

SACCHARUM OFFICINARUM L.: A COMPREHENSIVE REVIEW OF PHYTOCHEMISTRY, EXTRACTION, ISOLATION, PHARMACOLOGICAL ACTIVITIES, OMICS DATABASE AND NEUROPROTECTIVE POTENTIAL

Khushi Sharma¹, Akshay Sharma², Pooja Yadav³, Prashant Kumar⁴, Sudhir Kumar⁵, Amit Kumar Verma⁶, Kamal Kishore^{7*}

^{1,2,3,4,5,6,7*} Department of Pharmacy Mahatma Jyotiba Phule Rohilkhand University Bareilly, Uttar Pradesh., India, 243006

*Corresponding Author: Prof. Kamal Kishore, Email.id- kamalkbarilly@gmail.com

ABSTRACT

Saccharum officinarum L. (Sugarcane) is an important perennial grass that has been valued medicinally for a long time. In addition to its known industrial importance research has shown that it has a wide range of chemical components and health benefits. This review offers a look at the physical features of the plant how it has been used traditionally its chemical makeup, how to extract and isolate its components its health effects, its safety and the way it works at a molecular level. The plant has chemical substances such as phenolic acids, flavonoids, C-glycosyl flavones, terpenoids, alkaloids, saponins, tannins, steroids, coumarins and quinones. Some important substances found in the plant include acid derivatives, vitexin orientin iso-orientin ferulic acid and other similar compounds. Many different methods have been used to get and purify the parts of the plant. These include maceration, ultrasonic-assisted extraction, solid-phase extraction, solvent fractionation, soxhlet extraction and gel-filtration chromatography. The health effects that this review covers show that the plant has antioxidant, anti-inflammatory, kidney-protecting, urine-producing, anti-stone calming, and stimulating, brain-protecting, memory-enhancing, seizure-reducing and pain-relieving properties. Special attention has been given to the effects on the system and the possible role of flavonoids, phenolic acids and caffeoylquinic acid derivatives. This review also talks about the sugarcane genome and the latest progress in genome mapping, metabolomics, proteomics, RNA interference and genetic modification. These advances help us to understand the molecular mechanism behind the pharmacological effects shown by phytoconstituent of the plant.

KEYWORDS: *Saccharum Officinarum* L.; Phytochemical Profile; Pharmacological Activities; Neuroprotective Potential; Omics and Genome Analysis

1. INTRODUCTION

1.1. *Saccharum Officinarum* (Sugarcane)- Botanical Description

Officinarum Saccharum According to Ayurveda, linn is one of the primary therapeutic plants used in India's ancient medical systems. In the work Genus Plantarum, published in 1753, Linnaeus provided the first description of the species *Saccharum*. The name "Saccharum" comes from the Greek word "Sakcharon" which denotes sugar, especially sucrose. *Saccharum officinarum* L. is indigenous of the tropical south, India, and Southeast Asia [1]. India is the globe's second-largest producer of sugar cane, following Brazil. In tropical, hot and humid regions, it thrives on well-drained and initially fertile ground that has a somewhat basic pH [2]. Sugarcane, a well-known energy source, is a perennial grass of the Poaceae family. It is also known as chomping, Nobel cane, and wasteland weed [3]. Locals call it Kasi. The stems and leaves include lignin, proteins, carbs, and amino acids. The roots include polyphenolic chemicals and glucose [4].

The Sugarcane grows to a height of five metres (m), has a diameter of around five centimeters (cm), and produces new shoots by underground rhizomes. The plant features a fluffy, pinkish flower head and long, serrated leaves [4]. The fruit is a tiny, dry seed. The stem has a fibrous white inside that is packed with sugary sap and can be green, pinkish or purple. The elongated leaves, which can reach lengths of 30 to 60 cm and widths of roughly five cm, feature thick midribs and serrated edges. A panicle-shaped inflorescence up to 60 cm long, and tiny, dry fruits with a single seed are produced by the plant [5].

1.2. Traditional Uses

In addition to being used as a traditional treatment for diseases such as arthritis, ulcers, boils, malignancies, viruses, cough, diarrhoea, dry vision problems, fever, cramps, irritation, voice opacity, skin, sores, throat pain, spleen, tumors, and wounds, it additionally serves as an anti-inflammatory, bitter, antiseptic, fungicide, cardio fluid, stimulating, noxious substance, urinary stimulant, laxative, spleen, cooling fluid, and gastrointestinal [6,7].



Figure 1: *Saccharum Officinarum*

2. BIOLOGICAL CLASSIFICATION

Table 1: Taxonomical Classification of *Saccharum Officinarum* [8]

S.No.	Class	Names
1.	Family	Poaceae
2.	Kingdom	Plantae
3.	Sub-family	Panicoideae
4.	Order	Poales
5.	Tribe	Andropogoneae
6.	Sub- Tribe	Saccharinae
7.	Genus	Saccharum
8.	Species	<i>Saccharum officinarum</i>

The rich matrix of secondary metabolites revealed by *Saccharum officinarum* phytochemical profile is the basis for its medicinal uses in illnesses of the central nervous system (CNS). Alkaloids, terpenoids, saponins, and tannins are among the many bioactive groups the plant possesses; they have historically been linked to a variety of pharmacological effects [8].

