electrocardiogram (ECG) Sensor, Arduino IDE and connecting wires are used in this system. In this block diagram, ECG sensor is connected to core controller which accesses the sensor values and processes them to transfer the data through internet. NODE-MCU ESP8266 is used as a core controller. The obtained ECG signal can be viewed on the internet Wi-Fi system. Figure 1 shows the block diagram of the proposed wearable E-integrated sensor.

2.2. Internet of Things based ECG monitoring system

The ECG electrode (dry) is attached to the textile in three different positions as shown in the figure 2. The three electrodes were connected to the heart rate sensor and microcontroller which will acquire the ECG signal. Microcontroller signal could be received in the computer containing Arduino Integrated Development Environment (Arduino IDE) software via the Internet of Things (IoT). The signals were analyzed in smart phone application named blynk. The IoT-based ECG monitoring system is implemented using the advanced techniques of mobile sensing, cloud computing and Web. The ECG monitoring node is responsible for collecting ECG data from the human skin and then sending these data to the access point via a wireless channel.

2.3. Implementation

E-Textile integrated sensors are connected with the electronic textile including electrodes, sensor, and microcontroller, which are used to detect the ECG signal from the human body. Obtained ECG signals (Figure 3) can be viewed through phone application blynk. The data can be transferred from microcontroller to this application. A guardian or doctor can log in to this web portal to access the potassium levels in the blood serum. Through this E-Textile integrated sensor, the early detection of potassium homeostasis can be diagnosed from the obtained ECG signal in a non-invasive manner. Potassium is an important component for electrical activity of the human body. Variations in the potassium levels in the blood serum may lead to medical conditions called hyperkalemia and hypokalemia. A low potassium level called hypokalemia has many causes but usually results from vomiting, diarrhea, adrenal gland disorders or use of diuretics. Hypokalemia can make muscles feel weak, cramp, twitch or even become paralyzed and abnormal heart rhythms. A high potassium level called hyperkalemia can cause life-threatening heart rhythm changes, or cardiac arrhythmias. It can also cause paralysis and weakness. The novelty of our study is to develop a wearable E-textile integrated sensor for the detection of hyperkalemia and hypokalemia through ECG signal. The main advantage of this product is wearable and portable, and also ensures the patient safety and user friendly. It can be easily used for elderly and disabled patients and also for children.

3. RESULTS AND DISCUSSION

In general, the ranges of the serum potassium were clinically observed in blood as 3.5 - 5.0 mEq/L for adults, and greater than 5.0 mEq/L and 5.5 mEq/L; the range in infants and children. Similarly, < 3.5, < 3.0 and < 2.5 mmol/L ranges were observed in case of normal, moderate and severe hypokalaemia conditions (Palaka, Grandy, Darlington, McEwan, & van Doornewaard, 2020).The changes in the ECG signal can be used for indirectly predicting the serum potassium level in the hospitalized patients. The peaked T waves have been obtained when the serum potassium level is increased. Further increase in serum potassium level leads to the ECG report with wide range of PR interval, wide QRS duration and peaked T wave (Chew & Lim, 2005). At severe hyperkalemic condition, the ECG presentation will be like loss of P wave and sinusoidal wave (Galloway et al., 2019). At moderate hypokalemic condition, the ECG presentation looks like flattening and inversion of T waves. During severe hypokalemia, the ECG changes include prolonged Q-T interval, visible U wave and mild ST depression. Ultimately, the obtained ECG can be used to predict the potassium levels at various conditions like hyperkalemia and hypokalemia during remote monitoring without performing the blood test in an unobtrusive manner (Attia et al., 2016).

