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From the Editor-in-Chief

Dear Readers,

Greetings from *Anusandhan*!

It brings me immense joy and pride to present this latest edition of our journal, a testament to the tireless dedication of researchers and practitioners from across the globe. In each issue, we strive to curate a collection of thought-provoking, innovative, and impactful research that not only adds to the existing body of knowledge but also inspires actionable solutions to the challenges we face today.

As we stand on the cusp of a rapidly evolving technological era, the role of science, engineering, technology, and management in shaping our future has never been more pronounced. While advancements such as artificial intelligence, renewable energy solutions, and digital transformation hold great promise, they also bring forth critical concerns. Issues such as ethical AI deployment, sustainable resource management, and the environmental footprint of modern innovations require urgent attention and thoughtful discourse.

Moreover, the integration of science and management practices in addressing global challenges like climate change, water scarcity, and equitable access to technology underscores the need for interdisciplinary collaboration. As members of the global scientific community, we bear a shared responsibility to ensure that our contributions foster sustainable development, ethical practices, and a safer, more inclusive future for all.

In this issue, you will find articles that delve into these burning topics, offering insights and solutions that resonate with the ethos of responsible innovation. We hope these contributions will not only enrich your knowledge but also ignite a sense of purpose and curiosity to explore uncharted territories in your respective fields.

To our readers, I extend my deepest gratitude for your unwavering support and engagement. Your enthusiasm fuels our commitment to excellence and inspires us to continue fostering a platform for meaningful intellectual exchange. Together, let us strive to harness the power of knowledge to create a brighter, more sustainable world.

Happy reading!

Warm regards,

Dr. Rachna Chaturvedi

Chief Editor

Anusandhan: Journal of Science, Engineering, Technology, and Management

ANUSANDHAN

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Herbal Semiconductors as Tools for the Growth and Optimization of Flexible Digital Gadgets

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ABSTRACT

The development and enhancement of flexible digital gadgets The ability of natural semiconductors to transform digital devices has attracted plenty of interest in current years. This thorough research focuses on exploiting herbal semiconductors and covers a wide variety of elements of growing and optimizing bendy electronics. The synthesis and characterization of natural semiconductor substances are mentioned, highlighting strategies for precisely controlling their homes and assessing their performance. The role that tool fabrication techniques—together with printing technology and roll-to-roll manufacturing strategies—have in allowing the scalable and fee-powerful manufacture of bendy digital gadgets is investigated. Design optimization and material balance improvement are the principle areas of cognizance as optimization answers which might be towards tackling challenging situations together with balance, dependability, and overall performance boom are investigated. Even with such remarkable progress, there are nevertheless limitations in the manner of reaching the favored balance and dependability of bendy electronics primarily based on natural semiconductors. Future suggestions and increasing opportunities in the area are covered, together with the creation of bendy devices with many uses and the search for innovative substances and gadget designs. In the field of bendy electronics using natural semiconductors, cooperation among enterprise, academia, and politicians is confused as essential to fostering innovation and bridging the gap among studies and commercialization. All things taken into consideration, this research emphasizes the super capability of evidently taking place semiconductor-primarily based absolutely bendy electronics and draws interest to the non-stop efforts to overcome limitations and attain their complete capability.

I SYNTHESIS AND CHARACTERIZATION OF ORGANIC SEMICONDUCTORS

Since they may be fabricated at a low price and offer precise features like mechanical flexibility and customizable optoelectronic houses, natural semiconductors have attracted numerous attention in the discipline of bendy electronics. This chapter examines the several procedures used to create natural semiconductor substances and the characterisation strategies used to evaluate their traits. [1].

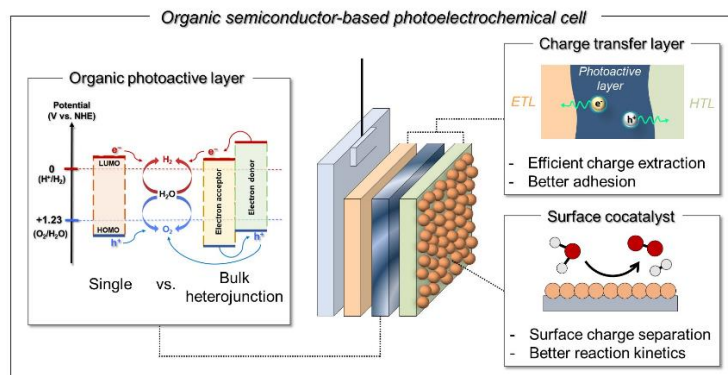


Fig. 1. Graphical method of producing and application of Organic Semiconductors

- (a) **Techniques for Synthesizing Organic Semiconductor Materials** - To create natural semiconductor substances with the right qualities for unique makes use of in flexible electronics, a variety of synthesis methods are used. Chemical synthesis is a broadly used approach that includes the response of natural substances to generate tiny molecules or conjugated polymers. This method allows the addition of useful organizations to regulate electric traits and presents genuine manage over molecule shape [2]. Furthermore, skinny films of organic semiconductors with high purity and homogeneity are deposited using bodily vapor deposition strategies such vacuum evaporation and molecular beam epitaxy. Scalability and versatility are furnished through answer-based techniques inclusive of spin coating, inkjet printing, and doctor-blading for depositing natural semiconductor layers over wide areas.
- (b) **Characterization Methods for Assessing Semiconductor Properties** - In order to evaluate the features and overall performance of organic semiconductors for flexible electronics packages, characterization is vital (fig. 1). To compare aspects along with fee transport properties, morphological features, and molecular structure, a number of analytical techniques are used. The electrical shape and optical traits of natural semiconductors may be understood through spectroscopic strategies as UV-Vis absorption spectroscopy, fluorescence spectroscopy, and infrared spectroscopy. Techniques for electron microscopy and X-ray diffraction offer information at the morphology of movies, grains, and crystals, all of which have an effect on the conduct of charge delivery. Charge provider mobility, conductivity, and device performance are assessed by way of electric measures, including impedance spectroscopy and area-effect transistor (FET) research [3]. Furthermore, nanoscale insights into surface morphology are furnished by means of strategies along with scanning tunneling microscopy (STM) and atomic pressure microscopy (AFM).

II DEVICE FABRICATION TECHNIQUES FOR FLEXIBLE ELECTRONICS

In order to evaluate the features and overall performance of organic semiconductors for flexible electronics packages, characterization is vital (fig. 1). To compare aspects along with fee transport properties, morphological features, and molecular structure, a number of analytical techniques are used. The electrical shape and optical traits of natural semiconductors may be understood through spectroscopic strategies as UV-Vis absorption spectroscopy, fluorescence spectroscopy, and infrared spectroscopy. Techniques for electron microscopy and X-ray diffraction offer information at the morphology of movies, grains, and crystals, all of which have an effect on the conduct of charge delivery. Charge provider mobility, conductivity, and device performance are assessed by way of electric measures, including impedance spectroscopy and area-effect transistor (FET) research [3]. Furthermore, nanoscale insights into surface morphology are furnished by means of strategies along with scanning tunneling microscopy (STM) and atomic pressure microscopy (AFM).

- (a) **Printing Technologies for Deposition of Organic Semiconductors** - Printing technologies offer scalable and low-cost methods to deposit natural semiconductors onto flexible substrates, taking into account the ideal and high throughput production of large-vicinity digital devices. One of the most flexible printing techniques is inkjet printing, which uses droplet ejection mechanisms to deposit semiconductor inks onto substrates exactly, allowing the patterning of natural semiconductor layers. Another famous method for depositing thick-movie semiconductor layers is screen printing, which makes use of a stencil-based totally method. This makes it appropriate for programs that need reasonably-priced manufacturing charges and high throughput. Furthermore, natural semiconductor inks may be continuously and quick deposited the usage of gravure and flexographic printing, which qualifies them for roll-to-roll processing [4].

- (b) **Roll-to-Roll Manufacturing Techniques for the Production of Scalable Devices** - Roll-to-roll (R2R) production techniques offer scalability and value-effectiveness for big-scale production by way of enabling the non-stop advent of bendy electronic devices on flexible substrates. In R2R processing, a bendy substrate is dispatched through a succession of processing stations that perform distinct patterning and deposition procedures in turn. A famous R2R method for depositing homogeneous layers of natural semiconductor materials onto flexible substrates is referred to as slot-die coating [5]. It provides outstanding manipulate over the thickness of the movie and high cloth usage. Further utilized in R2R methods for massive-place patterning of natural semiconductor layers are rotary display screen printing and flexographic printing, which allow the advent of bendy digital devices with complex designs.
- (c) **Optimization Strategies for Organic Semiconductor Devices** - The precise qualities of organic semiconductor gadgets, specifically their mechanical flexibility, low fabrication fee, and compatibility with large-place production techniques, make them extremely promising for bendy electronics packages. Nevertheless, optimization strategies are vital to improve price shipping, stability, and usual device performance so as for them to reach their full potential. This bankruptcy examines several methods and processes for enhancing the performance and balance of organic semiconductor devices, with a specific emphasis on design optimization for higher charge transport.

III DESIGN OPTIMIZATION FOR ENHANCED CHARGE TRANSPORT IN FLEXIBLE ELECTRONICS

In natural semiconductor gadgets, layout optimization performs a essential function in enhancing the characteristics of charge shipping, which ultimately ends in better device performance. The virtual structure, electricity levels, and intermolecular interactions of organic semiconductor materials can be optimally tuned via molecular engineering strategies to offer powerful price carrier transport. It is possible to create substances with improved charge mobility thru the construction of conjugated polymer backbones with distinct molecular topologies and issue-chain changes. This permits faster fee shipping and improved tool performance [6]. Additionally, the development of structured molecular packing structures is made feasible by using refining the morphology of natural semiconductor skinny film the usage of techniques inclusive of solvent engineering, annealing, and floor amendment. This reduces charge trapping and increases price provider mobility.

- **Electrical Characterization** - Ohm's Law, $V=IR$, where V is the voltage, I is the cutting-edge, and R is the resistance. Ohm's regulation describes the connection among voltage, cutting-edge, and resistance in a fabric.
- **Optimization Algorithms** - Gradient Descent Update Rule, $\theta_{t+1} = \theta_t - \alpha \nabla J(\theta_t)$, where θ_t is the parameter vector at iteration t , α is the learning rate, $\nabla J(\theta_t)$ is the gradient of the cost function J with respect to θ_t . The gradient descent algorithm is an iterative optimization technique used to minimize a cost function by updating the parameters in the direction of the steepest descent of the cost function.
- **Material Design:** Density Functional Theory (DFT) Energy Functional, $E[n] = T_s[n] + E_{ee}[n] + E_{xc}[n] + E_{ext}[n]$, Wherein $T_s[n]$ is the kinetic electricity of non-interacting electrons, $E_{ee}[n]$ is the power of electron-electron interplay, $E_{xc}[n]$ is the strength of alternate-correlation, and $E_{ext}[n]$ is the power of the outside capability. A quantum mechanical modeling method known as density practical concept is used to decide a cloth's electrical structure and other traits. The Hohenberg-Kohn theorems and the Kohn-Sham equations yield the overall energy purposeful.

- **Statistical Analysis:** Regression Equation, $y = mx + c$, where y is the dependent variable, x is the independent variable m is the slope, and c is the y-intercept. The regression equation describes the linear relationship between two variables, with the slope m representing the rate of change of the dependent variable with respect to the independent variable.

These mathematical concepts and derivations play a crucial role in understanding and optimizing the design of flexible electronics using organic semiconductors.

(a) Strategies for Improving Device Stability and Performance

For their sensible uses in bendy electronics, natural semiconductor gadgets should be made extra solid and carry out better. Numerous methods had been advanced to address troubles inclusive of cloth deterioration, environmental sensitivity, and device dependability. Thin-film limitations and conformal coatings are two examples of encapsulation techniques that guard organic semiconductor gadgets from moisture, air, and different environmental elements, extending their stability and working lifetime. Furthermore, price injection, extraction, and delivery at organic semiconductor/electrode interfaces are optimized using interface engineering techniques concerning the addition of interlayers and interface modifiers, which enhances tool performance and stability. In addition, the introduction of innovative tool architectures—along with tandem and inverted structures—lets in for progressed tool performance in a variety of running environments, reduced recombination losses, and advanced price balance.

IV INTERFACE ENGINEERING AND SIMULATION MODELING IN ORGANIC SEMICONDUCTOR DEVICES

Interface engineering and simulation modeling play crucial roles in optimizing the performance of organic semiconductor devices. This chapter delves into the methodologies and techniques employed in interface engineering to enhance charge injection and transport, as well as the computational approaches used for simulating and modeling organic semiconductor devices [7].

- (a) **Interface Engineering for Improved Charge Injection and Transport** - Interface engineering focuses on manipulating the properties of interfaces between organic semiconductors and electrodes to facilitate efficient charge injection and transport. Various techniques, such as surface treatments, interfacial layers, and molecular doping, are utilized to tailor the energy level alignment and charge carrier dynamics at the interface [8]. By optimizing the interface morphology and energy level alignment, interface engineering minimizes charge carrier barriers and traps, leading to improved charge injection and transport efficiency in organic semiconductor devices.
- (b) **Surface Modification Techniques for Enhancing Device Interfaces** - Surface amendment strategies contain the utility of chemical and biological remedies to herbal semiconductor layers or electrode surfaces that allows you to alter their houses and decorate device interfaces. The addition of interfacial layers, polymer brushes, or self-assembled monolayers (SAMs) to the surface complements its wettability, adhesion, and rate carrier injection efficiency. Furthermore, to reduce rate trapping and interface recombination and improve device stability and usual overall performance, floor passivation and interface modification using dielectric layers or interfacial dopants are used [9].
- (c) **Computational Approaches for Predicting Device Performance** - By simulating the electronic and optoelectronic residences of organic semiconductor gadgets, computational methods provide crucial insights into their performance. Atomic-stage predictions of the structural, electronic, and vibrational characteristics of natural semiconductor materials are made using density practical idea (DFT) and molecular dynamics (MD) simulations [10]. The strength levels, band structures, and fee

carrier mobility which can be furnished via these simulations help with cloth choice and design optimization for higher tool performance.

- (d) **Methods of Multiscale Modeling to Comprehend Charge Transport** - By bridging the space between atomistic and macroscopic scales, multiscale modeling strategies allow for an intensive understanding of the mechanisms underlying charge transport in organic semiconductor gadgets. The stochastic nature of rate provider motion and hopping dynamics within natural semiconductor layers is captured via coarse-grained fashions and kinetic Monte Carlo (KMC) simulations. Drift-diffusion and Poisson equations are two examples of continuum fashions that designate fee transport phenomena at longer period and time scales, making them beneficial for overall performance predictions and device-level simulations.

V APPLICATIONS AND FLEXIBLE SENSOR TECHNOLOGIES OF ORGANIC SEMICONDUCTOR-BASED ELECTRONICS

Flexible electronics based on organic semiconductors have attracted numerous interest because of their potential uses in plenty of industries. This chapter explores the diverse applications of organic semiconductor-based flexible electronics, including flexible displays and lighting devices, organic photovoltaics, energy harvesting devices, and flexible sensor technologies [11].