3. PHYTOCHEMICAL PROFILE

3.1. Phytochemical Composition

The major phytochemical constituents present in sugarcane are phenolic compounds, flavonoids, alkaloids, terpenoids, saponins, tannins, steroids, coumarins, and quinones. There are several phenols in sugarcane leaves. Several chlorogenic acids have been identified by Liquid chromatography-mass spectrometry (LC/MS) without hydrolysis with high certainty, including isomers of feruloyl and caffeoyl quinic acid, with less free phenolic acid. The main flavonoids found in sugarcane leaves are vitexin, a C-glycoside of apigenin, and orientin and iso-orientin, C-glycosides of luteolin. Polyphenols can only be identified by comparing their absorption spectra to standards, which reduces the degree of identification confidence. As a result, the identification of tricetin and diosmetin derivatives is merely speculative. Free phenolic acids and many flavonoids were found in two studies, with values significantly greater than those reported in other publications. However, these studies lack MS identification; therefore, they are not conclusive [9].

Table 2: Phytochemical Profile of *Saccharum Officinarum*

Phytochemical Category	Specific Identified	Compounds	Detection Method	Significance Activity	Biological	References
Phenolic Acids	Isomers of Feruloyl & Caffeoyl quinic acid (Chlorogenic acids)		LC/MS (High certainty without hydrolysis)	Strong antioxidant, Potential neuroprotective agent		[2]

Flavonoids glycosides)	(C-	Vitexin Orientin (Luteolin-based)	(Apigenin-based), & Iso-orientin	Standardized identification	MS	Precursors to CNS modulation, Antidepressant-like activity	[2]
Flavone Derivatives		Tricin and derivatives	Diosmetin	Speculative (Based on absorption spectra only)		Known for anti-inflammatory and Anti-cancer properties	[2]
Polyphenols (General)		Various identified absorption spectra	via	Moderate (Requires comparison to standards)	General scavenging	free radical	[2]
Secondary Metabolites		Alkaloids, Saponins, Coumarins, Quinones	Terpenoids, Tannins, Steroids,	Qualitative phytochemical Screening	Diverse potential Anxiolytic)	pharmacological (Antimicrobial,	[1]

➤ **The flavonoids profile is dominated by C-glycosides, specifically:**
 Orientin and iso-orientin are derivatives of luteolin, whereas vitexin is a derivative of apigenin. They have been demonstrated to alter dopaminergic and Gamma-aminobutyric acid pathways, which are directly related to the treatment of anxiety and depression.

Table 3: Identification and Functional Profile of Secondary Metabolites

Compound Class	Primary Markers	Identification Confidence	Role in Depression/CNS	References
C-Glycosyl Flavones	Vitexin, Orientin	High (LC/MS)	Neurotransmission modulation	[10]
Chlorogenic Acids	Feruloyl quinic acid	High (LC/MS)	Reduction of oxidative stress	[11]
Methylated Flavones	Tricin, Diosmetin	Low (Speculative)	Potential inflammatory anti-	[12]