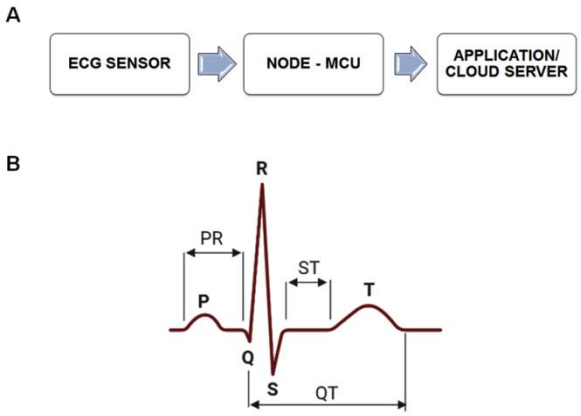

Figure1: Block Diagram of the proposed wearable E-integrated sensor (A) and normal ECG Waves (B)

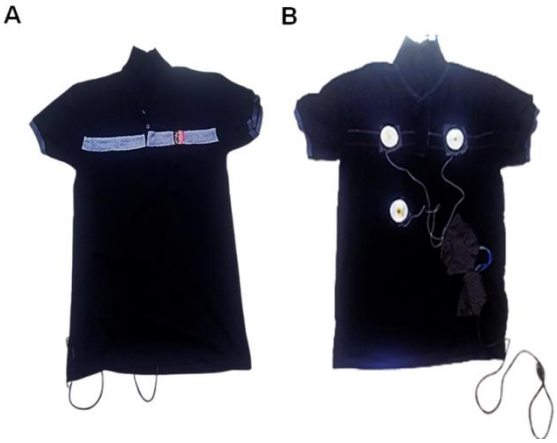

Figure 2: Positioning of Electrodes in the textile outside view (A) and inside view (B)

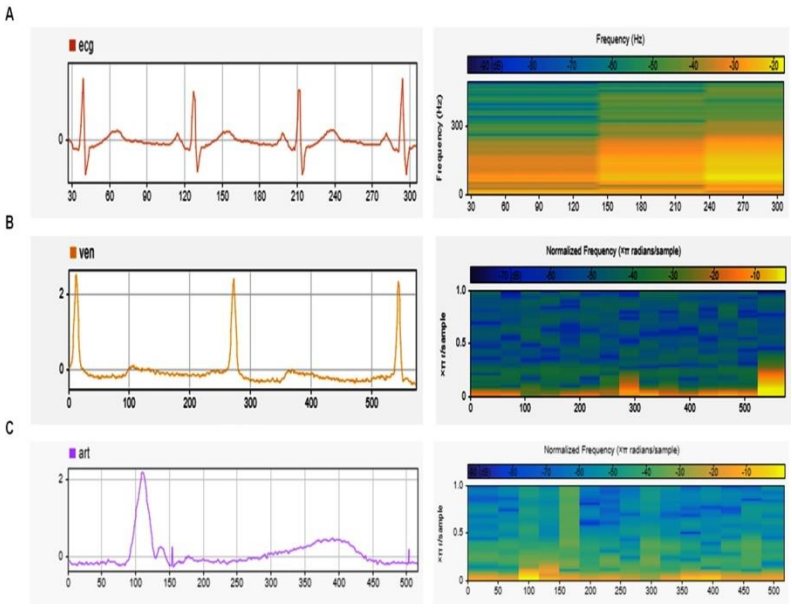

Figure 3: Comparative analysis of Normal ECG wave (A) ventricle wave (B) and atrium wave (C) and their frequency

ECG wave pattern depends on the level of serum potassium. When the serum potassium level is 5.5 to 6.5 mEq/L, the ECG will show tall, peaked T-waves. When the serum potassium level is 6.5 to 7.5 mEq/L, ECG will show loss of P-waves or prolonged PR interval (Kim, Oh, & Jeong, 2005).When the serum potassium level is greater than 9 mEq/L, the ECG will show widening of the QRS complex for greater than 0.12 seconds and leading to cardiac arrhythmia associated with severe hyperkalemia (Walter & Bachli, 2002).Potassium Loss Syndrome is a condition when the serum potassium isas below 3.5 mEq/l (Rastegar & Soleimani, 2001). 20% of hospitalized patients are susceptible to hypokalaemia. When the serum potassium level is < 3.0 mmol/L, this condition is called as moderate hypokalaemia, and when the serum potassium level is < 2.5 mmol/L, the condition is known as severe hypokalaemia. In mild hypokalemia, ECG changes include flattening and inversion of T waves, and in more severe hypokalemia condition, the Q-T interval prolongation and visible U wave and mild ST depression occurs. Severe hypokalemia can result in arrhythmias and ventricular tachycardia (Kishimoto, Tamaru, & Kuwahara, 2014).