- (a) **Flexible Displays and Lighting Devices Using Organic Semiconductors** - One of the maximum promising makes use of for bendy electronics primarily based on organic semiconductors is in bendy presentations and lights. OLEDs, or organic light-emitting diodes, are commonly utilized in bendy displays because of their thin profile, high coloration density, and low weight. Modern display standards like rollable and foldable displays had been made viable through OLED displays' capability to be bent, rolled, or even folded. Furthermore, organic light-emitting transistors, or OLETs, integrate the mild-emitting homes of OLEDs with the switching power of transistors to offer additional capability, paving the manner for customizable lighting panels and signage systems.
- (b) **Organic Photovoltaics and Energy Harvesting Devices** - Flexible sensor technology are an interesting location of software program for natural semiconductor-based total electronics, as they provide Natural photovoltaics (OPVs) have emerged as a promising replacement for traditional silicon-based sun cells in bendy electricity harvesting applications. The advantages of OPVs are their low weight, flexibility, and coffee value of fabrication. They work by converting sunlight into power through the use of natural semiconductor substances. These flexible solar cells allow for the manufacturing of renewable strength in loads of settings with the aid of being included into windows, garb, and building facades, amongst other surfaces. Furthermore, organic thermoelectric mills (OTEGs) offer a sustainable solution for electricity harvesting in wearable electronics, far flung sensing systems, and Internet of Things (IoT) devices by way of the use of waste warmth from commercial tactics or electronic devices to generate power [12].
- (c) **Flexible Sensor Technologies Using Organic Semiconductors** - Another captivating area of utility for organic semiconductor-based totally electronics is flexible sensor technology, which give possibilities for actual-time tracking and diagnostics throughout a range of industries. In order to create lightweight, bendy, and stretchable sensor devices, organic semiconductors are included with bendy substrates and sensor components as a part of the development of bendy sensor structures. Human-machine interfaces, environmental sensing, structural fitness monitoring, and healthcare tracking are only a few of the numerous makes use of for these sensors. The incorporation of natural semiconductors into healthcare and wearable sensors facilitates the creation of relaxed, non-invasive sensing options for ongoing fitness monitoring, illness identification, and wellbeing monitoring [13]. Furthermore, natural fabric-based totally bendy sensors have splendid mechanical

features that enable them to tolerate stretching, bending, and deformation without dropping their sensing abilities.

VI ADVANCEMENTS IN ORGANIC SEMICONDUCTOR DEVICE INTEGRATION

The integration of organic semiconductors with different materials to improve device capability and overall performance has advanced notably in recent years. In order to make use of the unique features of natural semiconductors for quite a number packages, this chapter investigates modern-day strategies [14].

- (a) **Novel Approaches for Integrating Organic Semiconductors with Other Materials** - The introduction of progressive techniques that permit seamless integration with other substances even as keeping the unique characteristics of organic semiconductors is one of the principal traits in natural semiconductor device integration. One technique for improving price shipping and interface compatibility with different practical layers in natural semiconductor films is the application of interfacial engineering strategies to alter the surface traits of the movies. To enhance device overall performance and stability, for instance, self-assembled monolayers (SAMs) may be used to exchange the surface electricity and chemical characteristics of organic semiconductor films [15]. The other promising method is the improvement of hybrid natural-inorganic composites, which fuse herbal semiconductors with inorganic substances to provide multifunctional device architectures. By cautiously selecting and high-quality-tuning the hybrid fabric composition, scientists can tailor the gadgets' optical and electric residences to satisfy particular software wishes. For example, hybrid organic-inorganic perovskite materials have proven terrific promise in photovoltaic devices due to their excessive absorption coefficients and provider mobility, which enhance power conversion efficiency.
- (b) **Hybrid Organic-Inorganic Device Architectures for Enhanced Functionality** - Hybrid inorganic-organic device architectures offer a bendy platform for mixing inorganic semiconductors with other materials to reap higher capability. The development of plasmonic or quantum-extra devices thru the fusion of metallic nanoparticles or quantum dots with natural semiconductors is one instance. These hybrid architectures enhance natural semiconductor gadgets with mild absorption, fee technology, and delivery by way of taking advantage of the fantastic optical and virtual homes of metallic nanoparticles or quantum dots.

Another method for producing bendable, conformable, and wearable electronics is the mixing of organic semiconductors into bendy or stretchable substrates. Engineers can create gadgets that could tolerate mechanical deformations without dropping electrical overall performance via combining organic semiconductors with bendy substrates like polymers or elastomers. These adaptable hybrid gadgets are perfect to be used in electronic skins, clinical devices, and wearable electronics.

Furthermore, hybrid organic-inorganic device architectures can be tailored for specific applications by controlling the morphology, composition, and interface properties of the hybrid materials. For instance, researchers can improve the photovoltaic gadgets' mild absorption and charge transport skills, main to better power conversion efficiencies, by enhancing the hybrid perovskite fabric's nanoscale morphology. Similar to this, researchers can enhance the rate injection and extraction residences of organic slight-emitting diodes (OLEDs) and lift the device's normal stability and overall performance by means of creating an interface between inorganic price shipping layers and herbal semiconductors.

VII CHALLENGES, OPPORTUNITIES, AND FUTURE DIRECTIONS IN ORGANIC SEMICONDUCTOR-BASED ELECTRONICS

Although natural semiconductor-primarily based electronics have loads of potential for use in lots of exceptional contexts, they also face many problems. This chapter explores the state of the sphere's studies, addressing issues, searching at new avenues for research, and speaking approximately capacity future paths.

- (a) **Addressing Challenges in Device Stability and Reliability** - Achieving tool balance and reliability is a prime undertaking in organic semiconductor-based electronics. When uncovered to environmental elements like moisture, oxygen, and light, organic substances are evidently liable to deterioration. Device lifetime limitations and overall performance degradation may result from this. Researchers are actively growing encapsulation techniques to guard organic gadgets from environmental elements, as one of the many processes they're using to address those demanding situations. Stable organic semiconductor fabric design with greater thermal and chemical stability is likewise a vital field of look at. Through enhancing the steadiness and dependability of natural gadgets, scientists wish to comprehend all of their capability for real-global uses.
- (b) **Exploring Emerging Opportunities for Organic Semiconductor Applications** - Organic semiconductor-based totally electronics provide a wealth of possibilities for innovative applications regardless of their difficulties. A new possibility is offered by way of the improvement of bendy and pliable electronics. Electronic devices that are bendable and conformable may be made by depositing natural semiconductors onto flexible substrates. Among the numerous makes use of for such flexible electronics are flexible presentations, wearable generation, and healthcare monitoring. Using herbal semiconductors within the discipline of natural photovoltaics (OPVs), which converts light into energy, offers a further option. The light-weight layout and coffee production prices of OPVs cause them to an acceptable option for use in renewable power programs. Additionally, a revolution in electronics based totally on natural semiconductors is needed to clear up the net of factors (IoT) trouble. Commonplace items can be prepared with organic sensors and actuators to experience and react to their environment. For example, natural actuators can alter the lighting, heating, and ventilation structures in clever houses, at the same time as natural sensors can be used to tune temperature, humidity, and air exceptional. These Internet of Things applications could enhance sustainability, efficiency, and comfort in some of areas.
- (c) **Future Directions in Flexible Electronics Using Organic Semiconductors** - Future directions for the development of organic semiconductor-based totally bendy electronics appear promising. The creation of bendy, multipurpose gadgets that integrate several features into an unmarried platform is one new trend. For instance, scientists are investigating a way to consist of sensing, energy harvesting, and communicate features into flexible electronic systems. The development of shrewd, self-sufficient systems with makes use of in environmental tracking, smart towns, and healthcare is made possible by way of this convergence of functions.

Investigating innovative materials and machine designs to enhance the capability and overall performance of electronics primarily based on organic semiconductors is every other direction for the future. Researchers are searching at new organic semiconductor substances which have better stability, process ability, and charge shipping characteristics. Furthermore, the advent of modern tool topologies like natural mild-emitting diodes (OLEDs) and natural thin-movie transistors (OTFTs), opens up new possibilities for flexible electronics. By pushing the boundaries of materials and device design, researchers aim to overcome existing limitations and unlock new capabilities for organic semiconductor-based electronics.

By pushing the envelope in terms of materials and device layout, scientists wish to overcome cutting-edge obstacles and offer new guidelines for electronics, which are regularly primarily based totally on plant-primarily based semiconductors.

The capacity for vast utility within the marketplace for bendable electronics making use of natural semiconductors will ultimately depend upon their commercialization and popularity. As studies progresses, fostering a courtship among industry and academia is important to enabling information transfer and commercialization. Working collectively, researchers, business partners, and legislators can solve manufacturing issues, boom output, and launch new goods. Bendy electronics, or the use of herbal semiconductors, has the ability to transform the electronics enterprise by using encouraging innovation and collaboration.

VIII CONCLUSION

A sizeable improvement inside the discipline of virtual gadgets is the refinement and optimization of bendy electronics thru using natural semiconductors. We have explored many aspects of designing and optimizing the ones flexible electronics at some stage in this research, taking into account the synthesis and characterization of natural semiconductors, device fabrication strategies, optimization tactics, tough scenarios, opportunities, and destiny instructions. Organic semiconductor materials provide particular advantages, along with flexibility, lightweight, and coffee-cost manufacturing, making them well-appropriate for bendy digital programs. Techniques for synthesizing organic semiconductor materials have been advanced, making an allowance for the right manipulate in their houses along with molecular shape, strength tiers, and price transport traits. Characterization methods enable really good sized improvement within the field of digital devices is the refinement and optimization of bendy electronics through using natural semiconductors. We have explored many aspects of designing and optimizing those flexible electronics throughout this investigation, deliberating the synthesis and characterization of natural semiconductors, device fabrication techniques, optimization techniques, tough scenarios, opportunities, and destiny directions. Searchers to assess the overall performance of those substances correctly and optimize their homes for precise applications. In tool fabrication, printing technology and roll-to-roll manufacturing processes have emerged as key techniques for depositing organic semiconductors onto bendy substrates. These methods enable the manufacturing of bendy virtual gadgets at a high rate of power and scalability, starting the door for sizeable commercialization. Furthermore, layout optimization, balance improvement, and universal overall performance enhancement optimization methodologies were efficaciously applied to address difficult scenarios related to herbal semiconductor-based gadgets. The stability, dependability, and typical overall performance of herbal semiconductor-based totally truly bendy electronics are still hard to gain regardless of sizeable improvements. Large-scale adoption is impeded by way of problems including constrained transit housing fees, scalability obstacles, and environmental elements that exacerbate the scenario. However, contemporary studies efforts are centered on growing efficient natural semiconductor substances, ahead-thinking device topologies, and encapsulating techniques to counter those uncomfortable occasions. Natural semiconductors have a vibrant future in advance of them in flexible electronics, with expanding opportunities and Multifunctional flexible devices with incorporated sensing, verbal exchange, and electricity harvesting abilities are predicted, taking into consideration the improvement of wise, self-powered structures for a lot of applications. The use of natural semiconductors in flexible electronics has a shiny destiny beforehand of it, with growing possibilities and Multifunctional flexible devices that integrate electricity harvesting, sensing, and communication abilities are estimated, enabling the introduction of clever, self-powered systems for diverse programs. Novel substances and tool designs are being explored to decorate device overall performance and

functionality, at the same time as opportunities for commercialization and marketplace adoption are being pursued to bridge the gap among studies and enterprise. In end, the layout and optimization of flexible electronics the usage of natural semiconductors maintain monstrous capacity for revolutionizing electronic gadgets. Researchers want to overcome tough contemporary circumstances and introduce new abilities for bendy electronics by using making use of the precise homes of natural semiconductor materials and employing advanced manufacturing and optimization methodologies. Working collectively, employers, legislators, and academics may be vital to information the overall ability of flexible electronics primarily based on herbal semiconductors and selling innovation within the area.

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Role of Chemistry in Everyday Life: A Comprehensive Review

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ABSTRACT

All physical and chemical processes occurring in this universe include chemistry. We human beings are knowingly or unknowingly surrounded by chemistry. Morning to evening, life to death, it is a big aspect of our day-to-day life. One may think that it is a branch of science that deals with chemicals in the lab only but unknowingly he/she is applying it in daily works. We find its use in the food we eat, cleaning chemicals, the air we breathe and, every object we touch. Literally, student's chemistry education takes place in lectures and books, lab playing with instruments and chemicals and they don't see the relevance in their everyday life. Understanding the importance of chemistry in our regular life is most important in our technological and competitive society. It also helps to understand the world issue arising currently. One might get surprised when we say that our body is made of chemical elements and compounds so we can say we are the products of chemistry. Our emotions like love, respect, jealousy, frustration are also the aspect of chemistry.

Keywords: Adulterants, Contamination, Purification, Chemical Processes, Chemistry, Chemicals, Education, Additives.

I INTRODUCTION

Chemistry is defined as the branch of science which deals with the composition of matter, the physical and chemical changes which it undergoes and the laws which govern these changes. Due to vast area and scope and for the sake of convenience it has been broadly divided into three main branches viz. Inorganic chemistry, Organic chemistry and Physical chemistry.

- (a) **Inorganic chemistry** deals with study of compounds of elements other than carbon. The entire material used in this world (except polymeric substances and substances of organic origin) are studied in this branch of chemistry.
- (b) **Organic chemistry** deals with the study of compounds of carbon. Carbon forms a large number of compounds with hydrogen and along with other elements like nitrogen, oxygen, sulfur, halogens etc.
- (c) **Physical chemistry** deal with the physical and chemical changes which the matter undergoes and the various principals which govern these changes.

With the modernization in education, the study on chemistry has been increased and its application on day to day life has been increased. Peoples in the past used to use chemistry in daily life without knowing it as there doesn't use to be more research and study. The principle of chemistry is a benefit for mankind. Foods we eat do have chemistry. They comprise organic compounds like carbohydrates, starch and sugar, protein, and lipids (Garforth,1986). Other nutrients like vitamins and minerals and water are all important chemical compounds. The respiration process which includes intake of oxygen and removal of carbon dioxide is used by the plant for photosynthesis. We use chemistry in the digestion of food in the alimentary canal which uses enzymes to break food into tiny absorbable molecules. Likewise, cooking is also a chemical reaction. The makeup creams and anti-aging creams are chemical products made in the lab (Bailin,2002). Vitamins, proteins, fats, carbohydrates, etc are chemistry in food.

Applications

1. Toothpaste

Do we wonder that what chemicals are on the paste that cleans and shines our teeth and protects it from germs? We have seen and used many kinds of toothpastes like Colgate, President, Deburred. What people in ancient times used to clean teeth? So toothpaste uses chemicals like Fluoride, Triclosan, Saccharin, Carrageenan, Aspartame, Parabens, Sodium Lauryl Sulphate & Sodium Lauretha Sulphate, Propylene Glycol (Childs, 1986).



Fig. 1: Toothpaste

2. Soap/Detergent

We used to feel surprised how soap cleans our hand and kill germs present in our hand? The soap contains some chemicals to do this activity so it is the application of chemistry in our daily life. Likewise, detergent acts as a surfactant and helps to wash clothes. The soap contains fatty acid e.g. Stearic, oleic, palmitic acid, and strong alkali and detergent contain Sodium Lauryl Sulphate & Sodium Lauretha Sulphate, Phosphates, etc. They act as an emulsifier.



Fig. 2: Soap/Detergent

3. Food Preservatives

Food preservatives protect food from decaying and spoiling by bacteria and other microorganisms. Salt, sugar, oils, and sodium benzoate are common in our household. **Cosmetics** They increase the appearance of our body. Lipsticks, oils, beeswax, perfumes, nail polish mascaras are commonly used and they contain chemicals that can harm us too. They contain polymers, solvents, grease, petroleum oils, colorants, pigments, etc.



Fig. 3: Food Preservatives

5. Drugs and medicine

Chemistry is very important for preparation of the medicine. Medicine is prepared by the use of several chemicals in a definite ratio using titration. Medicine interact inside our body with a macromolecular target and create biological response (ASE, 1985). Chemistry is also used to measure the amount of sodium, potassium, and many other elements. Blood and urine analysis is done with the help of chemistry.



Fig. 5: Drugs and medicine

6. Agriculture

Agriculture is very important for our survival. We get food from it. We use fertilizers and insecticide to increase the fertility of the soil and protect crops from pests, rats, and locusts. Fertilizers and insecticides contain chemicals like hydrogen cyanide, naphthalene, nicotine, and methyl bromide, etc (Hosteller, 1983).