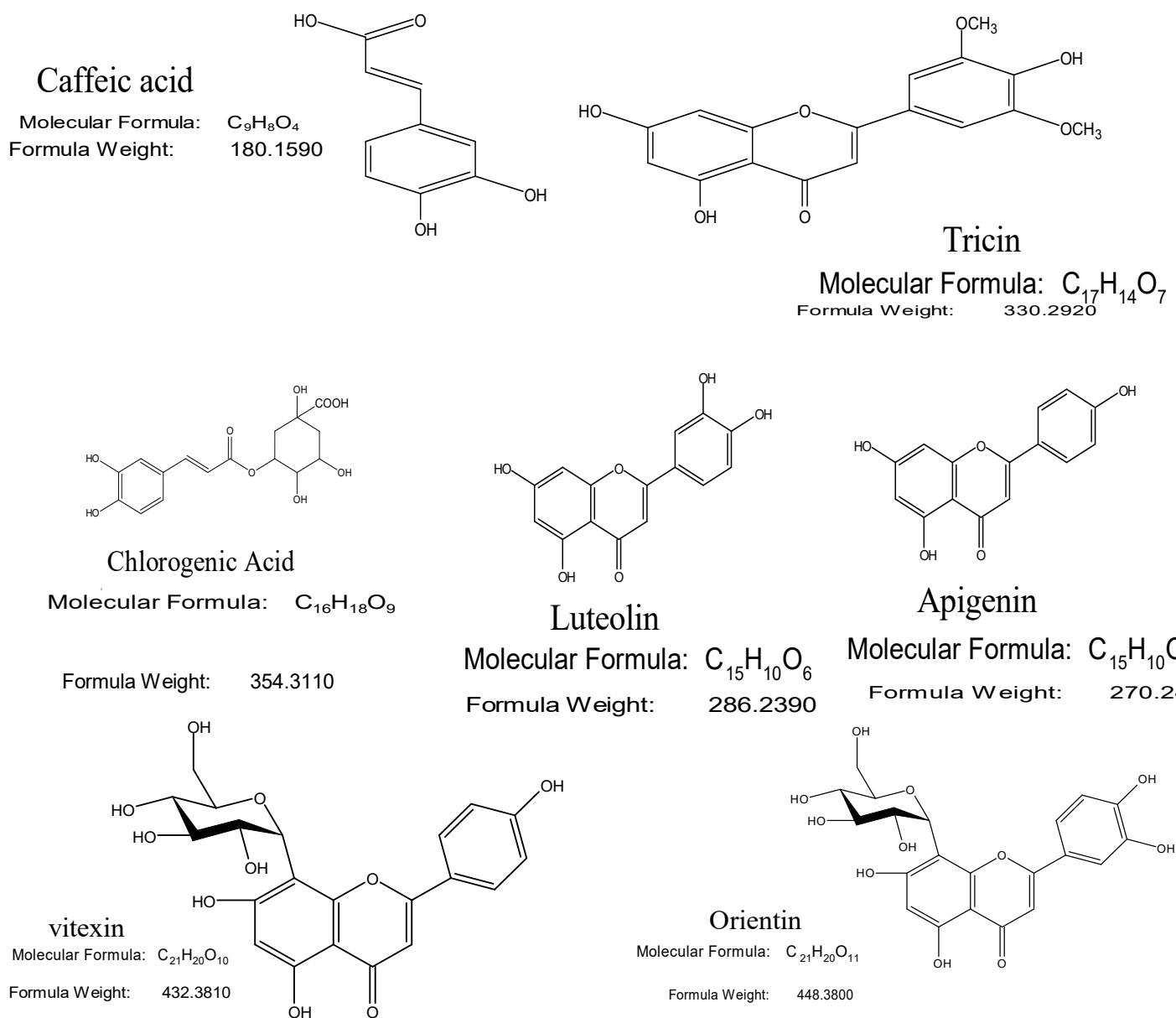


Figure 2: Structure of Chemical Compound in Phytochemical Profile

4. EXTRACTION TECHNIQUES

The most popular method for pharmacological research is to extract bioactive Policosanols from the wax or make a Sugarcane Top Ethanolic Extract (STEE).

4.1. Maceration

To collect a wide spectrum of polyphenols, milled plant parts (usually the “top” or leaves) are extracted for up to two weeks using a mixture of ethanol and water (e.g., 70:30 v/v) [13].

4.2. Ultrasonic-Assisted Extraction (UAE)

This contemporary method sonicates ethanol that has been acidified (e.g., 60% ethanol with 1.6 M HCl) for about half an hour. According to Azlan.A, *et al.* (2023), it is quite successful at raising the production of flavonoids and total phenolics [13].

4.3. Solid-Phase Extraction (SPE)

Utilized for additional purification, in which particular phenolic fractions are isolated by passing crude extracts through polyamide columns and eluting them with methanol or methanol/ammonia [14].

4.4. Fractionation

Low-molecular-weight polyphenols such as quercetin and p-coumaric acid are frequently concentrated by partitioning standard ethanol extracts (50–60%) with ethyl acetate [15].

Table 4: Extraction and Purification Techniques of *Saccharum Officinarum*

Technique	Conditions/Description Supplied Source	in	Purpose	References
Maceration	70:30 ethanol-water, up to two weeks		Broad extraction of polyphenols	[13]
Ultrasonic-Assisted Extraction	Acidified ethanol; example 60% ethanol with HCl		Increase flavonoid and Total phenolic recovery	[14]
Solid-Phase Extraction	Polyamide columns, Methanol		Further purification of phenolic fractions	[14]
Fractionation	Partitioning ethanol with ethyl acetate	extracts	Concentration of lower-molecular-weight polyphenols	[15]

5. ISOLATION TECHNIQUES

Bioactive constituents of *Saccharum officinarum* can be isolated and purified using several chromatographic and solvent-based techniques. Solid-phase extraction (SPE) using polyamide columns with methanol or methanol/ammonia elution is employed for purification of phenolic fractions, while solvent fractionation with ethyl acetate concentrates low-molecular-weight polyphenols such as quercetin and p-coumaric acid. Gel-filtration chromatography using Bio-Gel P-2 has been used for isolation of tricin and Schaftoside from molasses. Soxhlet extraction with methanol has been reported for obtaining flavonoids glycosides from stems, whereas acidified methanol extraction can recover anthocyanins from sugarcane peel [16, 17, 18, 19].

