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Review Article

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Exploring the Phytochemistry and Anticancer Properties of *Cassia occidentalis* Linn: A Comprehensive Study

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Abstract

This study delves into the phytochemistry and anticancer properties of Cassia occidentalis Linn., highlighting its potential as a source of novel therapeutic agents. The research revealed the presence of several bioactive compounds, including steroids, alkaloids, phenols, flavonoids, saponins, tannins, and amino acids. Quantitative analysis demonstrated a particularly high concentration of flavonoids in the flowers, measured at X mg/g, while the leaves exhibited lower levels of alkaloids, recorded at Y mg/g. Essential minerals such as potassium, phosphorus, sulfur, and calcium were also detected in both leaves and flowers, further contributing to the plant's medicinal value.

To obtain these results, a series of techniques were employed, including morphological assessment, organoleptic evaluation, and fluorescence analysis. These methods were used to confirm the presence of key phytochemicals in powdered leaf and flower samples, which were extracted using aqueous, ethanol, and petroleum ether solvents. The qualitative and quantitative analyses provided a comprehensive profile of the bioactive compounds present in *C. occidentalis*.

The findings of this study underscore the significant potential of *C. occidentalis* in cancer treatment, particularly due to its high flavonoid content, known for its strong antioxidant and anticancer properties. The diverse range of phytochemicals identified in this plant suggests it could serve as a valuable resource for the development of new anticancer therapies. The study not only provides a foundational understanding of the phytochemical composition of *C. occidentalis* but also sets the stage for future research focused on isolating and characterizing these bioactive compounds. By doing so, it may be possible to fully elucidate their mechanisms of action and maximize their therapeutic efficacy in modern medicine.

Keywords: *Casia occidentalis*; Phytochemistry; Anticancer Properties; Flavonoids; Alkaloids; Phenols; Saponins; Tannins; Anthraquinones; Amino Acids; Essential Minerals; Traditional Medicine; Fluorescence Analysis; Crude Extracts; Therapeutic Applications

Abbreviations

WHO: World Health Organization; SOD: Superoxide Dismutase; TDW: Triple Distilled Water; GAE: Gallic Acid Equivalents.

Introduction

Phytochemical"s are a diverse group of naturally occurring compounds found in plants, known for their significant role in disease prevention. They are abundant in fruits, vegetables, beans, cereals, and plant-based beverages like tea and wine. These compounds are categorized based on their chemical structures into groups such as tannins, flavonoids, glycosides, saponins, alkaloids, triterpenoids, and sterols [1].

For centuries, plants have served as valuable sources of natural products essential for maintaining human health. In recent decades, the interest in natural therapies has surged, with more intensive studies conducted on these medicinal plants. Approximately 80% of individuals in developing countries rely on traditional medicine, including plant-derived compounds [2]. These plants offer new, safe, biodegradable, and renewable drugs, reinforcing their historical role in therapeutic applications [3].

Early civilizations utilized plants for therapeutic purposes without scientific explanations. However, there is now a heightened awareness of the importance of medicinal plants, as recognized by the World Health Organization (WHO) in various resource-poor nations [4]. This recognition has spurred efforts to document medicinal plants and their uses [5]. Given their potential, it is crucial to investigate these plants to better understand their properties, safety, and efficacy. The high cost of modern pharmaceuticals has searched for affordable antimicrobial substances in nature essential, with plants offering a promising source [6].

Cassia occidentalis L.: An Overview

Cassia occidentalis L. is an annual or perennial plant widely recognized for its use in traditional medicine to treat various diseases. This spiny herb thrives across India, both in shaded and open conditions, growing up to an altitude of 1,000 meters in the Himalayas. It is commonly found in wastelands, coastal areas, and deltaic regions throughout the plains of western, eastern, and southern India [7]. Beyond India, *C. occidentalis* is prevalent in Burma and Sri Laka and is also cultivated as an ornamental plant due to its aesthetic appeal [8].

Known by various regional and vernacular names, *C. occidentalis* is referred to as Badikasondi, Chakunda, or Kasonda in Hindi; Coffee Senna, Negro Coffee, or Stinking Weed in English; Kasamarda in Sanskrit; and Kasonji in Urdu. The diversity of names across different languages and regions reflects the widespread recognition and use of this plant in traditional medicine practices.

Ethnobotanical and Nutraceutical Potential of *Cassia occidentalis*

This review compiles the ethnobotanical and nutraceutical potential of Cassia occidentalis, focusing on its food and medicinal applications. A comprehensive baseline survey was conducted from 2011 to 2015, gathering information through semi-structured interviews and discussions with local healers, elderly individuals, and experienced community members. Extensive literature on *C. occidentalis* was also reviewed through online databases like Scopus and Google Scholar, covering the period from 1965 to 2015.

Distribution and Botanical Description

C. occidentalis is a spiny herb that grows extensively throughout India, thriving in both shaded and open conditions, and is prevalent in the deltaic regions of western, eastern, and southern India. Beyond its medicinal and nutritional uses, it is also grown as an ornamental plant due to its attractive appearance.

The plant has several distinctive botanical characteristics:
Leaves: Evergreen, lanceolate, compound, with a glossy surface.
Root System: Deep taproot.
Stem: Hard and woody.
Seeds: Dicotyledonous, with a characteristic odor and bitter taste.
Flowers: Yellow, 1 to 2 cm in diameter, arranged in raceme-type inflorescences.
Fruits: Flat pods, 10-12 cm long, containing 10-30 seeds.

These features aid in identifying *C. occidentalis* and understanding its adaptability to various environments. The plant's comprehensive distribution and diverse applications underline its significance in traditional medicine and potential nutraceutical use.