Fig. 6: Agriculture

7. Oxidation

The food we take is oxidized in our stomach and produces energy which is used to do work in our daily life.



Fig. 7: Oxidation

8. Industries and transport

Industries like petroleum industries, cloth mills, lather factories, food industries, and many others use fuels and chemical products for power production and processing the products. Vehicles like cars, buses, airplanes use petrol and diesel to produce energy and run them. So chemistry paved the way for modernization in daily life



Fig. 8: Industries and transport

9. Science and Technology

Nowadays nuclear energy is the topic of study. The destruction of the atom bomb in Hiroshima and Nagasaki are results of chemistry. Reactors are facilitating through energy generation by chain reactions. Forensic Science uses the law of chemistry for analysis. Tele-communications, IT, Space missions also use the chemistry of semiconductors and nano-tubes.



Fig. 9: Science and Technology

10. Environment Issues

Environmental issues arising currently like pollution, global warming, UV radiation, and the production of harmful chemicals can be solved by the education of chemistry. Chemistry is important there because they are results of chemistry so the environment can be saved by chemistry.



Fig. 10: Environment Issues

II MATERIAL AND METHODS

There are many physical and chemical processes which occur around us every day but we are never aware of them. We shall consider here some simple liquids of daily use, common types of impurities present in them, their effect on human health and methods to remove or minimize them.

- **Water:** Water is known as universal solvent as it is essential for all forms of life. The water which we use is known as mineral water which contain optimum amount of salts dissolved in it. If the quantity of dissolved salts is too low or too high the water becomes unfit for use. Due to rapid industrialization, unorganized urbanization and uncontrolled population the contamination in water bodies has reached at an alarming stage. There are many forms of contamination of water viz. water pollution, bacterial contamination, surface water contamination, well water or ground water contamination, mineral impurities, water turbidity, waste water contamination non-biodegradable water contamination, colloidal water impurities etc. Contaminated water affects the entire biosphere. It causes a number of diseases which are harmful to human health. Some of these diseases are very dangerous and are difficult to cure. To minimize contamination and effect of diseases causing organisms it is suggested to boil the water before its use. The traditional methods of purification of water include filtration through winnowing sieve, filtration through cloth (common in India), filtration through clay vessels, clarification and filtration through plant material, japing stone filter methods etc. However now a day, to purify the contaminated water the modern techniques like RO or use of UV are in practice. These techniques minimize dissolved impurities in water. However, these are mainly concentrated in urban areas.
- **Tea:** This is the early morning drink for many people. It is obtained from cured leaves of the shrub *Camellia sinensis* by boiling in water. It is considered that after water it is the most widely consumed drink in the world. Tea is divided into different categories based upon the methods how they are processed. Some examples are white, yellow, green, oolong, black, post-fermented tea etc. Out of these the most common are white, green, oolong and black tea. Tea contains mainly caffeine and small amount of the bromine and theophylline.

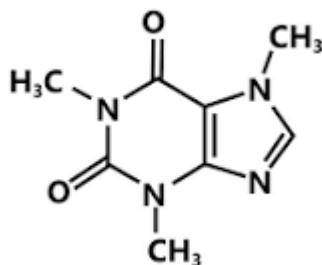


Fig. 11: Caffeine

It has been found that no essential nutrients are present in black or green teas with the exception of dietary mineral, manganese as 0.5 mg per cup. It has been suggested that green and black tea may protect against cancer or diseases like obesity and Alzheimer but the compounds found in green tea have not been conclusively demonstrated to have any effect on human diseases. Multiple recent reports have found that most Chinese and Indian teas contain residues of banned toxic pesticides. At the same time use of too much tea can lead to anxiety, restlessness and difficulty in sleeping. More over the impurities present in tea are also harmful. The impurities or unwanted material such as dust, fiber, wooden splinter, stones, sand particles, sometimes small glass pieces, ferrous and nonferrous particles, plastics, dead insects etc. are embedded in leaves. These particles get mixed with tea at the time of production. If not

cleaned, they can cause large harm to human health. At the same time some adulterants like Prussian blue, indigo, graphite, gypsum, soapstone etc. are mixed from outside.

It is very difficult to identify adulterants mainly the colour in tea. However, some simple tests can be used to detect colour in tea. One such test includes the use of microscope. The portion of the leaves can be mounted as an opaque object; the colouring matter present will appear in small dots. Artificially coloured tea can also be detected by simply rubbing a small quantity of tea between thumb and fore finger. Artificially coloured tea leaves a bright stain when rubbed. Another simple test to detect colour in tea is to fill a clear glass with cold water and then put some tea on the surface. If the colour of water changes immediately, it surely means that the tea has been dyed with some water soluble colour.

If iron filling is present in tea they can be removed by moving a magnet through the sample.

Due to pollution, fluoride and aluminum are also sometimes present in tea.

- **Milk:** Milk and milk products is very important constituent of food used in daily life. It is a white liquid produced in the mammary glands of mammals. It is the primary source of nutrition for the young ones of the mammals before they are able to digest other foods. Early lactation milk contains colostrum's which carries the mother's antibodies that provide protection to the new born baby as well as nutrients and growth factors and reduces the risk of many diseases. Milk contains many other nutrients and the carbohydrate lactose. In almost all mammals milk is fed to infants through breastfeeding, either directly or by extracting the milk to be stored and consumed later. The formation of colostrum's and the period of secretion vary from species to species. In humans World Health Organization has recommended breastfeeding for six months and breastfeeding along with some food for at least two years. In some cultures, breastfeeding to children is common for three to five years or even longer. Sometimes fresh goats' milk is used as substitute of milk. But it may be harmful because it introduces the risk of child developing electrolyte imbalances, metabolic acidosis, megaloblastic anemia, and a host of allergic reactions. The milk act as a source of food and all its contents are beneficial. It is an emulsion or colloid of butterfat globules in water which contain dissolved carbohydrates and protein aggregates with minerals.

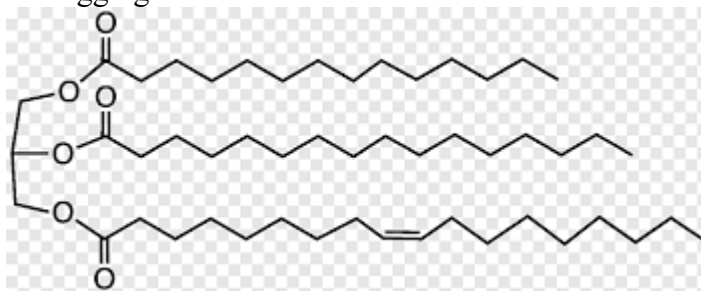


Fig. 12: Butterfat

(a) Adulterants Present in Ghee/Cottage Cheese or Paneer/Condensed Milk, Khoa, Milk Powder

The common adulterants present in the above milk products are coal tar dyes and starch.

- **Coal Tar Dyes:** Take melted sample of the product. Add about 5 ml of dil. H_2SO_4 . Appearance of pink colour indicates the presence of coal tar dye. If we add conc. HCl red colour shows the presence of coal tar dye.
- **Starch:** Add a few drops of iodine to the sample; if the brown colour becomes blue, it indicates the presence of starch in the form of mashed potatoes.

(b) Adulterants Present in Ghee/Butter

The adulterants present in Ghee or Butter and the tests to indicate their presence are given below

- **Vanaspati:** Take a little melted ghee, add equal amount of HCl and a pinch of sugar to it. Shake well and then let it set for about 5 minutes. The appearance of crimson colour in lower layer shows the presence of vanaspati.
- **Mashed Potatoes/Sweet Potatoes:** Take a little sample in a test tube. Add few drops of iodine solution to it. If the brown colour becomes blue, it indicates the presence of massed potatoes.

(c) **Fruit Juices:** The fruit juices are considered the healthiest drinks for human beings. They provide large number of nutrients including vitamins, essential elements, carbohydrates, minerals, proteins, fiber etc. to human body. However, the presence of any adulterant in juice makes it not only unfit for drinking but harmful too. We shall discuss here some common juices and the adulterant present in them.

(d) **Orange Juice:** The orange juice is a rich source of vitamin C. Along with sugar (Approx. 8%) it supplies potassium, thiamin and folate. It is a good source of antioxidant hesperidin. The juice is acidic due to citric acid content with a pH around 3.5. The pulp of orange juice contains flavonoids.

For adulteration the juice is diluted and synthetically produced juices are mixed in it which includes other juices or sugar derived from fruits or vegetables. One adulterant which is commonly added is partially inverted sucrose in which about one- half of the sucrose has been hydrolyzed to glucose and fructose. The ratio in this mixture is approximately 1:1:2 (glucose: fructose: sucrose) which matches the ratio sugars found in actual orange juices.

(e) **Carrot Juice:** Carrot juice contains β -carotene which is a rich source of vitamin A. The juice also contains B complex vitamins like folate, fats, carbohydrates, fibers, protein, cholesterol and many minerals like calcium, copper, magnesium, phosphorus, iron etc. Thus carrot juice provides a number of nutrients to the body. However, the carrot juice is not good for diabetic people. The sweet and enjoyable taste of carrots is due to high content of natural sugar. Therefore, diabetics' people should take the carrot juice according to the advice of their doctor.

Like many products high in β - carotene, it may cause carotenoderma, a skin condition resulting an orange-yellow hue to the skin. Drinking more carrot juice (above 3 cups) over a prolonged period of time may cause this condition. Diet-induced carotenemia is observed in infants and young children. Mothers may induce the condition by giving their infants large amounts of carrots in commercial infant food preparations.

(f) **Mosambi or Sweet Lime Juice:** Citrus limetta commonly known as Mosambi is a member of citrus family. It is a perfect combination of sweet and sour juice which can refresh you within no time. It can be used by chewing its pulpy flesh or by having a glass full of its yellowish green juice. Due to high content of vitamin C its juice prevents and treat dehydration, boosts immunity and help in weight loss. It protects against arthritis, scurvy and gastrointestinal problems. It is useful in treatment of jaundice, heals peptic ulcers and boosts hair and skin health. Mosambi contains compound lemonades which fight against different types of cancers. Sweet lime remains fresh for two weeks at room temperature and four to eight weeks when refrigerated. However, its juice becomes bitter after some time which is harmful.

(g) **Pine-apple Juice:** Pine-apple juice contains a large number of nutrients like calcium, magnesium, iron etc. It is very useful for human health. It possesses anti-inflammatory and anti- cancer properties. Its juice is useful for heart. It helps to prevent cataract and asthma. It is considered to boots fertility both in men and women. When pineapple concentrate is adulterated, organic acids are often added to "naturalize" the chemical composition which are harmful.

With today's technology, it is not possible to detect all adulterants in juices. These tests cannot detect adulterant below 10 percent. The tests which examine sugars in the juices should be more sensitive. The tests used for this purpose generally detect adulteration rates as low as 10 to 20 percent.

III RESULTS AND DISCUSSIONS

Chemistry is important branch of science. It tells about the nutrients present in different type of foods, vegetables and fruits. Thus a little knowledge of chemistry can help the people to live a healthy life. We have discussed adulteration and its effect for only few food articles. In daily life we come in contact of large number of items, we eat various types of food articles, drink several types of liquids, uses different substances of daily need such as tooth paste, toilet soaps, perfumes, oils, nail polish, shoe polish etc. Any unwanted chemical in these items may be harmful to human health. Without knowledge people suffer from various diseases. Therefore, some knowledge of chemistry is necessary, otherwise we would not be able to know that the ice-cream which we are eating is safe for us or not, the cold- drink which we are drinking is not harmful for us. It means chemistry plays an important role in everyday life.

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Unlocking the potential of Apigenin from chamomile: A Novel Approach for Skin Cancer Cell Intervention

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ABSTRACT

Skin cancer is a significant global health concern, necessitating the exploration of novel therapeutic approaches to combat its prevalence and impact. Apigenin, a bioflavonoid compound abundantly present in chamomile (Matricaria chamomilla), has emerged as a promising candidate for intervention due to its potent anti-cancer properties. This abstract introduces the potential of apigenin as a therapeutic agent against skin cancer cells, shedding light on its pharmacological attributes and mechanisms of action. Through a brief overview, we highlight the urgent need for new therapeutic strategies in skin cancer treatment, introduce apigenin as a natural compound, and emphasize its remarkable anti-cancer potential against various types of skin cancer cells. This research paper aims to delve deeper into the pharmacokinetic properties of apigenin using Swiss ADME analysis, offering insights into its feasibility as a therapeutic agent for skin cancer intervention

Keywords: Apigenin Chamomile, Therapeutic intervention, Swiss ADME analysis,

I INTRODUCTION

Skin cancer is one of the most prevalent and rapidly increasing forms of cancer globally. It arises from the abnormal and uncontrolled growth of skin cells, primarily due to excessive exposure to ultraviolet (UV) radiation from the sun or tanning beds. The three main types of skin cancer are basal cell carcinoma (BCC), squamous cell carcinoma (SCC), and melanoma, with melanoma being the most aggressive and life-threatening form.

The incidence of skin cancer has been steadily rising over the past few decades, this alarming trend can be attributed to various factors, including increased UV exposure, an aging population, and a lack of effective prevention measures. While early detection and treatment can significantly improve outcomes, advanced or metastatic skin cancer remains a significant challenge, with limited therapeutic options and high mortality rates.

Current treatments for skin cancer include surgery, radiation therapy, chemotherapy, and targeted therapies, such as immunotherapies and BRAF inhibitors. However, these conventional approaches often have limited efficacy, severe side effects, and high treatment costs. Additionally, the development of resistance to existing therapies poses a significant obstacle in achieving long-term remission.

Given the limitations of current treatment modalities and the increasing prevalence of skin cancer, there is an urgent need to explore novel therapeutic agents, particularly those derived from natural sources. Natural compounds have garnered significant attention due to their potential for potent anti-cancer activities, reduced toxicity, and synergistic effects with existing therapies.

One such promising natural compound is apigenin, a flavonoid found abundantly in various plants, including chamomile, parsley, and celery. Apigenin has a unique chemical structure characterized by a flavone backbone and hydroxyl substitutions, which confer its biological activities (Shukla & Gupta, 2010). Numerous studies have demonstrated the anti-inflammatory, antioxidant, and anti-cancer properties of apigenin against various types of cancer, including breast, prostate, and lung cancer (Bishayee et al., 2013; Pandey et al., 2016; Zhu et al., 2017).