Table 5: Isolation and Purification Techniques of *Saccharum Officinarum* Bioactive Compounds

Technique	Conditions / Method	Target compounds / Fraction	Purpose	References
Solid-Phase Extraction (SPE)	Crude extract passed through polyamide columns, followed by elution with methanol or methanol/ammonia	Phenolic fractions and Policosanols	Purification and Concentration of bioactive compounds	[16]
Solvent Fractionation	Ethanol extract (50–60%) partitioned with ethyl acetate	Low-molecular-weight polyphenols such as quercetin and p-coumaric acid	Concentration of specific polyphenolic compounds	[17]
Ultrasonic-Assisted Extraction (UAE)	Acidified ethanol, e.g. 60% ethanol + HCl, approximately 30 min	Flavonoids and Phenolic compounds	Improved recovery of phenolics and Flavonoids	[18]
Gel-Filtration Chromatography	Bio-Gel P-2 column	Tricin and Schaftoside from molasses	Separation/Purification of bioactive compounds	[19]

Soxhlet Extraction	Methanol extraction of sugarcane stems	Flavonoid glycosides	Isolation of CNS-active flavonoids fractions	[19]
Acidified Methanol Extraction	Methanol containing approximately 1% HCl	Anthocyanins from peel	Recovery of anthocyanins-rich fractions	[19]

Table 6: Bioactive fractions and their pharmacological targets

Plant Part	Extraction/Isolation Technique	Isolated Bioactives	CNS/Non-CNS Activity	Pharmacological Mechanism	References
Tops/Leaves	UAE / 70% Ethanol	3-CQA, 5-CQA, Isoorientin	CNS	Enhances neurogenesis and PGC-alpha expression, antidepressant-like effect.	[20]
Wax	SPE / n-Hexane	Policosanols (Octacosanol)	CNS and Non-CNS	Modulates ACh release (CNS), Antihyperlipidemic (Non-CNS).	[20]
Molasses	Gel filtration / Bio-Gel P-2	Tricin, Schaftoside	Non-CNS	Alpha-glucosidase inhibition, potent antioxidant.	[20]
Stems	Soxhlet / Methanol	Flavonoid Glycosides	CNS	Mild anti-psychotic and Amnesic effects in mice.	[21]
Peel	Acidified methanol (1% HCl)	Anthocyanins	Non-CNS	Antiproliferative activity against HT29 cell lines.	[21]

6. TOXICITY AND SAFETY PROFILE OF THE PLANT

In the prior examined literature, the acute ingestion of the water-based extract of the root *Saccharum officinarum* L. (Poaceae) leaves was found to be ineffective when given orally to rats at doses of 300 mg/kg of body weight and 2000 mg/kg body weight, as recommended by the World Organisation for Economic Cooperation and Development guideline 423. However, mice whose work receives a dosage of 2000 mg/kg of body weight should not eat for at least half an hour before returning to their usual condition. Mice with dilated eyes, shaking hands, and tremors had a sedative effect at a dosage of 6000 mg/kg body weight, and they mostly perished after their second session [22].