The proposed work represents the detection of serum potassium levels using electrocardiography. Real-time monitoring and detection of electrolyte imbalance is essential for the management of metabolic disorders. Kwon et al demonstrated an artificial intelligence based model using ECG presentations for the detection of electrolyte imbalance including hypokalemia, hyperkalemia, hypercalcemia, hypocalcemia, hypernatremia and hyponatremia. In this report, the artificial intelligence based model is employed to promptly visualize the important ECG regions for detecting imbalances of each electrolytes, and variations in the P wave, QRS complex, or T wave helped to detect the electrolyte imbalances (Kwon et al., 2021). Deep-learning based model, ECG12Net guides physicians to expeditiously recognize severe hypokalemia and hyperkalemia and thereby possibly reducing cardiac events. In this study, six clinicians-three emergency physicians and three cardiologists were participated in human-machine competition and reported that the specificity, sensitivity performance of ECG12Net has better results compared with that of the physicians for detecting dyskalemias based on ECG signals (C. S. Lin et al., 2020).

Wang et al developed and validated a deep learning model (DLM) for non-invasively screening hypokalemia condition in hospitalized emergency patients and reported that artificial intelligence can be used as promising tool for the detection of hypokalemia after ECG examination. The Convolutional Neural Network based DLM has high accuracy and rapid detection capability and reliable detection of serum potassium level compared with the other traditional methods, and thereby improvising the clinical outcome of the hospitalized patients (Wang et al., 2021). Recent studies suggested that AI assisted ECG can be not only used for early detection of electrolyte imbalance but also employed for prediction of adverse outcomes of hospitalized patients. Lin et al also determined that this point of care non-invasive AI assisted ECG has improved clinical accuracy, specificity and sensitivity compared with that of the invasive blood tests (C. Lin et al., 2022).

The evolution of e-textile technologies is expansively used for various medical applications especially for real-time health monitoring of physiological parameters. The design and development of wearable e-textile based integrated sensor is used for detection of serum potassium level using the obtained ECG signal. In this study, the ECG sensors were completely integrated with clothing which can be used for continuously monitoring the ECG signal. The obtained ECG signal can be sent to the physicians and clinicians for indirectly calculating the serum potassium level. It is also helpful to detect the heart related abnormalities like hyperkalemia and hypokalemia in our body. The main aim of our project is to propose a method to remotely record the ECG of a patient and thereby detecting the serum potassium levels by correlating it with normal ECG waves. This ECG based authentication of serum potassium level has many advantages over the conventional ECG techniques. The main advantage of our system is portable, wearable and comfortable, reduces anxiety level among patient, and ensures patient safety and no need of technicians to obtain the ECG signal.

6. CONCLUSION

The wearable e-textile integrated sensors for ECG measurement were constructed and the obtained ECG signals were indirectly correlated with serum potassium levels. The obtained ECG can be analyzed to detect the conditions like hyperkalemia and hypokalemia which are life threatening conditions in hospitalized elder and disabled patients. Based on our results, we conclude that the changes in ECG presentation can be strongly correlated with the serum potassium level for detecting potassium homeostatic conditions. However, the correlation between the ECG presentation and serum potassium level might be refined and improved towards the accuracy of estimation of serum potassium levels in the larger population. The unobtrusive and non-invasive E-textiles based potassium level prediction strategy can be implemented with more advancements and sustainability in the future.

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