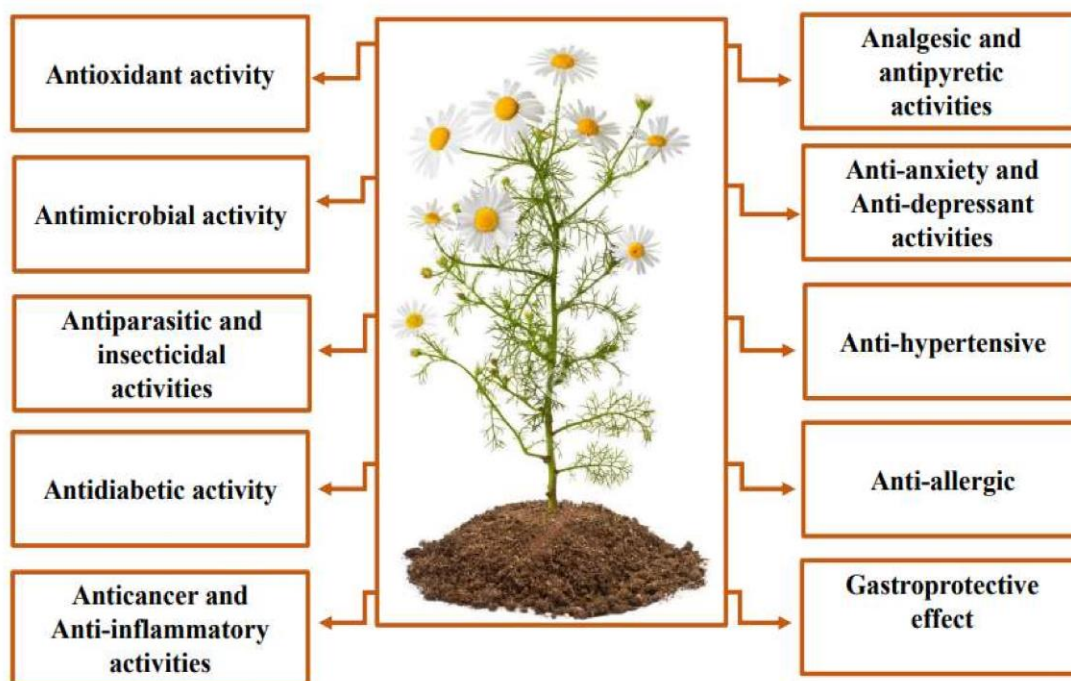
Despite the promising anti-cancer potential of apigenin, its specific effects on skin cancer cells remain largely unexplored. Given the unique characteristics and challenges associated with skin cancer, it is crucial to investigate the potential of apigenin as a novel therapeutic agent for this malignancy. The rationale for exploring apigenin for skin cancer intervention lies in its ability to modulate multiple molecular targets, induce selective cytotoxicity in cancer cells, and potentially overcome treatment resistance.

By elucidating the mechanisms of action and therapeutic efficacy of apigenin against skin cancer cells, this study aims to contribute to the development of innovative and targeted treatment strategies, ultimately improving patient outcomes and quality of life.

(a) Apigenin: A Bioactive Compound in Chamomile

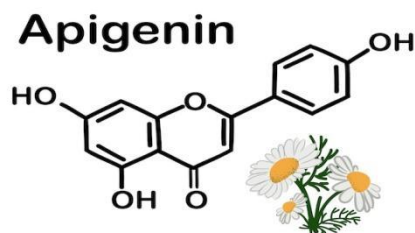
Apigenin is a natural bioactive compound found in various plants, including chamomile (*Matricaria chamomilla*). It belongs to the flavonoid class of compounds, which are known for their antioxidant and anti-inflammatory properties. Apigenin has been extensively studied for its potential health benefits and pharmacological activities.

(b) Plant Picture: Chamomile (*Matricaria chamomilla*)



<https://www.mdpi.com/2075-1729/12/4/479#B24-life-12-00479>

(c) Structure of Apigenin:



<https://stock.adobe.com/in/images/chemical-structure-of-apigenin-chamomile-officinalis-apigenin-is-one-of-the-most-common-aglycone-flavonoids-a-natural-antioxidant-with-anti-inflammatory-and-anti-carcinogenic-properties/530605064>

- It consists of two benzene rings (also known as aromatic rings) fused together.
- Attached to one of the benzene rings is a heterocyclic ring containing oxygen, which is called a pyran ring.
- The structure also includes several hydroxyl (-OH) groups attached to different parts of the molecule, contributing to its antioxidant properties and biological activity.
- The molecular formula of apigenin is C₁₅H₁₀O₅, indicating it contains 15 carbon atoms, 10 hydrogen atoms, and 5 oxygen atoms. Its structure is similar to other flavonoids, but its specific arrangement of atoms gives it unique properties and therapeutic potential.

(d) Mechanisms of Action of Apigenin in Skin Cancer Cells:

- **Induction of Apoptosis:** Apigenin has been shown to induce apoptosis, or programmed cell death, in various cancer cells, including skin cancer cells. It activates pathways involved in apoptosis while inhibiting survival pathways, leading to the elimination of damaged or cancerous cells.
- **Modulation of Signaling Pathways:** Apigenin modulates several signaling pathways implicated in cancer development and progression, including the PI3K/Akt, MAPK/ERK, and NF-κB pathways. By targeting these pathways, apigenin inhibits cancer cell survival, proliferation, and metastasis while promoting apoptosis and sensitivity to chemotherapy.
- **Immunomodulatory Effects:** Chamomile and apigenin have immunomodulatory properties, enhancing the activity of immune cells involved in recognizing and eliminating cancer cells. By boosting immune surveillance, chamomile may help prevent the development and progression of skin cancer.

(e) Preclinical Studies and Clinical Evidence

(i) Preclinical Studies:

- **Antiproliferative and pro-apoptotic effects:** Numerous in vitro studies have demonstrated the ability of apigenin to inhibit the proliferation and induce apoptosis (programmed cell death) in various skin cancer cell lines, including melanoma, squamous cell carcinoma, and basal cell carcinoma cells (Caltagirone et al., 2000; Lepley et al., 1996; Yin et al., 2001).
- **Anti-inflammatory and antioxidant properties:** Apigenin has been shown to possess anti-inflammatory and antioxidant activities, which may contribute to its chemopreventive effects against skin cancer. These properties can help mitigate the effects of chronic inflammation

and oxidative stress, which are known risk factors for cancer development (Sharma et al., 2007; Zheng et al., 2005).

- **Inhibition of angiogenesis and metastasis:** Studies have demonstrated that apigenin can inhibit the formation of new blood vessels (angiogenesis) and metastasis (the spread of cancer cells to other parts of the body) in skin cancer models (Fang et al., 2007; Zhong et al., 2012).
- **Modulation of signaling pathways:** Apigenin has been reported to modulate various signaling pathways involved in skin cancer progression, such as the PI3K/Akt, MAPK, and NF- κ B pathways, which can contribute to its anticancer effects (Budhraja et al., 2012; Tong and Pelling, 2013).

(ii) Clinical Evidence:

While preclinical studies have shown promising results, clinical evidence for the use of apigenin from chamomile in skin cancer intervention is limited. Most of the available data comes from epidemiological studies and a few small-scale clinical trials:

- **Epidemiological studies:** Some epidemiological studies have suggested an inverse association between the consumption of dietary flavonoids, including apigenin, and the risk of certain types of cancer, including skin cancer (Batra and Sharma, 2013; Zamora-Ros et al., 2013).
- **Clinical trials:** A few small-scale clinical trials have investigated the potential benefits of apigenin-rich chamomile extract in skin conditions:
- **A pilot study by Vaughn et al. (2015)** examined the topical application of chamomile extract cream in patients with melanoma and found promising results in terms of promoting apoptosis and reducing tumor growth.
- **Another study by Donà et al. (2004)** evaluated the efficacy of a chamomile extract cream in patients with chemotherapy-induced oral mucositis and reported improvements in pain and healing.

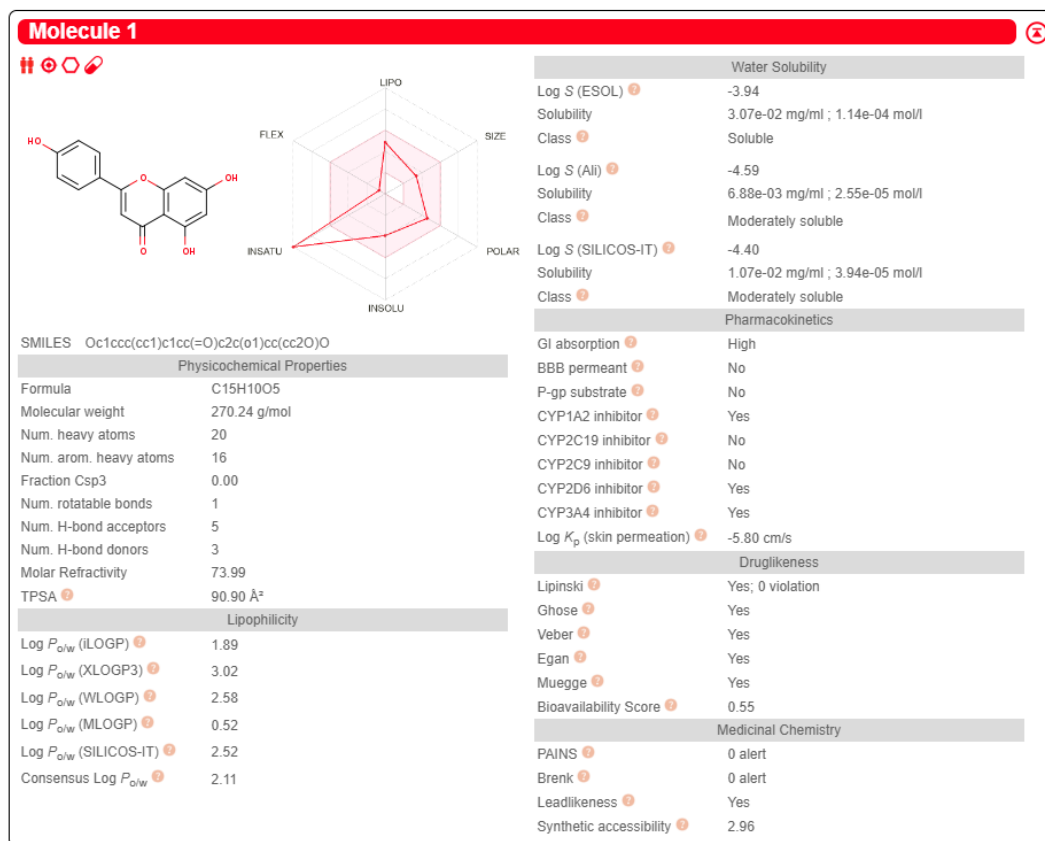
II MATERIALS AND METHODS

The research will be conducted on computational modeling using Swiss ADME tools.

(a) Computational Modeling:

In this study, we will utilize state-of-the-art computational tools to investigate the pharmacokinetic profiles of apigenin, including its absorption, distribution, metabolism, and excretion (ADME) properties.

The Swiss ADME web tool is a powerful computational platform that integrates various *in silico* models and predictive algorithms to evaluate the ADME characteristics of small molecules (Daina et al., 2017). This tool will be employed to simulate the pharmacokinetic behavior of apigenin and gain a comprehensive understanding of its potential bioavailability and disposition within the human body.



III RESULTS AND DISCUSSION

Here is the SwissADME data for apigenin, presented under the headings of Absorption, Distribution, Metabolism, and Excretion (ADME), highlighting its potential for skin cancer treatment via topical application:

(b) Absorption:

- Moderate lipophilicity (consensus log P(o/w) = 2.11) could facilitate dermal absorption and penetration into skin cells.
- Reasonable aqueous solubility (log S ranging from -3.84 to 3.07e-02 mg/ml) for topical formulation development.
- High gastrointestinal absorption potential but low blood-brain barrier (BBB) permeability, suggesting potential for topical administration without significant systemic exposure.
- Not a substrate for the P-glycoprotein (P-gp) efflux transporter, which could further aid dermal absorption.

(c) Distribution:

- Low fraction of sp³ hybridized carbon atoms (0.00) indicates a planar and rigid structure, which could influence tissue distribution.
- Satisfies drug-likeness criteria (Lipinski's rule of five, Ghose, Veber, Egan, and Muegge filters), suggesting potential for favorable distribution within target skin cells/tissues.

(d) Metabolism:

- Predicted to inhibit CYP1A2, CYP2C9, and CYP3A4 enzymes, indicating potential for drug-drug interactions and the need for further evaluation of metabolic stability and clearance.

(e) Excretion:

- Low BBB permeability suggests limited potential for systemic exposure and excretion via systemic circulation.
- Topical administration could facilitate localized activity and minimize systemic excretion.

In summary, the SwissADME analysis indicates that apigenin possesses promising physicochemical and pharmacokinetic properties for topical application in treating skin cancer. Its balanced lipophilicity, reasonable aqueous solubility, high dermal absorption potential, and favorable drug-likeness characteristics support its further investigation as a topical anticancer agent, while considering potential drug-drug interactions and metabolic stability.

IV CONCLUSION

In conclusion, this study aims to investigate the potential of apigenin as a novel therapeutic intervention for skin cancer. Through computational modeling using Swiss ADME tools, we will gain a comprehensive understanding of its mechanisms of action and pharmacokinetic profiles. This research has the potential to contribute to the development of innovative and targeted treatment strategies for skin cancer, ultimately improving patient outcomes and quality of life. Overall, the study highlights the importance of exploring natural compounds like apigenin for their potential anti-cancer properties and encourages further research in this area. So far, the results are promising and warrant further investigation into the use of apigenin as a possible treatment option for skin cancer. With its multiple molecular targets, selective cytotoxicity, and potential to overcome treatment resistance, apigenin holds great promise in the fight against skin cancer. By continuing to study this compound and its potential applications, we can potentially improve the lives of those affected by this disease. Let us continue to explore the vast potential of natural compounds and their therapeutic benefits for human health.

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Adsorptive Removal of Dyes from Aqueous Solutions: A Comprehensive Review

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ABSTRACT

The present review compiles recent progress in the use of adsorption techniques for the elimination of dyes from aqueous environments. Dyes are extensively used in textiles, paper, leather, plastics, food, and cosmetics due to their stability and strong chromophoric properties. However, their widespread discharge into aquatic systems has created severe environmental and health concerns owing to persistence, toxicity, and resistance to biodegradation. Conventional treatment methods including physical, chemical, and biological processes offer varying degrees of success but are often limited by cost, efficiency, or sludge generation. Adsorption has emerged as a promising alternative because of its simplicity, effectiveness, and adaptability to diverse wastewater conditions. This review discusses dye classifications, toxicity, existing treatment technologies, and key factors influencing adsorption such as pH, temperature, initial dye concentration, and adsorbent dosage. It also emphasizes the use of low-cost, locally available adsorbents as sustainable alternatives to commercial activated carbon. The review concludes with insights from the surveyed literature and highlights potential directions for future research.

I INTRODUCTION

Dyes are synthetic or natural compounds that possess chromophoric groups capable of binding to substrates, imparting color with high resistance to detergents and other degrading agents. Owing to their stability and versatility, synthetic dyes are extensively applied in industries such as textiles [1], paper [2], leather tanning [3], food processing, plastics, cosmetics, rubber, printing, and dye manufacturing [4–6]. They are also utilized in environmental and analytical fields, including groundwater tracing [7], surface area determination of activated sludge [8], sewage analysis [9], and wastewater treatment studies [10]. However, their indiscriminate discharge into aquatic environments presents a critical ecological concern. Due to their recalcitrant molecular structures, dyes persist in water bodies, impair sunlight penetration, hinder photosynthesis, and resist photochemical or microbial degradation, ultimately threatening aquatic biodiversity [11]. It is estimated that more than 100,000 commercial dyes exist, with global annual production exceeding 7×10^5 tonnes [12], while the textile sector alone consumes over 10,000 tonnes per year and contributes approximately 100 tonnes annually to water pollution [13]. This review therefore aims to critically evaluate the adsorption of dyes from aqueous media using a wide range of conventional and low-cost adsorbents, providing an integrated perspective for future research and sustainable wastewater treatment.

II CLASSIFICATION AND TOXICITY OF DYES

Commercial dyes can be classified according to their chemical structure, color, or mode of application [14]. Among these, application-based classification is more commonly adopted because of the complexity of structural nomenclature [15]. Based on ionic properties in aqueous solutions, dyes are broadly divided into three groups: cationic (basic dyes), anionic (direct, acid, and reactive dyes), and non-ionic (disperse dyes) [16]. These dyes are widely employed in textiles, paper, printing, plastics, food, and cosmetic industries, and significant fractions of them are eventually released into wastewater streams [17].