7. PHARMACOLOGICAL ACTIVITIES

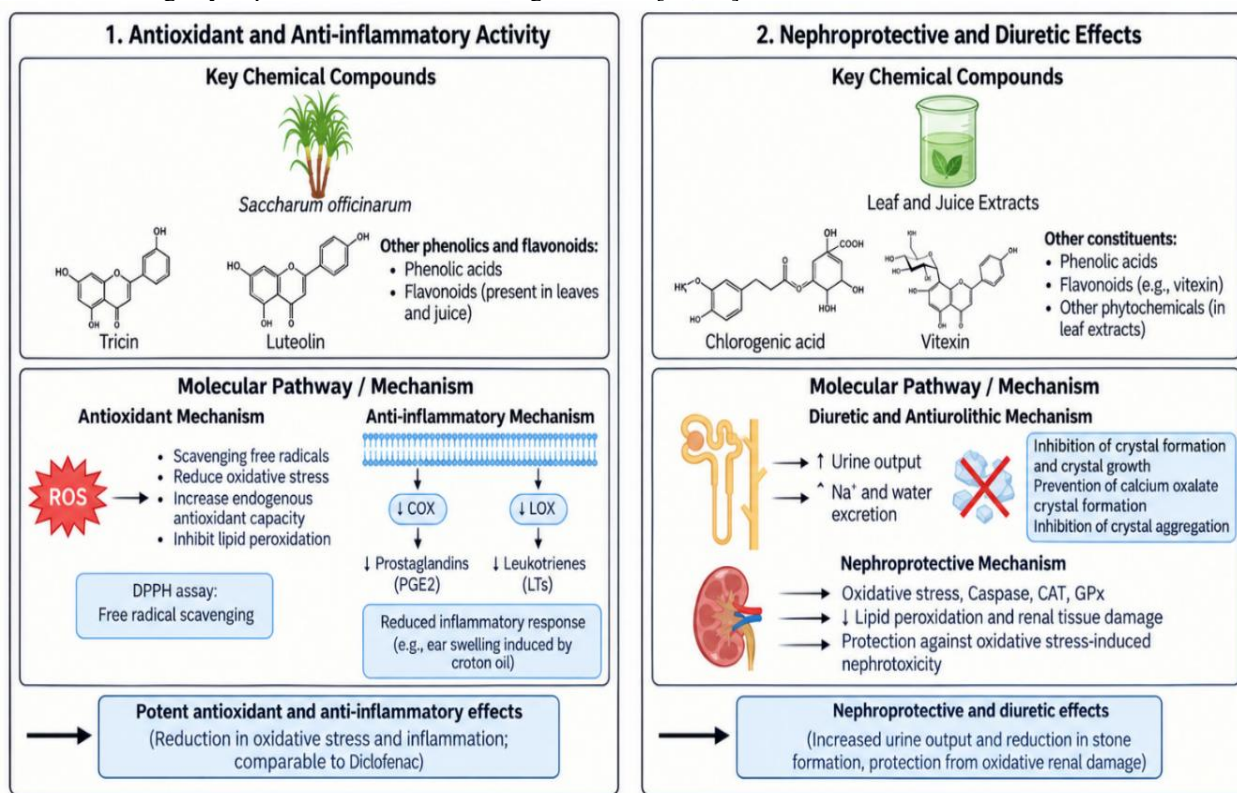
7.1. Non-CNS Pharmacological Activities

1. Antioxidant and Anti-inflammatory Activity

High levels of phenolic acids and flavonoids (such as triclin and luteolin) are found in the leaves and juice of *Saccharum Officinarum*. As shown by 2,2-diphenyl-1-picrylhydrazyl (DPPH) and hyaluronidase inhibition tests, these components scavenge free radicals. Carrageenan-induced paw edema is significantly reduced by the anti-inflammatory impact, which is frequently compared to common medications like Diclofenac [23].

2. Nephroprotective and Diuretic Effects

The ethanolic extract of sugarcane leaves was recorded for showing strong diuretic and antiurolithiatic activity. The phytochemicals present in extract were showing action by preventing calcium oxalate from crystallizing and promoting the excretion of water and salt. According to Dewi *et al.* (2024), it also prevents renal tissue from oxidative damage by nephrotoxic substances like gentamicin [21, 23].



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Figure 3: Non-CNS pharmacological Activities of *Saccharum Officinarium*

7.2. CNS Pharmacological Activities

7.2.1. Anxiolytic-like Effects

The aqueous and ethanolic extract of sugarcane leaves have the property of showing psychostimulant and anxiolytic effects by interacting with dopaminergic pathways, according to preclinical research conducted on rat models (such as the Elevated plus maze and Open field tests). Certain phytochemicals have been found to pass the blood-brain barrier and alter neurotransmitters linked to mood and emotional regulation, including ferulic acid and vitexin [24].

7.2.2. Neuroprotective and Cognitive Enhancement

Extracts from the top of Sugarcane have shown promise in the treatment of age-related cognitive impairment. Strong antioxidants called caffeinylquinic acid (CQA) derivatives are abundant in the plant. These substances may have a preventive effect against neurodegenerative diseases including Alzheimer's and Parkinson's disease because they improve mitochondrial energy metabolism (ATP generation) and prevent amyloid-beta aggregation [13, 24].

3. Anticonvulsant and Analgesic Activities

Sugarcane leaf extracts have demonstrated central nervous system inhibitory activities that result in analgesic and anticonvulsant effects. Its capacity to increase pain threshold is confirmed by studies employing mice's tail-flick and benzoyl peroxide-induced writhing tests; this is most likely due to the manipulation of opioid or prostaglandin-related pathways [3, 24].

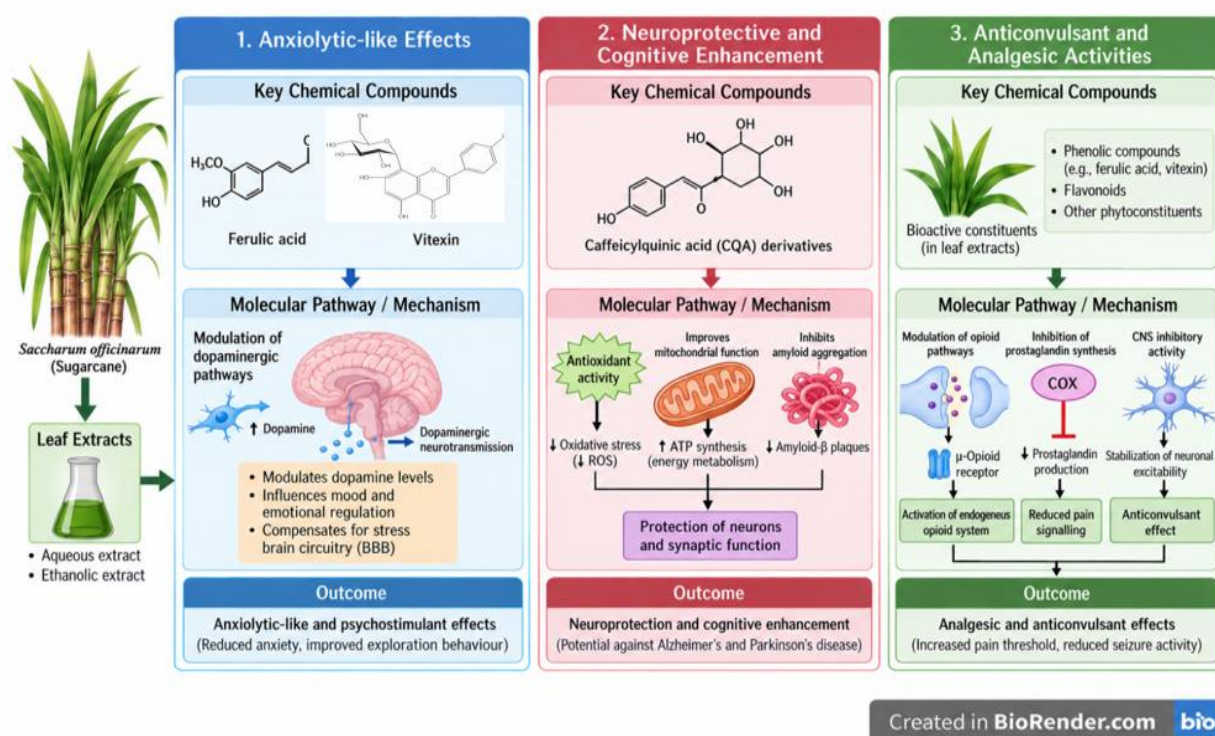


Figure 4: CNS Pharmacological Activities of *Saccharum officinarum*

Table 7: Pharmacological Activities of *Saccharum officinarum* (CNS and Non-CNS)

Activity Type	Targeted Effect	Plant Part Used	Key Phytoconstituents	References
CNS	Anxiolytic and Psychostimulant	Leaves	Vitexin, Ferulic acid	[24]
CNS	Neuroprotective	Top/Leaves	Caffeoylquinic acid	[24, 13]
CNS	Anticonvulsant	Leaves	Flavonoids, Glycosides	[24, 3]
Non-CNS	Anti-inflammatory	Juice / Leaves	Tricin, Luteolin	[23]
Non-CNS	Nephroprotective	Leaves	Polyphenols, Tannins	[21]
Non-CNS	Anti-hyperlipidemic	Wax / Stalk	-	[25, 26]

Non-CNS	Antioxidant	Leaves/Juice	Phenolic Anthocyanins	acids, [25, 26]
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8. THE SUGARCANE GENOME

8.1. Genome Sequencing in Sugarcane

Genome sequencing is one approach to studying genetic and other traits of sugarcane. Sequencing the sugarcane genome is difficult due to its size and polyploidy, as there are several homoeologous genes. The cultivar genome is thought to be approximately 10 gigabases in size and more complex than other sequenced crop genomes. International initiatives such as SUGESI have been launched to help with genome sequencing of sugarcane and other genome-related projects [27, 28].

8.2. Genotype

The R570 cultivar has been a model for sugarcane genome sequencing because of available information and resources about this cultivar, such as genetic maps, BAC libraries, and previous sequence assemblies. Recent publications include a reference sequence of 8.72 Gb for R570. Knowledge of the large-scale organization and haplotypes in the R570 genome and its origins from sugarcane and *Saccharum Spontaneum* has been gained using these data. Information about the parents, *Saccharum Officinarum* LA Purple and *Saccharum Spontaneum*, has been useful for other studies of the R570 genome sequence. Knowledge of the chromosome segments inherited from each parent has been useful. Other chromosome-scale genome sequences have been reported for LA Purple, *Saccharum Spontaneum*, R570, and SP80-3280. These sequences provide information about the genome structure and evolution of modern cultivated sugarcane [27, 28]. Genome sequences of other cultivars, including SP80-3280 and Q165, have been published and used for comparative studies to learn more about structural variation among sugarcane germplasm [29].

9. SUGARCANE METABOLOMICS AND PROTEOMICS

9.1. The Sugarcane Metabolome

Metabolomics provides a tool for studying the system in relationship to sugar storage in sugarcane. Metabolomic studies provide information about carbon flow and other metabolic processes in sugarcane. Combined transcriptomic and metabolomic studies have identified compounds and pathways involved in sugar and other processes in sugarcane. These studies demonstrate the usefulness of metabolomics in studying other traits in sugarcane [30]. Studies observing sugarcane development over time show decreasing glucose and fructose levels in sugarcane tissue as sugar accumulates and changes in other compounds, including acids and amino acids, based on the sugarcane variety [31]. Other recent reviews note the importance of sugar sensing, transport, and breakdown in carbon partitioning and storage in the sugarcane stem. Recent studies using targeted metabolomics and other omics data have compared different sugarcane varieties to identify important compounds for sugar storage and other traits. Advances in metabolomics research, including combined transcriptomics and proteomics studies, offer more detailed knowledge of carbon allocation and storage in sugarcane [32].