The toxic effects of dyes are of considerable concern due to their persistence and visibility even at very low concentrations [18]. Many dyes contain heavy metals such as chromium, which are carcinogenic and pose risks to aquatic ecosystems [19]. They interfere with light penetration, thereby reducing photosynthesis in aquatic flora, and may release toxic aromatic amines or other hazardous intermediates [18,19,20]. In humans, exposure to certain dyes has been linked to kidney, liver, reproductive, and neurological disorders, in addition to mutagenic, teratogenic, and carcinogenic effects [21]. Given these environmental and health hazards, the presence of dyes in wastewater has raised global concern. Therefore, the development of effective and sustainable treatment methods to eliminate dye pollutants from diverse wastewater streams is of paramount importance.

III PRESENT TREATMENT METHODS FOR DYE REMOVAL

Various treatment methods are available for removing dyes from wastewater, including coagulation, oxidation, membrane filtration, electrochemical processes, and microbial degradation. These approaches fall under three main categories: physical, chemical, and biological. Although each method is effective to some extent, they also present certain limitations in cost, efficiency, or environmental impact. Thus, selecting a suitable technology depends on wastewater characteristics. Table 1 highlights the comparative advantages and disadvantages of these dye removal methods.

Table-1
Adsorptions method with Advantages and Disadvantages

Category	Method	Advantages	Disadvantages
Chemical treatments	Oxidative process	Simple to apply	Requires activation of oxidizing agent
	Fenton's reagent ($\text{H}_2\text{O}_2 + \text{Fe}^{2+}$)	Effective chemical treatment	Generates sludge
	Ozonation	Applied in gaseous state; no increase in sludge volume	Short half-life (~20 min)
	Photochemical process	No sludge formation; reduces foul odor	Produces by-products
	Sodium hypochlorite (NaOCl)	Initiates and accelerates azo-bond cleavage	Releases aromatic amines
Biological treatments	Electrochemical destruction	No chemical consumption; avoids sludge buildup	High flow rates reduce dye removal efficiency
	White-rot fungi	Enzyme-based degradation of dyes	Enzyme production may be unreliable

Category	Method	Advantages	Disadvantages
Physical treatments	Mixed microbial cultures	Decolorization within 24–30 h	Limited degradation of azo dyes under aerobic conditions
	Microbial adsorption	Affinity between dyes and microbial species	Not effective for all dye types
	Anaerobic bioremediation	Effective for azo and soluble dyes	Produces methane and hydrogen sulfide
	Activated carbon adsorption	Wide range dye removal	Very costly
	Membrane filtration	Removes all dye types	Generates concentrated sludge
	Ion exchange	Regenerable adsorbent	Limited dye specificity
	Irradiation	Effective at laboratory scale	Requires high oxygen supply
	Electrokinetic coagulation	Economically feasible	Produces high sludge volume

- (a) **Factor affecting dye concentration** - Several factors influence dye adsorption, including solution pH, temperature, and initial dye concentration. These parameters strongly affect adsorption efficiency and must be carefully optimized to enhance performance. Proper adjustment of such conditions is essential for designing effective and sustainable large-scale dye removal processes.
- (b) **Effect of Initial Dye Concentration** - The initial dye concentration significantly influences adsorption efficiency. At higher concentrations, the percentage of dye removal often decreases due to the saturation of available adsorption sites. However, the overall adsorption capacity may increase because of the greater driving force for mass transfer [22,23]. Optimizing dye concentration is therefore essential to balance removal efficiency and adsorption capacity [13].
- (c) **Effect of Temperature** - Temperature plays a crucial role in dye adsorption behavior. An increase in adsorption with rising temperature indicates an endothermic process, likely due to enhanced dye mobility and more active sites. Conversely, reduced adsorption at higher temperatures suggests an exothermic process, where elevated temperatures weaken the interactions between dye molecules and the adsorbent surface [23].
- (d) **Effect of Amount of Adsorbent** - The dosage of adsorbent directly affects dye removal efficiency. Increasing the amount of adsorbent provides more active sites, enhancing dye uptake. Studying this parameter helps determine the optimal quantity needed for maximum removal while maintaining cost-effectiveness in large-scale applications [23].

IV CONCLUSION

Adsorption is an effective, simple, and adaptable method for dye removal compared to conventional treatments. Low-cost and locally available materials show great potential as alternatives to commercial activated carbon. Adsorption efficiency is strongly influenced by parameters such as pH, dye concentration, temperature, and adsorbent dosage. Most studies report Langmuir and Freundlich isotherms with kinetics following the pseudo-second-order model. Further research is needed on real effluents, mixed pollutants, and industrial-scale applications to advance sustainable dye removal technologies.

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Bridging Tradition and Technology: Role of AI and Digital Tools in Preserving Traditional Knowledge

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ABSTRACT

Traditional knowledge (TK), rooted in indigenous practices, culture, and heritage, is an invaluable resource for sustainable living, healthcare, and biodiversity conservation. However, with modernization and globalization, much of this knowledge is at risk of being lost. Emerging technologies, particularly Artificial Intelligence (AI) and digital tools, offer innovative pathways to document, analyze, and safeguard these practices for future generations. A narrative review of recent literature and case studies was undertaken to explore the applications of AI, machine learning, natural language processing, and digital databases in the preservation of TK. Special focus was placed on initiatives in Ayurveda, herbal medicine, folklore, and agricultural wisdom, where digital tools have been successfully implemented. The results highlight that AI-driven text mining and natural language processing enable the digitization and categorization of ancient manuscripts, making them searchable and accessible. Image recognition tools assist in identifying medicinal plants and artifacts. Digital platforms and mobile applications facilitate community participation, ensuring the intergenerational transfer of knowledge. Furthermore, blockchain technologies enhance authenticity and intellectual property protection, while virtual reality provides immersive educational experiences for cultural preservation. The integration of AI with digital archiving enhances accessibility, accuracy, and global reach of TK. Challenges such as ethical concerns, data privacy, intellectual property rights, and the risk of cultural appropriation remain critical. Nevertheless, the synergy between tradition and technology can create a sustainable model for knowledge conservation. AI and digital tools play a transformative role in safeguarding traditional wisdom, bridging the gap between ancient practices and modern science. Responsible implementation ensures not only preservation but also revitalization of cultural heritage for future generations.

I INTRODUCTION

Traditional knowledge (TK) encompasses the skills, innovations, and practices developed by communities through long-term interaction with their environment. These knowledge systems are evident in diverse domains such as Ayurveda, herbal medicine, folklore, agriculture, architecture, and performing arts. For centuries, TK has contributed to sustainable living and healthcare, while simultaneously safeguarding biodiversity and cultural identity (Gupta, 2021).

However, rapid globalization, urbanization, and the dominance of Western scientific paradigms have marginalized these practices. Younger generations often perceive TK as outdated, while commercialization and biopiracy threaten its authenticity and rightful ownership (WIPO, 2019). At the same time, climate change and biodiversity erosion further endanger the ecosystems in which TK thrives. The digital era presents both challenges and opportunities. Emerging technologies such as Artificial Intelligence (AI), natural language processing (NLP), image recognition, blockchain, and virtual reality (VR) are now being leveraged to document, preserve, and disseminate traditional wisdom (Patwardhan & Vaidya, 2020).

This article examines how AI and digital tools are reshaping TK preservation, with particular emphasis on Ayurveda, herbal medicine, folklore, and agricultural wisdom.

II METHODS

This study followed a narrative review approach. Literature from academic journals, case studies, and institutional reports (2015–2025) was analyzed. Databases including PubMed, Scopus, and Google Scholar were searched using terms such as “AI and Ayurveda,” “digital preservation of folklore,” “blockchain for traditional knowledge,” and “VR in cultural heritage.”

Additionally, case studies of:

- Traditional Knowledge Digital Library (TKDL) in India,
- UNESCO Intangible Cultural Heritage Projects, and
- AI-based plant recognition apps (e.g., PlantNet, iNaturalist) were included to illustrate practical applications.

III RESULTS

1. Digitization and NLP

- TKDL, launched in 2001, has digitized more than 300,000 medicinal formulations from Ayurveda, Unani, and Siddha. AI-driven NLP allows multilingual accessibility, preventing patent misuse and biopiracy (CSIR, 2022).
- Machine learning-based translation systems have enabled Sanskrit and Prakrit manuscripts to be searchable and understandable for researchers worldwide.

2. Image Recognition

- Mobile apps such as PlantNet and iNaturalist combine AI algorithms with community participation to identify medicinal plants.
- Image recognition also assists archaeologists in categorizing cultural artifacts, improving the accuracy of digital archives.

3. Digital Platforms and Community Knowledge Sharing

- Mobile applications facilitate farmer-to-farmer knowledge sharing of indigenous soil conservation and climate-resilient agricultural practices.
- Oral traditions, folklore, and storytelling have been preserved through online repositories that allow younger generations to engage with community elders' wisdom.

4. Blockchain for Authenticity

- Blockchain technology provides traceability, authenticity, and benefit-sharing mechanisms. For instance, registering traditional medicinal formulations on blockchain prevents unauthorized commercialization and ensures community rights.

5. Virtual and Augmented Reality (VR/AR)

- VR simulations of Ayurvedic healing practices and AR reconstructions of indigenous festivals provide immersive educational tools for students and researchers.
- Museums and cultural centers are increasingly adopting these tools to enhance experiential learning.

IV DISCUSSION

Benefits of AI in TK Preservation

- **Accessibility:** Digitization democratizes knowledge, making it available to scholars, policymakers, and communities worldwide.
- **Accuracy and Standardization:** AI reduces human error in cataloging manuscripts and artifacts.
- **Youth Engagement:** Gamified apps and VR experiences increase interest among younger generations.
- **Sustainability:** Reviving traditional agricultural and ecological practices supports climate adaptation strategies.

V CHALLENGES

- **Ethical Concerns:** Open-access digitization may expose TK to exploitation without community consent.
- **Intellectual Property Rights (IPR):** Many indigenous communities lack legal frameworks to protect their heritage from commercial misappropriation.
- **Cultural Appropriation:** Misuse of TK in fashion, cosmetics, and pharmaceuticals often strips knowledge from its cultural context.
- **Technological Bias:** AI models, trained on limited datasets, may fail to capture local dialects, symbolic meanings, and cultural nuances.

VI LIMITATIONS AND FUTURE DIRECTIONS

This review is limited by its reliance on secondary sources and case studies, as many TK preservation initiatives remain unpublished or community-based. Future research should focus on:

- Developing inclusive AI models trained on indigenous languages and dialects.
- Creating ethical frameworks that balance open access with community control.
- Expanding blockchain adoption for fair benefit-sharing agreements.
- Integrating AI with environmental monitoring, enabling the revival of TK-based climate adaptation strategies.

VII CONCLUSION

The convergence of traditional knowledge (TK) with artificial intelligence (AI) and digital tools has opened a new chapter in cultural and scientific preservation. While challenges remain, the opportunities outweigh the risks if implemented responsibly. Several key conclusions can be drawn from this review:

- **AI strengthens preservation and accessibility.** Through natural language processing, text mining, and image recognition, traditional manuscripts, medicinal plants, and artifacts can be systematically digitized, catalogued, and made globally accessible.
- **Technology revitalizes interest among younger generations.** Digital storytelling, mobile apps, and immersive experiences such as VR/AR engage youth, ensuring intergenerational transfer of knowledge that might otherwise be forgotten.
- **Blockchain ensures authenticity and equity.** By recording TK on decentralized ledgers, communities can protect their intellectual property and ensure fair benefit-sharing, reducing the risk of exploitation and biopiracy.

- **Traditional knowledge supports sustainable futures.** AI-enabled revival of indigenous agricultural practices, herbal medicine, and ecological wisdom contributes to biodiversity conservation and climate resilience.
- **Ethical frameworks are essential.** The digitization of TK must be guided by strong ethical principles, ensuring community ownership, cultural sensitivity, and protection from misuse. Without safeguards, technology could accelerate cultural appropriation.
- **Collaboration is the key to success.** The preservation of TK requires partnerships between technologists, policymakers, researchers, and indigenous communities. Only through co-creation can digital preservation achieve legitimacy and inclusivity.
- **Integration with modern science bridges tradition and innovation.** When responsibly applied, AI not only preserves knowledge but also provides a platform for cross-disciplinary research, where traditional practices can complement modern medicine, agriculture, and sustainability science.
- **The future lies in balance.** Neither tradition nor technology alone is sufficient; the synergy between the two creates a sustainable model where cultural heritage is not only safeguarded but actively revitalized and adapted for modern needs.

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Adjustable Battery-Operated Grass and Brush (Haze) Cutting Machine —A Research Review

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ABSTRACT

Battery-operated grass and brush (haze) cutting machines are rapidly replacing small gasoline engines for many light-to-medium vegetation tasks. Improvements in lithium-ion battery energy density, brushless-DC motor drives, power electronics, and lightweight materials have enabled cordless trimmers and brushcutters that approach the performance of petrol units while offering lower noise, zero on-site exhaust, and simpler operation. This review summarizes the technical state of the art for adjustable battery-operated grass and brush cutting machines, covering powertrain choices, battery systems and management, cutting heads and mechanical design, ergonomics and vibration control, safety and standards, testing methods, environmental and lifecycle considerations, and business/operational models. We synthesize practical design guidance and identify research gaps and priorities for future development. ([Allied Motion](#))

Keywords: battery-operated, brush cutter, grass trimmer, BLDC motor, lithium-ion, ergonomics, safety standards, life-cycle assessment

I INTRODUCTION

Hand-held and small walk-behind machines for trimming grass and cutting coarse vegetation (often called brushcutters, string trimmers, or trimmers/brush cutters) are essential tools for municipal maintenance, landscaping, and small-scale agriculture. Historically powered by two-stroke or four-stroke petrol engines, these machines are noisy, emit exhaust, require fuel handling, and impose high maintenance. Battery-operated versions have grown in capability, driven by improvements in battery energy density, motor technology (especially brushless DC motors), and lightweight materials. This review examines current engineering approaches, evaluation studies, standards and safety considerations, and environmental and user-acceptance dimensions. Where possible we reference empirical studies and standards relevant to design and deployment.