9.2. The Sugarcane Proteome

When compared with transcriptomics experimental work on the sugarcane proteome has historically been more limited. However, advances in proteomics are now increasingly allowing analysis of protein abundance and post-translational modifications. Recent proteomic studies have found proteins that are linked to carbohydrate metabolism, energy production, antioxidant defense, cell wall metabolism and stress responses in sugarcane showing how useful proteomics is for understanding traits. Dynamic proteome and acetylome profiling has recently found seventy-three proteins that show both changes in abundance and changes in acetylation during accumulation. This highlights proteins that are involved in metabolic regulation and points to targets for improving sugar content. Proteomic analyses have also been used to study enzymes that're part of sucrose metabolism. A recent nano-LC-MS/MS study showed that changes, in the abundance of synthase sucrose phosphate phosphatase, sucrose synthase and several invertase isoforms were linked to altered sucrose metabolism in sugarcane stalks. These findings show how proteomic and multi-omics approaches can complement data by giving information at the protein and post-translational level and can help find candidate regulators of accumulation and other important sugarcane traits [33].

9.3. Silencing and Over-expression of Endogenous Genes of Sugarcane

Gene silencing is really helpful in polyploid sugarcane because RNA interference (RNAi) can lower the activity of alleles or similar gene copies. This makes it a great tool for studying genes in this crop. RNAi works by introducing or creating stranded RNA (dsRNA). This dsRNA is then broken down into interfering RNAs that help destroy matching mRNA. The success of RNAi in sugarcane was shown by focusing on the phytoene desaturase (PDS) gene. When RNAi reduced the activity of PDS it caused a change in color proving that it works for studying genes. More recent research has used RNAi in sugarcane to look at genes involved in making lignin moving sugar around building up oil in the plant and making cell walls harder to break down. This shows that RNAi is still very useful for understanding genes and improving the plant. Another way to study genes is by making them work

harder. This is called over-expression. Scientists have used this to look at genes involved in dealing with stress making sugar building up plant material and other important traits, in sugarcane. Since it takes a time to change sugarcane plants and see what happens other systems and lab methods can help test ideas before trying them in real plants [34].

9.4. Precision Engineering: Mini-chromosomes and Zinc-finger Nucleases

Precision engineering offers ways to improve the genetics of polyploid sugarcane. Engineered mini-chromosomes that carry centromere and telomere parts can act as platforms to stack several genes together and pass them on independently. So far using mini-chromosomes in real plants is mainly still in research and trial phases. These chromosome- engineering methods might let us put new traits into complex crop genomes at once [35]. Site- specific genome- editing tools, such as zinc- finger nucleases (ZFNs) TALENs and CRISPR/ Cas systems give us chances to change the genome in places. In sugarcane recent reviews show that ZFNs have not been shown experimentally often as TALENs and CRISPR methods. Also, because sugarcane has genome copies, we face a hard task of changing many similar or related gene copies. Because of this recent sugarcane studies are turning more to multiplex CRISPR/ Cas editing. Multiplex CRISPR/ Cas editing can change alleles, at once and looks very promising for precise improvement of polyploid sugarcane [36, 37, 38].