II CORE TECHNICAL COMPONENTS

(a) Powertrain: motor selection and control

Brushless DC (BLDC) motors have largely become the preferred choice for cordless garden tools because of higher torque density, better efficiency, reduced maintenance (no brushes), and more precise speed control via electronic commutation and PWM/field-oriented control (FOC). BLDC drives enable higher peak power for short durations (useful for sudden heavy cutting loads) and permit electronic torque-limiting, stall protection, and soft-start features. Brushed DC motors remain cheaper and simpler but suffer from brush wear and lower overall efficiency. For adjustable, battery-operated cutting machines, BLDC motors paired with a robust electronic speed controller (ESC) are recommended to meet variable cutting demands and enable features like automatic current limiting and thermal protection. ([Allied Motion](#))

III BATTERY CHEMISTRY, PACK DESIGN, AND BMS

Lithium-ion cells (e.g., NMC, NCA, or Li-FePO₄ variants) dominate commercial cordless tools due to favorable energy-to-weight ratios and mature supply chains. Pack voltage (e.g., 18–60 V nominal systems in commercial tools) and capacity (Ah) selection trade off runtime, mass, and cost. A Battery Management System (BMS) with cell balancing, over-/under-voltage protection, temperature monitoring, and safe charge/discharge cutoffs is mandatory. High-power tools benefit from cells capable of high C-rates and low internal resistance to supply peak currents during heavy cutting. Recent prototypes and academic designs also consider swappable battery modules for continuous operation and fast charging strategies, though fast charging must be balanced with cell lifetime and thermal considerations. Emerging solid-state and higher energy density chemistries promise future gains but are not yet widely available in tools. ([The Verge](#))

IV MECHANICAL CUTTING HEAD AND ADJUSTABLE GEOMETRY

Cutting heads include nylon line (filament) heads for grass/soft vegetation and metal blade attachments for thicker brush and woody stems. Mechanical design must consider torque transmission, gearbox (if present) or direct-drive arrangement, rotational speed, tip kinetic energy, and safety guards. Adjustable geometry—telescoping shafts, interchangeable handles (loop vs. bicycle-style), and adjustable balance points—improves ergonomics across user sizes and tasks. Designs that allow quick switching between line and blade heads, with secure locking and anti-vibration couplings, increase machine versatility. Empirical studies indicate the choice of cutting attachment strongly affects noise and vibration emissions and operator exertion. ([Crojfe](#))

V ERGONOMICS, VIBRATION, AND NOISE

Operator comfort and long-term health risks (hand-arm vibration syndrome, musculoskeletal strain) are critical for hand-held cutting tools. Handle design (loop vs. bicycle), shaft balance, mounting harnesses, and grip materials materially influence perceived exertion and measured vibration exposure. Studies measuring hand-arm vibration on brushcutters show significant exposures in some operational modes and recommend vibration-damping mounts and operator rotation schedules to limit daily exposure. Noise levels vary with cutting head and rotational speed; selection of cutting attachments and motor RPM control strategies can reduce peak noise. Battery machines are typically quieter than petrol equivalents but still require hearing protection in many use cases. ([ScienceDirect](#))

VI SAFETY AND STANDARDS

Electric garden equipment is covered by international and regional standards (e.g., EN 50636 series and related IEC/EN 60335 parts) specifying electrical safety, mechanical guarding, labelling, and limits for kinetic energy of cutting elements. Designers must ensure insulation, IP protection for electronics, fail-safe stop on release, secure guards, and safe battery integration to meet these standards. Compliance simplifies market entry and protects users from predictable hazards. Standards also recommend testing methods for sound power level and vibration measurement. ([iTeh Standards](#))

VII PERFORMANCE EVALUATION AND TESTING METHODS

Evaluating a battery-operated cutter requires standardized protocols for measuring: (a) cutting performance across vegetation types (grass, sedge, woody shoots); (b) runtime and energy per unit mass of vegetation removed; (c) peak and continuous current draw; (d) thermal behavior of motor and battery; (e) noise and vibration metrics; and (f) operator subjective ratings. Bench tests (dynamometer or motor test rigs) combined with field trials across representative vegetation types provide robust data. Several recent prototype studies include lab and field validation showing that well-designed battery machines can achieve performance comparable to small petrol units for many tasks when optimized for torque and duty cycles. ([Journal JERR](#))

VIII ENVIRONMENTAL AND LIFE-CYCLE CONSIDERATIONS

Replacing internal combustion engines reduces local air pollution and noise and can offer lifecycle greenhouse-gas benefits depending on electricity grid carbon intensity and battery manufacturing impacts. Life cycle assessments (LCA) of cordless tools should account for battery production, expected cycle life, end-of-life recycling, and electricity sources for charging. Designers should aim for modular, swappable battery packs to extend useful life and facilitate recycling streams. Consumer advocacy reports highlight that although electric tools reduce on-site emissions, battery sourcing and disposal remain important environmental considerations. ([Sustainability at Williams](#))

IX ADJUSTABILITY & USABILITY

Key adjustable features that increase machine utility and user uptake:

- **Telescoping shaft and adjustable handle positions** to fit operators of different heights.
- **Multiple power modes** (eco/normal/turbo) to match vegetation density and conserve energy.
- **Quick-change cutting heads** with secure locking to swap between line and blade.
- **Swappable battery packs** and clear state-of-charge indicators.
- **Integrated torque monitoring and stall protection** to protect motor and battery from overload.
- **Lightweight materials** (high-strength polymers, aluminum alloys) for low inertial mass.

X COMMERCIAL, OPERATIONAL, AND SOCIO-TECHNICAL ASPECTS

Market traction for cordless tools is growing as battery costs decline and performance improves. Product positioning should consider: duty cycles (home vs. municipal vs. agricultural), accessory ecosystems (batteries shared across tools), warranty and maintenance, and total cost of ownership (including battery replacement). Shared battery systems and battery-as-service models could reduce upfront costs in institutional use. Training and clear instructions on battery care are necessary to achieve long battery life and safe operation.

XI RESEARCH GAPS

- (a) **High-torque, high-efficiency compact motors:** optimization for persistent heavy cutting without excessive battery drain. (More empirical comparative studies between motor topologies are needed.) ([Allied Motion](#))

- (b) **Battery pack thermal management in heavy duty cycles:** Field studies on pack temperature rise and cell balancing under repeated high C-rate draws. ([Sustainability at Williams](#))
- (c) **Standardized performance test protocols** for small-engine replacement tools to enable fair comparisons across petrol and battery units. ([Journal JERR](#))
- (d) **Ergonomic long-term exposure studies** for battery brushcutters focusing on vibration, posture, and cumulative musculoskeletal effects. ([AAEM](#))
- (e) **Sustainable battery end-of-life strategies** and circular business models to minimize lifecycle impacts. ([TIME](#))

XII CONCLUSION

Adjustable battery-operated grass and brush cutting machines are a viable and increasingly mature alternative to small petrol engines for many use cases. Advances in BLDC motors, battery technology, and power electronics enable compact machines with strong torque, acceptable runtime, and lower noise and emissions. However, robust BMS design, modular battery serviceability, attention to ergonomics and vibration, and compliance with international safety standards are essential. Further research should focus on standardized performance testing, thermal management for high C-rate operation, and lifecycle impacts of batteries. With careful design and validation, battery-operated cutters can deliver the performance and usability required by both household and professional users while reducing environmental and occupational health impacts. ([IJSAT](#))

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TDS Se Sudh Jal: A Commerce-Driven Approach to Water Quality Testing in Rural and Semi-Urban Kota — A Research Review

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ABSTRACT

Total Dissolved Solids (TDS) is a simple, rapid proxy measurement widely used to assess water “mineralization” and—by extension—a first-cut indicator of water quality. In many Indian smaller cities and peri-urban/rural settlements, including Kota (Rajasthan), elevated or variable TDS frequently prompts household-level treatment, purchasing of packaged water, or use of untested sources. This review synthesizes: (1) the scientific and regulatory background on TDS in drinking water; (2) evidence on water quality and TDS issues in Kota and surrounding rural areas; (3) technologies and testing approaches suitable for low-resource settings; (4) the case for commerce-driven TDS testing (market-based testing, pay-per-test, micro-franchise, and digital reporting models); and (5) policy and design recommendations for piloting a TDS-centric water quality service tailored to rural and semi-urban Kota. The review draws on international guidelines, Indian standards, local water quality assessments, and literature on portable testing and community water services.

Keywords: TDS, drinking water, Kota, rural water, portable testing, market-based testing, BIS IS 10500, WHO.

I INTRODUCTION

Access to safe drinking water is both a public health imperative and a daily household economic decision. In many rural and semi-urban Indian contexts, households rely on multiple sources (handpumps, borewells, municipal supply, packaged water). Total Dissolved Solids (TDS) is widely used by consumers, NGOs, and small water enterprises as an accessible indicator of palatability and potential salinity/mineralization problems. Although TDS alone is not a comprehensive indicator of toxicity (toxic metals and specific anions require targeted tests), it is a practical screening tool: TDS meters are cheap, fast, and easily deployed in the field. For Kota — an industrial and fast-growing district with mixed water sources — deploying a commerce-driven TDS testing network could both fill an information gap and create sustainable livelihood opportunities for local micro-entrepreneurs. This review frames the evidence base supporting such an approach.

II METHODS

This is a narrative literature review combining: WHO technical/background documents on TDS, Indian regulatory standards (BIS IS 10500), Central Pollution Control Board (CPCB) monitoring datasets, peer-reviewed studies on Kota and Rajasthan water quality, and literature on portable TDS testing and market models for decentralized water services. Searches targeted guideline documents and local/regional studies; where municipal or CPCB monitoring data were publicly available, these were used to illustrate regional patterns. The review emphasizes accessibility and pragmatic recommendations for implementation in Kota.

III SCIENTIFIC & REGULATORY BACKGROUND ON TDS

- (a) **What TDS measures and limitations?**- Total Dissolved Solids quantify the combined concentration of dissolved inorganic salts and some organic matter in water (commonly expressed in mg/L or ppm). TDS is commonly inferred from electrical conductivity (EC) measurements, and portable “TDS meters” provide rapid on-site readings. However, TDS is a **non-specific** indicator: similar TDS values may result from benign mineral content (calcium, magnesium) or from problematic dissolved contaminants (sodium, chloride, nitrate, arsenic, etc.). WHO therefore treats TDS as an aesthetic/acceptability indicator rather than a comprehensive health-based parameter; specific constituents require targeted chemical/analytical tests.
- (b) **Guideline and standard values** - WHO does **not** set a single health-based guideline value for TDS but notes its relevance for taste and acceptability; high TDS often indicates further testing is warranted. Many countries set aesthetic or secondary standards (e.g., US EPA secondary standard~500 mg/L). In India, BIS IS 10500 (2012) lists a desirable limit of **500 mg/L** for TDS and a permissible limit of **2000 mg/L** when alternate sources are unavailable. These thresholds guide both municipal supply monitoring and community messaging.

IV WATER QUALITY & TDS IN KOTA

- (a) **Local studies and monitoring** - Several academic and governmental assessments have examined Kota’s water. City-level studies and monitoring exercises have found variation in physico-chemical parameters (including TDS), with some sampling points exceeding BIS desirable limits, especially in peri- urban or groundwater sources affected by geology, irrigation return flow, or industrial inputs. Public datasets (CPCB/NWMP) and local research indicate spatial and seasonal variability in TDS across the district and municipal supply systems.
- (b) **Drivers of elevated or variable TDS in the region** - Drivers include natural geology (saline aquifers), agricultural runoff, wastewater discharge, and industrial effluents. In semi-urban and peri-urban areas, unregulated borewells and shallow groundwater may show elevated mineralization or seasonal concentration increases during dry months. These are well-documented patterns across Rajasthan and observed in localized Kota assessments.

V TESTING TECHNOLOGIES SUITABLE FOR KOTA

- (a) **Portable TDS/EC meters (field-pen style)**
- **Pros:** low cost (~INR hundreds–a few thousands for basic models), rapid results (<1 min), minimal training required.
 - **Cons:** non-specific; cannot detect specific toxicants (e.g., arsenic, fluoride); subject to calibration drift and temperature effects. Practical deployment requires a calibration and QA protocol and periodic cross-validation with lab analyses. Studies reviewing portable devices conclude they are useful screening tools when integrated into clear referral/testing pathways. ([Amazon](#))
- (b) **Test-strip and colorimetric kits** - Useful for certain constituents (nitrate, chloride, hardness components) but less direct for total dissolved solids; often used as complements.
- (c) **Mobile digital sensors & IoT aggregation** - Low-cost EC/TDS probes with Bluetooth/GSM can feed community dashboards, enabling aggregation of readings by location/time — useful for commerce models where consumers pay for verified, timestamped readings.

- (d) **Laboratory confirmation** - For regulatory or health investigations, portable results must be confirmed in accredited labs for key constituents and toxicants; a commerce model should include a pathway for subsidized lab confirmation when a screening test exceeds thresholds.

VI COMMERCE-DRIVEN MODELS FOR TDS TESTING: RATIONALE AND DESIGN OPTIONS

(a) Why a market approach?

- **Sustainability:** user fees or micropayments can maintain supplies, calibration, and operator livelihoods without sole dependence on grant cycles.
- **Reach:** local entrepreneurs and small shops are often more ubiquitous than government labs in peri-urban/rural areas.
- **Demand:** households already pay for packaged water or treatment; offering fast, low- cost testing + advice can substitute or complement purchases.

(b) Candidate business models

(i) Micro-franchise testing shops

- Local kiosks (e.g., tea shops, water vendors) trained to perform TDS/EC tests for a small fee and provide a printed/digital certificate. Franchise provides supply of calibrated meters, test cards, and monthly QA visits.

(ii) Pay-per-test mobile teams

- Mobile testers (two-person team) hired to provide doorstep screening for communities or schools; payments per household or via bundled community campaigns.

(iii) Subscription / membership for bulk testing

- Neighborhood committees pay a monthly fee for regular monitoring and early alerts.

(iv) Integration with packaged-water / RO vendors

- Vendors offer “free” baseline testing as value add, or tie test results to sales (e.g., lower TDS households are offered mineralized bottled water vs. desalinated RO water).

(v) Digital marketplace and dashboards

- Tests are geo-tagged, uploaded to a public dashboard; premium services include lab confirmation, remediation advice, and vendor referrals. Micro-insurance or guarantee schemes could be layered for repeat business.

VII PRICING AND AFFORDABILITY CONSIDERATIONS

Small nominal fees (e.g., INR 10–50 per test) keep services accessible while covering consumables, meter amortization, and operator compensation. Subsidized community testing can be balanced with commercial customers (schools, small industries).

VIII IMPLEMENTATION DESIGN: A PILOT FOR RURAL & SEMI-URBAN KOTA

✓ Pilot Objectives

- Map TDS variability across 20–30 sampling points (mix of municipal taps, borewells, schools, small-market zones).
- Test viability of two commerce models: micro-franchise kiosk and mobile pay-per-test team.

- Measure user willingness-to-pay, operator income, data reliability (agreement with lab), and public health/referral follow-ups.

IX OPERATIONAL COMPONENTS

- **Hardware:** 10–20 calibrated portable TDS/EC pens, spare electrodes, cleaning supplies, portable temperature correction charts.
- **Training:** 1–2 day training for operators (sampling protocol, calibration, data entry, customer counseling).
- **QA/QC:** weekly calibration checks and monthly lab cross-validation (10% of samples).
- **Digital tools:** lightweight mobile app for logging geo-tagged readings, QR code printed certificates for customers, and a dashboard for aggregating results.
- **Referral network:** list of accredited labs, municipal contacts, and low-cost remediation options (point-of-use filters, blending advice).
- **Business support:** micro-franchise pack (branding, receipt templates, starter calibration kit).

X DATA & EVALUATION METRICS

- Technical: meter-lab concordance (Bland-Altman / correlation), percentage of samples exceeding BIS desirable limit (500 mg/L).
- Commercial: number of tests/day, average revenue per operator, retention after 6 months.
- Social: user satisfaction, change in household behavior (switching sources, buying treatment), referrals to lab tests for constituents beyond TDS.

XI CHALLENGES & RISK MITIGATION

(a) Scientific/technical limitations

- TDS alone cannot detect toxicants like arsenic or fluoride—high TDS may give false reassurance. **Mitigation:** clear messaging: “TDS is a screening test—if TDS is high or taste/smell is unusual, get targeted lab tests.” Include bundled targeted strips where local risks exist (e.g., fluoride testing in Rajasthan hotspots).

(b) Quality assurance and trust

- Risk of uncalibrated meters and erroneous results. **Mitigation:** enforce mandatory monthly QA, visible calibration stickers, and third-party lab cross-checks.

(c) Equity concerns

- Market models may under-serve poorest households. **Mitigation:** subsidized community drives, school testing campaigns, and partnerships with local NGOs/PHED for low-income households.

(d) Regulatory & ethical issues

- Data privacy for geo-tagged tests, liability for incorrect advice. **Mitigation:** consent forms, disclaimers, and formal partnerships with municipal bodies.

(e) Policy & Practice Recommendations

- **Recognize TDS testing as a valid screening service:** Municipalities and PHED should incorporate verified TDS screening into community outreach, and permit accredited micro-franchises to operate with simple licensing. ([Law Resource](#))
- **Standardize QA:** Adopt a simple QA protocol: daily meter checks, monthly calibration, and quarterly lab cross-validation for a fraction of samples. ([PMC](#))
- **Develop clear customer messaging:** Simple leaflets in Hindi and local dialects explaining (a) what TDS means, (b) BIS thresholds (500 mg/L desirable; 2000 mg/L permissible), and (c) when to seek lab testing or treatment. ([Law Resource](#))
- **Pilot blended financing:** Mix small user fees with seed grants to underwrite initial QA and training; evaluate cost-recovery after 6–12 months.
- **Link to governance:** Share aggregated anonymized TDS maps with municipal authorities and CPCB-style monitoring to target remediation and infrastructure investments. Public dashboards increase transparency and build trust.

XII CONCLUSION

A commerce-driven TDS testing network in rural and semi-urban Kota is technically feasible and can fill an urgent information gap that shapes household water decisions. However, TDS must be positioned as a **screening** tool within a broader water-safety ecosystem that includes targeted lab testing, remediation pathways, and regulatory oversight. Successful models will combine local entrepreneurship, affordable pricing, and strong QA backed by public-sector linkages. The pilot design sketched above balances technical robustness with commercial viability and can be scaled if it demonstrates consistent data quality and user adoption. Regional datasets and city studies indicate real variability in Kota that justifies localized, frequent monitoring. ([ResearchGate](#)). TDS testing is not a panacea but is an effective screening instrument that—if embedded in a commerce-driven, quality-assured delivery model—can empower households in Kota to make better water decisions while generating livelihoods. A carefully monitored pilot (micro-franchise + mobile teams), combined with digital reporting and public-sector partnerships, offers a pragmatic path to scale. Future research should measure health outcomes, behavior change, and long-term financial sustainability.

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Millets for Nutrition and Sustainability: A Comprehensive Review

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ABSTRACT

Millets, including major, minor, and pseudo-cereals like buckwheat and amaranth, are gaining recognition for their role in nutrition security, climate resilience, and sustainable food systems. They are rich in protein, fiber, and micronutrients, offering benefits in managing diabetes, obesity, and cardiovascular diseases. Their adaptability to drought, low input needs, and suitability for marginal soils make them climate-smart crops. Advances in processing, value addition, and market strategies highlight opportunities for improved consumer acceptance and farmer income. However, gaps remain in breeding, post-harvest technologies, and clinical validation of health effects. Policy support through integration into food distribution, school programs, and value chain development is essential. Positioning millets as “nutri-cereals” can strengthen global efforts toward resilient agriculture and healthy diets.

I INTRODUCTION

Millets, derived from the Latin *milum* (“grain”), are ancient small-seeded cereals cultivated for thousands of years across Asia, Africa, and Europe. Naturally gluten-free and nutrient-rich, they provide dietary fiber, essential minerals (iron, calcium, zinc, magnesium), B-vitamins, and high-quality protein, making them valuable for both general nutrition and individuals with gluten sensitivity (Sharma et al., 2021). In the face of population growth, climate change, and resource scarcity, they represent sustainable alternatives to rice and wheat (Muthamilarasan & Prasad, 2021; Patel et al., 2023).

Agronomically, millets thrive in drought-prone, nutrient-poor soils, require minimal inputs, and have short growing cycles that ensure reliable yields in marginal lands (Gupta et al., 2017; Harish et al., 2024). Nutritionally, they contain 60-75% carbohydrates, moderate fat, protein enriched with essential amino acids, and bioactive compounds with antioxidant, anti-inflammatory, and metabolic health benefits (Afsana Kheya et al., 2023; Priya et al., 2024). With their adaptability and health-promoting properties, millets are increasingly promoted as “nutri-cereals” to enhance food and nutrition security while supporting climate-resilient and sustainable agriculture (Mohanani et al., 2025; Timilsina et al., 2025).

II HISTORICAL BACKGROUND

Millets are among the earliest domesticated cereals, with evidence of cultivation in the Indian subcontinent over 4,000 years ago (Weber & Fuller, 2008; D’Agostini et al., 2022). References in the *Yajurveda* and Tamil Sangam literature highlight their role as staple foods in agrarian societies (Weber & Fuller, 2008). Traditionally, these hardy grains supported agriculture, cuisine, and culture in semi-arid regions where other cereals performed poorly (Mirza & Marla, 2019).

India remains a center of diversity for major and minor millets, long valued in traditional systems for their resilience to drought, poor soils, and low inputs (Anitha et al., 2024; Wambi et al., 2020). Although their cultivation declined during the Green Revolution due to the rise of rice and wheat, renewed interest stems from their nutritional richness and climate resilience (Muthamilarasan & Prasad, 2021; Harish et al., 2024).

Globally, consumer demand for healthy, sustainable, and gluten-free foods is driving a revival of millets. The international market is projected to approach USD 12 billion by 2025, positioning millets as “smart foods” in strategies for nutrition security and climate-smart agriculture (Kumar et al., 2018; Patel et al., 2023; Dimitrova et al., 2024).

III TYPES OF MILLETS

Millets are commonly categorized into major (large-grained) and minor (small-grained) groups, a practical classification used in agronomy and policy documents (ICAR-IIMR, 2024; Muthamilarasan & Prasad, 2021). Major millets typically include sorghum (*Sorghum bicolor*), pearl millet (*Pennisetum glaucum*), finger millet (*Eleusine coracana*), foxtail millet (*Setaria italica*), and proso millet (*Panicum miliaceum*) (Mirza & Marla, 2019; Anitha et al., 2024). Minor millets commonly comprise kodo (*Paspalum scrobiculatum*), little millet (*Panicum sumatrense*), barnyard millet (*Echinochloa frumentacea*), browntop millet (*Brachiaria ramosa*), and regionally important species such as fonio (*Digitaria exilis*) (ICAR-IIMR, 2024; Anitha et al., 2024).

Several pseudo-cereals, notably amaranth (*Amaranthus* spp.) and buckwheat (*Fagopyrum esculentum*) are often discussed alongside millets in nutrition and product-development contexts because they share similar culinary uses, are gluten-free, and offer complementary nutrient profiles (Saleh et al., 2013). This inclusive, functional grouping is useful when designing composite flours, value-added foods, or nutrition programmes that aim to exploit synergies between different small grains (Anitha et al., 2024; Muthamilarasan & Prasad, 2021).

Table 1
Major Millet Species, Their Common Names, and Key Uses

Sn.	Type (Common Name)	Botanical Name	Key Uses / Noted Health Benefits
1	Finger millet (Ragi)	<i>Eleusine coracana</i>	High in calcium; supports bone health and is used in traditional weaning foods and porridges (Mirza & Marla, 2019).
2	Foxtail millet (Kakum/Kangni)	<i>Setaria italica</i>	Good source of B-vitamins and fibre; useful for glycaemic control and traditional flatbreads (Saleh et al., 2013; Anitha et al., 2024)
3	Sorghum (Jowar)	<i>Sorghum bicolor</i>	Common for porridge and flatbreads; high dietary fibre and antioxidant phenolics are useful in digestion and glycaemic management (Muthamilarasan & Prasad, 2021).
4	Proso millet (Cheena/Barri)	<i>Panicum miliaceum</i>	Relatively higher protein content among small grains; suitable for cereals and composite flours (Saleh et al., 2013; Anitha et al., 2024).
5	Pearl millet (Bajra)	<i>Pennisetum glaucum</i>	High energy and protein for semi-arid regions; staple in many Indian and African diets (Mirza & Marla, 2019; ICAR-IIMR, 2024).
6	Little millet (Kutki)	<i>Panicum sumatrense</i>	Good fibre and antioxidant content; used regionally in porridges and traditional dishes (Anitha et al., 2024; Saleh et al., 2013).

7	Kodo millet	<i>Paspalum scrobiculatum</i>	Traditional staple in parts of South Asia; low glycaemic index and suitable for marginal soils (ICAR-IIMR, 2024; Anitha et al., 2024).
8	Barnyard millet (Sanwa)	<i>Echinochloa frumentacea</i>	Gluten-free, fast-maturing; potential benefits for diabetes and cardiovascular risk management when used in balanced diets (Saleh et al., 2013).
9	Browntop millet	<i>Brachiaria ramosa</i> (syn. <i>Urochloa ramosa</i>)	Good fibre and mineral content; used locally as an alternative cereal (ICAR-IIMR, 2024; Anitha et al., 2024).
10	Fonio	<i>Digitaria exilis</i>	Small West African millet; whole-grain use supports micronutrient intake and gut health in traditional diets (Muthamilarasan & Prasad, 2021;).
11	Amaranth (Rajgira)*	<i>Amaranthus cruentus</i>	Technically a pseudo-cereal; notable for lysine content and anti-inflammatory phytochemicals (Saleh et al., 2013;).
12	Buckwheat (Kuttu)*	<i>Fagopyrum esculentum</i>	Used in flours and noodles; supports cardiovascular health and is gluten-free (Saleh et al., 2013;).

Amaranth and buckwheat are technically pseudo-cereals but are often grouped with millets for culinary and nutritional discussions.

IV NUTRITION VALUE OF MILLETS

Millets, often described as “nutri-cereals,” are nutrient-dense grains rich in complex carbohydrates, dietary fibre, and bioactive compounds that support blood glucose regulation and cardiovascular health (Saleh et al., 2013; Sharma et al., 2021; Anitha et al., 2024). They provide 7-15% protein with generally favorable amino-acid profiles, though lysine is often limiting; combining with legumes enhances protein quality (Dwivedi et al., 2012; Singh & Raghuvanshi, 2012). Finger millet, foxtail millet, and proso millet, for example, contain ~7-15% protein.

Micronutrient contributions are notable, with finger millet exceptionally high in calcium and other species rich in iron, magnesium, potassium, and zinc (ICAR-IIMR, 2024; Anitha et al., 2024). Additionally, phenolic compounds and antioxidants in millets are linked to anti-inflammatory and potential anti-carcinogenic properties (Saleh et al., 2013; Zamaratskaia et al., 2021).

Table 2
Key Nutritional and Bioactive Profiles of Major Millets

Millet Type	Protein (g/100 g)	Dietary Fibre (g/100 g)	Key Minerals	Notable Functional Properties	References
Finger millet	7.3	3.6	Calcium 344 mg, Iron 3.9 mg	Bone health, high antioxidant content	Sharma et al., 2021
Foxtail millet	12.3	8.0	Magnesium, Iron	Supports digestion, gluten-free	Timilsina et al., 2025
Sorghum	10.0	4.0	Calcium, Iron	Low glycaemic index, antioxidant-rich	Sharma et al., 2021
Pearl millet	10.6	1.3	Iron 16.9 mg, Calcium 38 mg	Cardiovascular support, high fibre	Sharma et al., 2021
Proso millet	12.5	2.2	Magnesium, Zinc	Protein-rich, supports metabolism	Sharma et al., 2021
Kodo millet	8.3	9.0	Iron, Calcium	Low glycaemic index, immune support	Sharma et al., 2021
Little millet	7.7	7.6	Iron, Zinc	Antioxidant activity, supports gut health	Sharma et al., 2021
Barnyard millet	11.2	10.1	Iron, Calcium	Gluten-free, cardiovascular benefits	Sharma et al., 2021

- *Note. Values are per 100 g edible portion. Data compiled from ICAR-Indian Institute of Millets Research (2024) and representative published sources; actual composition varies with genotype, environment, and post-harvest processing*
- Values are approximate averages; they can vary with variety and cultivation conditions.
- Functional properties highlight potential health benefits for human diets.

V CULTIVATION OF MILLET IN INDIA

Millets have traditionally sustained Indian agriculture, particularly in regions prone to heat, drought, and poor soils, making them vital for smallholder farmers (Muthamilarasan & Prasad, 2021). Their resilience has prompted renewed policy attention, with initiatives such as the Sub-Mission on Nutri-Cereals under the National Food Security Mission and global promotion of 2023 as the International Year of Millets (DA&FW, 2024; Dimitrova et al., 2024).

India is the largest producer of millets, contributing about 40-41% of global output in 2021, though its average yield ranks around 12th worldwide (FAO, 2023; Harish et al., 2024). This gap underscores the need for improved seed systems, agronomy, irrigation, and post-harvest practices. Government measures, including seed hubs, MSP, and market linkages, aim to enhance productivity, farmer income, and national food security (ICAR-IIMR, 2024; DA&FW, 2024).

Table 3
Top Millet-Producing States in India, 2021-22

Rank	State	Production (million t)	Share of National Production (%)
1	Rajasthan	4.30	26.7
2	Maharashtra	2.32*	14.4
3	Uttar Pradesh	2.24*	13.9
4	Karnataka	2.06*	12.8
5	Madhya Pradesh	1.19*	7.4

Courtesy: Exim Bank, based on MoA&FW data (2021-22)

VI ECONOMICS OF CULTIVATION

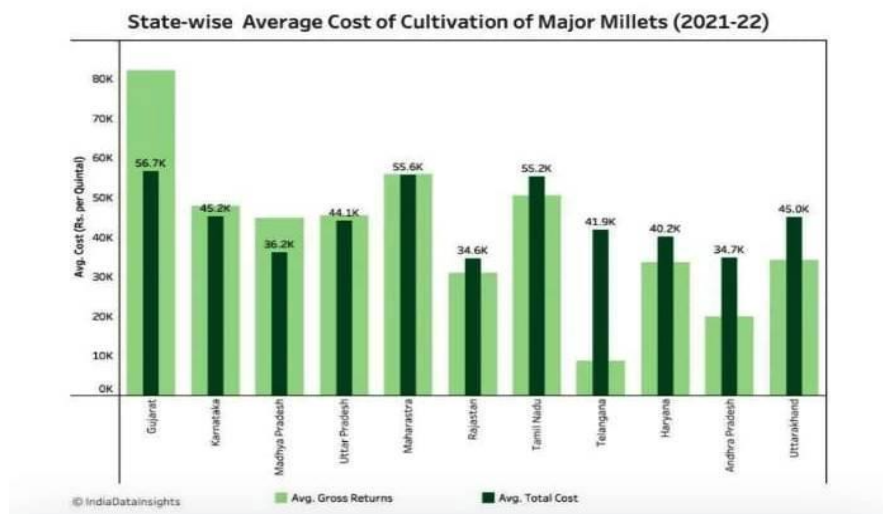
State-level data show that millet cultivation often yields low or negative monetary returns due to high input costs and weak market linkages (India Exim Bank, 2023; MoA&FW, 2023). Yet, their low water demand, minimal fertilizer needs, and resilience to erratic monsoons make them sustainable, risk-buffering crops for smallholders (FAO, 2023). Profitability is improving through rising MSPs for jowar, bajra, and ragi, along with “nutri-cereal” branding and urban demand, though in 2021-22 only Gujarat and Madhya Pradesh reported positive net returns (India Exim Bank, 2023).

Table 4
Cost of Cultivation and Net Returns of Major Millets in Selected Indian States (2021-22)

State	Cost of Cultivation (₹/ha)	Gross Returns (₹/ha)	Net Returns (₹/ha)
Gujarat	32,500	37,400	+4,900
Madhya Pradesh	30,800	34,100	+3,300
Rajasthan	33,200	30,900	-2,300
Maharashtra	34,500	31,600	-2,900
Karnataka	35,700	32,400	-3,300

Note. Figures are indicative averages compiled from India Exim Bank (2023) and MoA&FW (2023). Actual values vary with variety, input use, and market price.

Graph



In 2021-22, most states, barring Gujarat and Madhya-Pradesh, incurred losses cultivating millets.

VII CONCLUSION

Millets, among the earliest domesticated cereals, are nutritionally dense, climate-resilient, and culturally significant crops with renewed global relevance. Their adaptability to drought-prone, low-input systems makes them vital for smallholder farmers and sustainable agriculture. Despite India's position as the largest producer, productivity and profitability remain constrained by low yields, high input costs, and weak market linkages. Recent policy initiatives such as inclusion under the National Food Security Mission, increased MSPs, and promotion of the International Year of Millets reflect growing recognition of their potential. Strengthening seed systems, improving post-harvest and value-addition technologies, and expanding market access will be crucial to transform millets into modern "nutri-cereals." By integrating nutritional, agronomic, and economic dimensions, millets can play a pivotal role in addressing food security, climate resilience, and sustainable dietary transitions.