10. CONCLUSION

Sugarcane is a type of grass that grows for years and plays a role in the economy. Its importance goes beyond just being food or something used in factories. This review gathers all the facts about sugarcane. It covers the plant's features, how it has been used in the past, the chemicals it contains, how to get those chemicals out, the health benefits, how safe it is, and the newest research using science and technology. Research shows that every part of sugarcane has chemicals. These include kinds of acids, flavonoids, C-glycosyl flavones, terpenoids, alkaloids, saponins, tannins, steroids, coumarins, and quinones. Scientists are especially interested in acid derivatives, vitexin orientin, iso-orientin ferulic acid, and similar substances because they can act as antioxidants and may affect the brain. The review shows that the way sugarcane is processed affects how much of these chemicals can be collected. Methods such as maceration, ultrasonic-assisted extraction, solid-phase extraction, solvent fractionation, Soxhlet extraction, and gel filtration chromatography are used to collect or strengthen compounds like flavonoids, policosanols, anthocyanins, and similar groups. Choosing the part of the plant, the correct liquid, the right conditions, and the proper steps for cleaning up the chemicals is very important. This helps make products that're the same each time. Studies show that sugarcane has effects on the body. Outside the body, it can act as an antioxidant, reduce swelling, protect the kidneys, help with urine flow, and stop kidney stones. For brain research, sugarcane has been found to reduce signs of anxiety, act like a stimulant, protect nerve cells, help with memory, stop seizures, and reduce pain. Many of the health benefits of *Saccharum officinarum* L. are due to components such as flavonoids, phenylpropanoids, and caffeoylquinic acid derivatives. Beneficial and other properties of sugarcane warrant further investigation of its components as potential treatments for neurological diseases. Limitations of the current research on sugarcane include a lack of human studies and identification of specific components responsible for reported benefits. Information on the safety of aqueous preparations of sugarcane indicates that they have been studied for safety outcomes. However, data are limited, and adverse effects can occur at high doses. Additional studies are needed to evaluate the safety of sugarcane for medicinal use. The review highlights advances in scientific techniques applied to research on sugarcane. Genomic analysis reveals a highly repetitive genome in *Saccharum officinarum* L. Studies of chemical and protein components provide insights into sugar production processes and other traits in sugarcane. Other scientific techniques, including RNA interference and genome editing methods such as CRISPR/Cas9, can be applied to basic and applied research on sugarcane. In summary, *Saccharum officinarum* L. contains a range of potentially useful chemical components. An interdisciplinary approach to basic and applied research on sugarcane, including chemical and medical research and the application of scientific techniques, can increase understanding of *Saccharum officinarum* L. and support evidence-based medicinal uses of its chemical components. An interdisciplinary approach can help link chemical findings to reported health outcomes and other effects and support additional research using commercial sugarcane products.

11. FUTURE PERSPECTIVE

Future research on *Saccharum officinarum* should focus on improving the quality and standardization of bioactive preparations. Variations in *Saccharum officinarum* species or cultivars and other factors, such as the plant part and growing and harvesting conditions used to produce *Saccharum officinarum* extracts, may affect their chemical composition. Analytical methods, including chromatographic and spectroscopic techniques, can be used to identify and quantify compounds, including caffeoylquinic acids, vitexin, orientin, iso orientin, ferulic acid, and other phenolic compounds, found in *Saccharum officinarum*. Further studies are needed to understand the mechanisms of reported central nervous system effects, such as anxiolytic and neuroprotective effects. Preclinical studies to explore mechanisms, such as those affecting neurotransmitter systems, oxidative stress, neuroinflammation, and mitochondria, using multiple models are warranted. Additional studies are needed to evaluate the absorption, distribution, metabolism, and concentrations of active compounds in the brain. Studies to evaluate potential safety risks, including those related to repeated dosing, genetic damage, reproduction, and drug interactions, are also necessary. Bioassay guided fractionation and comparative studies may help distinguish

individual compound effects from effects of multiple compounds in complex extracts. Use of metabolomic, proteomic, transcriptomic, and genomic analyzes in combination with pharmacologic analyzes may help identify biomarkers and other targets. Functional genomic techniques, including RNA interference and multiplex genome editing, may be useful in identifying genes related to phenotypic traits. Ultimately, standardized preclinical and clinical research studies will be needed to explore therapeutic and other uses of products derived from *Saccharum officinarum*.

12. ABBREVIATION

Ach- Acetylcholine
 ATP- Adenosine Triphosphate
 BAC- Bacterial Artificial Chromosome
 CNS- Central Nervous System
 CQA- Caffeoylquinic Acid
 GABA- Gamma-Aminobutyric Acid
 HCl- Hydrochloric Acid
 HT29- Human Colorectal Adenocarcinoma Cell Line
 LC/MS- Liquid Chromatography–Mass Spectrometry
 MS- Mass Spectrometry
 OECD- Organization for Economic Co-operation and Development
 PDS- Phytoene Desaturase
 PGC- α -Peroxisome Proliferator-Activated Receptor Gamma Coactivator 1-alpha
 RNAi - RNA Interference
 SAMP8- Senescence-Accelerated Mouse Prone 8
 SPE- Solid-Phase Extraction
 TALENs- Transcription Activator-Like Effector Nucleases
 UAE- Ultrasonic-Assisted Extraction
 ZFNs- Zinc-Finger Nucleases

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14. AUTHORS CONTRIBUTION: All authors made substantial contributions to conception and design, acquisition of data, or analysis and interpretation of data; took part in drafting the article or revising it critically for important intellectual content; agreed to submit to the current journal; gave final approval of the version to be published; and agree to be accountable for all aspects of the work. All the authors are eligible to be author as per the International Committee of Medical Journal Editors (ICMJE) requirements/guidelines.

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16. CONFLICTS OF INTEREST

There are no conflicts of interest.

17. ETHICAL APPROVALS

This study does not involve experiments on animals or human subjects.

18. DATA AVAILABILITY

All the data is available with the authors and shall be provided upon request.

19. USE OF ARTIFICIAL INTELLIGENCE (AI) ASSISTED TECHNOLOGY

The authors declare that they have not used artificial intelligence (AI) tools for writing and editing of the manuscript, and no images were manipulated using AI.

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