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Significances of Phytochemicals for better Human Health Care

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ABSTRACT

Phytochemicals are often considered as the link between the food and pharmaceuticals for the regulation of metabolic pathways in the living, significantly. Nowadays, food products that are naturally rich in such phytochemical compounds are also known as functional foods and nutraceuticals. Phytochemicals are bioactive components that help maintain and promote better growth. Current research has shown the medicinal properties of such phytochemicals is very important in the growth of living. Phytochemicals have various pharmacological effects on the body, such as anti-inflammatory, anti-allergic, antioxidant, antibacterial, antifungal, antispasmodic, anti-cancer, hepatoprotective, lipid-lowering, neuroprotective, blood pressure regulating, anti-aging, and protection against diabetes, osteoporosis, DNA damage, heart diseases, and UVB-induced cancer. They also strengthen the immune system, act as a diuretic, are pain-relieving, and aid in digestion. Phytochemicals are mainly classified into categories like phytoestrogens, terpenoids, carotenoids, limonoids, phytosterols, glucosinolates, polyphenols, flavonoids, isoflavonoids, and anthocyanidins. These biochemical compounds include various nutrients, dietary supplements, special diets, genetically modified foods, herbal products, and beverages. Most foods, such as whole grains, legumes, fruits, vegetables, and herbs, are rich in phytochemicals. Phytochemicals are formed during the normal metabolic process in plants. Their composition is complex in structural basis and depends on the nature of plant species. Higher plants store them as a reserve in the fruits or seeds found responsible for the various and effective medicinal properties. These medicinal effects are the result of the interaction of secondary metabolic products bio-synthesized in the plants. In the future, phytochemical-based drugs will play a significant role in the treatment of cancer, heart disease, diabetes, neurological disorders, and all other body-related diseases. Overall, phytochemicals not only act as protectors in our daily nutrition but are also a strong source of potential for the development of new and safe medicines. Future research on their bioavailability, molecular mechanisms, and synergistic effects will aid in the creation of evidence-based nutraceuticals and functional foods, strengthening global health management. Current study confirmed the significance of these phytochemicals during the routine consumption of various fruits and vegetables, which help us to live a long and disease-free life. Phytochemicals have bigger impact on our body healing against various microbial infections and physical disorders.

Keywords: Phytochemicals, Nutraceuticals, Pharmacological effect, Health, food, medicinal properties, Plants

I INTRODUCTION

Phytochemicals are naturally occurring compounds synthesized by plants and encompass various functional elements, including polyphenols, flavonoids, and vitamins. The majority of foods, including whole grains, beans, herbs, fruits, and vegetables, contain phytochemicals that are important for nutraceuticals. Consuming these physiologically active plant-derived ingredients has been linked to a lower risk of developing chronic illnesses such as coronary heart disease, osteoporosis, and cancer. Anti-inflammatory, antiallergic, antioxidant, antibacterial, antifungal, chemo-preventives, antiaging, and anti-

osteoporosis are some of the specific pharmacological effects they have on human health (Agrawal et al., 2023).

Phytochemicals are not essential nutrients and are not required by the human body for sustaining life, but have important properties to prevent or fight some common diseases. Because of this property, many studies have been undertaken to reveal the health benefits of phytochemicals. In this review, we provide an overview of the role of phytochemical compounds present in medicinal herbs in relation to disease management and human health (Dw, et al., 2016).

The common sugars, amino acids, chlorophylls, purines, and pyrimidines of proteins and nucleic acids are examples of phytochemicals categorized as primary constituents. Alkaloids, flavonoids, terpenes, phenolics, lignans, plant steroids, curcumins, saponins, and glucosides are among the other substances categorized as secondary constituents. Phenolics are thought to be the most prevalent of these secondary constituents, accounting for 45% of the secondary phytochemical constituents of plants, followed by terpenoids and steroids (27%), alkaloids (18%), and other substances (10%). Phytochemicals having great significances in the livings by regulating various metabolic pathways. They are the bioactive ingredients that preserve health and act as a link between the pharmaceutical and food sectors(Nwozo et al., 2023). These phytochemicals have enormous therapeutic potential for treating a variety of illnesses, either by themselves or in combination. Because they protect against a wide range of illnesses and conditions, including cancer, coronary heart disease, diabetes, high blood pressure, inflammation, microbial, viral, and parasitic infections, psychotic diseases, spasmodic conditions, ulcers, osteoporosis, and related disorders, phytochemicals with nutraceutical qualities found in food are extremely important (Prakash et al., 2012).

The physiological processes of photosynthesis, respiration, growth, and development in plants depend on primary metabolites. Secondary metabolites are specific phytochemicals that don't play direct roles. Secondary metabolites are important because they attract pollinators and shield plants from diseases and herbivore attacks. Flavors, dyes, fibers, glues, oils, waxes, pharmaceutical medications, and fragrances are just a few of the many uses for secondary metabolites (Wani et al., 2023). There is currently limited scientific data on how phytochemicals affect human health and the prevention of illness. To better understand the role of phytochemicals in human health and their potential in preventing chronic diseases, further research is needed(Yang & Ling, 2025).

III LITERATURE REVIEW

Medicinal plants provide all of their first medical treatment for more than 80% of individuals worldwide. Although some of these herbs are said to assist in the recovery of disease-causing substances, others are known to alleviate symptoms and so prevent secondary complications. pathogens and the production of anomalous cells. They also contain phytochemicals, including phenolic acids, stilbenes, lignans, tannins, terpenoids, alkaloids, flavonoids, phenolic acids, and lignans. Their chemical makeups are varied, and they have a wide range of medical applications. Hence, in the drug discovery and design process, these phytochemicals provide a qualified lead for the development of new medication compounds (Forni et al., 2019). Earlier studies also provide informations on the prevalence of phytochemicals and how they could be used to treat human diseases linked to them. oxidative stress, especially those where inflammatory cells are critical for the pathogenic pathways. For instance, their possible employment with DMARDs might be quite advantageous in minimizing side effects and being inexpensive. Moreover, influencing the rate at which new medications are created are socioeconomic variables. Along with this, there is increasing

interest in repurposing and reorienting antiquated drugs and other items regularly utilized in traditional medicine (Prakash et al., 2012).

According to the earlier citations, phytochemicals are widely used and could be utilized for treating illnesses affecting humans. Either alone or in combination, these phytochemicals have great medicinal promise for treating several diseases. For health claims, functional foods, and the presence of particular phytochemicals, the related health advantages are based in ethics and science. They have particular therapeutic effects on human health as anti-inflammatory, anti-allergic, antioxidants, antibacterial, antifungal, antispasmodic, chemo-preventives, hepato-protective, hypolipidemic, neuroprotective, hypotensive, antiaging, diabetes, osteoporosis, DNA damage, cancer, and heart diseases. Additionally, inducing apoptosis, diuretics, CNS stimulants, analgesics, guard against UVB-induced carcinogenesis, immunomodulators, and carminatives (Siddiqui et al., 2021).

The data reveal that *Tribulus terrestris*, *Glycyrrhiza glabra*, and *Smilax china* contain tannins, while all except *Curcuma amada* have saponins. Only *Glycyrrhiza glabra* had good anthocyanin along with *Smilax china* were the only species that showed least concentration. In contrast to *Glycyrrhiza glabra*, which only contained tannins and saponins, the extract of *Curcuma amada* contained all four of the targeted phytochemicals: saponin, reducing sugar, tannins, and anthocyanins. *Smilax china* only had tannins, reducing sugar, and saponin, whereas none of the desired phytochemicals were present as per (Li, 2023). According to studies on humans, different phytochemicals possess significant potential in the prevention and treatment of cancer. According to a study done in the United States, curcumin has potent anticancer properties against colon cancer since it causes programmed cell death, which improves the prognosis. Nanoparticulate systems improve the poor bioavailability of curcumin, and clinical studies have demonstrated its promise as a therapy.

III MATERIAL METHODS

- (a) **Sample collection** - Collected samples from Fresh plant material, such as leaves, fruit, seeds, and bark from authenticated sources. Samples were washed with distilled water, air-dried at 40- 50 degrees, and ground into fine powder.
- (b) **Solvent extraction in different fractions** - The extraction can take place in four steps: the solvent penetrates the matrix, the solute dissolves in the solvent, the solute diffuses out of the collection and purification of the extracted solutes; and matrix. The extraction process will be made easier by elements that increase the solubility and diffusivity at these stages. The efficiency of extraction is also influenced by the solvent properties, the ratio of solvent to solid, the size of the material particles, the length of the extraction, and the temperature of the extraction. The production of bioactive chemicals from plant materials has been increased by a number of techniques, such as ohmic heating, pulsed electric field, ultrasound, maceration, and enzyme digestion. microwave heating, extrusion, supercritical fluids, accelerated solvents, and other methods. Different plant components are extracted from the dried powder by the Universal Extraction System, which is used for solvent extraction. For a variety of reasons, the approach utilizes different solvents. Using the appropriate solvents like ethanol, water, acetone, chloroform etc. The procedure is carried out ten times for each extract while maintaining the temperature little below the boiling point of each extract. Phytoconstituents may be identified by filtering, concentrating, and utilizing the resultant solvent extract in a vacuum concentrator etc.

- (c) **Confirmation of desired Phytochemicals** - The study of complex mixtures benefits from both spectroscopic and chromatographic techniques; therefore, the process of phytochemical identification combines them. Based on their chemical characteristics, isolated and recognized through various chromatographic techniques, including thin-layer chromatography (TLC), gas chromatography (GC), and high-performance liquid chromatography (HPLC), which is frequently used as a first step in phytochemical analysis, HPLC has proven its utility in the high-resolution separation of complex mixtures.

Major Phytochemicals and Related Health Benefits

No.	Common phytochemicals	Sources	Health benefits	References
1	Polyphenols	Fruits, vegetables, tea, coffee, wine, grains, and seeds	Anti-inflammatory and antioxidant effects on cardiovascular, cancer, diabetes, and neurodegenerative disease	(Yang & Ling, 2025)
2	Tannins	Chocolate, black walnuts, red beans, berries, tea, and wines	Reduce the risk of cardiovascular disease,	(Arora & Suvartan, 2019)
3	Lycopene	Tomatoes, watermelon, pink grapefruit	Antioxidant, cardiovascular health	(Fernandez-Pan et al., 2024)
4	Lutein	Spinach, corn, egg, yolk	Antioxidant, vision health	(Eom et al., 2023)
5	α -carotene	Avocado, banana, mango, pumpkin, green bean, tangerine	Protects against lung and prostate cancer and eye health	(Kumar et al., 2023)
6	β -carotene	Sweet potatoes, carrots, spinach	Antioxidant, immune system support, and vision health	(Hossain et al., 2025)
7	Quercetin	Barries, apples, onion	Antioxidant, anti-inflammatory, cardiovascular health	(Xu et al., 2024)
8	Anthocyanidins and anthocyanins	Soybean, purple corn, blueberry, red grapes, red cabbage	Cardiovascular disease, inflammation, and allergies	(Kumar et al., 2023)
9	Xanthophylls	Papaya, pepper, mushroom, pumpkin	Antioxidant Properties, protect eye health and blood flow	(Kumar et al., 2023)
10	Saponins	Almond, black, bean, common bean	Antimicrobial and treatment of chronic disease	(Shakya, 2025)
11	Alkaloids	Barberry, goldenseal	Diabetes management anti-inflammatory	(Yang & Ling, 2025)

12	Phenolic acid	Coffee, whole grains	Cardiovascular disease, anti-inflammatory	(Yang & Ling, 2025)
13	Curcuminoids	Turmeric	Anti-inflammatory and antioxidant activity	(Peng et al., 2025)
14	Cellulose	Rice, wheat, sisal, jute, hemp, corn	Improves insulin sensitivity, gut microbial viability diversity, reduces the level of bad cholesterol, and reduces free radical damage to cells	(Kumar et al., 2023)
15	Pectin	Apples, cherries, oranges, carrots, apricots, citrus fruit, rose hips	Lower LDL cholesterol, cures diarrhea, promotes the generation of peripheral regulatory T cells	(Kumar et al., 2023)

IV OBSERVATIONS OF PHYTOCHEMICALS DURING CLINICAL TRIALS

The term "phytochemicals" in food science encompasses a variety of plant compounds with diverse structures that may have health-promoting effects. Phytonutrients are organic substances. They are not considered nutrients in the traditional sense because they are produced by plants during neither energy metabolism nor anabolic or catabolic metabolism. They are distinguished from main plant compounds because the plant does not need them. Since the phytochemicals are a natural source of these health-promoting compounds, they may present a better chance for creating fortified foods with these functional ingredients. However, the production of food products containing bioactive substances that promote and sustain health necessitates significant research and epidemiological investigations. In addition to shielding cells from oxidative damage, substances such as polyphenols, flavonoids, and carotenoids are also crucial in regulating antioxidant enzymes, such as superoxide dismutase (SOD) and catalase. Plant secondary metabolism includes chemicals that are present at low concentrations and often have pharmacological effects, acting as growth regulators and repellents to pests and the sun.

V RESULT AND DISCUSSION

Results obtained from the clinical trials are highly encouraging as per the earlier citations which have versatile effects on the Human health. The detailed results are underway and send to further confirmation by biochemical analysis. These effects have been used in naturopathy since ancient times in the form of therapeutic herbs, spices, teas, and meals. By neutralizing free radicals and reactive oxygen species (ROS), phytochemicals offer potent antioxidant properties that aid in preventing oxidative stress and cellular harm. By disrupting bacterial cell membranes, blocking bacterial enzymes, and interfering with bacterial DNA replication, phytochemicals have potent antibacterial activity. Because they help to combat bacterial illnesses, these processes are particularly helpful in the fight against bacteria that are resistant to antibiotics. Phytochemicals may have potential antitumor effects through processes like the

induction of apoptosis, inhibition of cell proliferation, and prevention of angiogenesis. These substances aid in cancer therapy and research by interfering with the signaling channels of cancerous cells. Phytochemicals, which are a potent class of compounds that are part of the secondary metabolism of plants, include a wide variety of chemical species, such as polyphenols, flavonoids, and flavonoids. vitamins, organosulphur substances, and steroidal saponins. As members of essential physiological processes such as reproduction, symbiotic interactions, and interactions with the environment and other species, they play significant roles in the growth of plants. Many of the red, orange, and yellow colors of flowers, leaves, and fruits are caused by carotenoids, which are potent antioxidants. The following subclasses belong to flavonoids: anthocyanidins, isoflavones, flavan3ols, flavanones, flavones, and flavonols. Researchers have paid attention to them due to their beneficial effects on a variety of illnesses. Another extremely big class of plant secondary metabolites are the terpenoids. Monoterpenes, sesquiterpenes, and diterpenes, which were taken from aromatic plants, were shown to have significant antioxidant activity in vitro. The creation of supplemental diets that are sold as capsules, tablets, powders, and liquid extracts depends heavily on phytochemicals. Bioavailability, stability, and convenience to the user are all factors to take into account when creating these medications. The tablet and capsule forms guarantee regulated dosages and simple storage for later use, while liquid extracts offer quick absorption.

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9. Payment Mode- DD/Cheque/RTGS as per following details
10. Enclose Following (Cross whichever not applicable)
DD No.....for Rs.....
Cheque No..... for Rs.....
RTGS Details.....
RTGS on Account no 3227002100050952 (Punjab National Bank IFSC Code- PUNB0655300)

Date:.....

Place:.....

Signature & Seal

Note- For prompt action please mail scanned copy of this form and DD/Cheque/RTGS details also on crig_agu@aisect.org

Send this format at University Address by post

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