Pharmacognostic Details and Chemical Constituents

Cassia occidentalis contains a wide array of phytochemicals, including anthraquinones, flavonoids, triterpenoids, and other compounds like essential oils and tannins. The phytochemical composition varies significantly depending on geographic location. For example, plants from the Ivory Coast contain small amounts of saponins and no alkaloids, while those from Ethiopia have been found to contain large amounts of alkaloids in the stems, leaves, and fruits.

Integrating Recent Studies and Highlighting Anticancer Potential

Recent studies have focused on the anticancer properties of *Cassia occidentalis*, building on its traditional uses. The presence of bioactive compounds such as flavonoids, known for their strong antioxidant and anticancer properties, underscores the plant's potential in modern therapeutic applications. Given the growing interest in natural therapies, exploring *C. occidentalis* for its anticancer properties is crucial. This plant holds promise as a source for developing new, effective cancer treatments, linking traditional knowledge with modern scientific research.

Traditional and Modern Uses

Cassia occidentalis has been utilized in traditional medicine for centuries, particularly in Ayurveda and other indigenous healing systems, to treat a wide range of ailments such as skin diseases, fevers, respiratory issues, and gastrointestinal disorders. The plant's leaves, roots, and seeds are commonly used in decoctions, infusions, and topical applications.

Correlation Between Traditional Uses and Modern Findings

Recent scientific studies have begun to validate the traditional uses of *C. occidentalis* by identifying its rich phytochemical profile, which includes flavonoids, anthraquinones, alkaloids, and tannins. These bioactive compounds have been found to possess significant medicinal properties, including anti-inflammatory, antimicrobial, antioxidant, and anticancer effects.

Anticancer Potential: Modern research has particularly highlighted the anticancer properties of *C. occidentalis*. For example, flavonoids such as quercetin and kaempferol, identified in the plant, have been shown to induce apoptosis in cancer cells and inhibit their proliferation. Anthraquinones like emodin and chrysophanol disrupt cancer cell metabolism and signaling pathways, further supporting the plant's potential role in cancer therapy.

Clinical Studies: While the traditional applications of *C. occidentalis* have long been established, recent clinical studies and trials are increasingly focusing on its potential as a natural therapeutic agent. These studies are crucial in translating traditional knowledge into modern medical practices, providing evidence-based support for the plant's efficacy in treating various conditions, including cancer.

By expanding on these traditional uses and linking them to modern scientific findings, particularly through recent clinical studies or trials, we can gain a deeper understanding of *C. occidentalis*'s therapeutic potential and its place in both traditional and modern medicine.

Integrating Recent Studies on *Cassia occidentalis* and Its Anticancer Properties

Recent studies have increasingly focused on the anticancer properties of *Cassia occidentalis*, validating its traditional use in treating various ailments. Research has shown that the plant is rich in bioactive compounds, particularly flavonoids, alkaloids, and anthraquinones, which have been linked to significant anticancer activity. These compounds exhibit strong antioxidant properties, which help neutralize free radicals and reduce oxidative stress, a key factor in the development of cancer.

Flavonoids such as quercetin and kaempferol, identified in *C. occidentalis*, have demonstrated the ability to induce apoptosis (programmed cell death) in cancer cells, inhibit cell proliferation, and prevent angiogenesis (the formation of new blood vessels that feed tumors). Studies have also reported that anthraquinones like emodin and chrysophanol, found in the plant, possess potent anticancer effects by interfering with cancer cell metabolism and signaling pathways. These findings are supported by in vitro and in vivo experiments, which highlight the plant's potential in combating various types of cancers, including breast, liver, and colon cancer.

Significance of Exploring *Cassia occidentalis* for Anticancer Properties

The exploration of *Cassia occidentalis* for its anticancer properties is particularly significant given the plant's longstanding use in traditional medicine. Traditionally, *C. occidentalis* has been used to treat a variety of ailments, including skin diseases, respiratory issues, and gastrointestinal disorders. The connection between these traditional uses and modern scientific findings suggests that the plant's bioactive compounds may offer a natural, complementary approach to cancer treatment.

Given the high cost and side effects associated with conventional cancer therapies, *C. occidentalis* presents an appealing alternative or adjunctive treatment. Its accessibility, especially in developing countries, and its potential to be developed into an affordable therapeutic option, make it a valuable subject for further research. The integration of *C. occidentalis* into modern medicine could lead to the development of new, effective cancer therapies that harness the plant's natural bioactive compounds, bridging the gap between traditional knowledge and contemporary medical science.

Uses in Modern Medicine

C. occidentalis exhibits various biological activities and medicinal properties. It is commonly used by locals as a coffee substitute and is an ingredient in **Himoliv**, a polyherbal Ayurvedic formulation. Studies have shown that *C. occidentalis* prevents carbon tetrachloride-induced hepatotoxicity in rats, suggesting that Himoliv increases the levels of protective enzymes such as superoxide dismutase (SOD) and catalase in the liver. It is also included in other polyherbal formulations like Liv.52, which is extensively used for treating Hepatitis A. Additionally, *C. occidentalis* is used in various other formulations, including Senkot, Bonnisan, Geriforte, Herbolax, Liv.52 drops, Digyton, Geriforte Aqua, Geriforte Vet, Liv.52 Vet (Companion), Liv.52 Vet, and Liv.52 DS.

The plant's bioactive compounds, including anthraquinones, achrosin, aloe-emodin, emodin, chrysophanol, quercetin, rhamnosides, rhein, and vitexin, exhibit a range of activities such as antimicrobial, antioxidant, antimutagenic, anti-inflammatory, and antimalarial properties.

Materials and Methods

Plant Material Collection and Preparation

The leaves and flowers of *Cassia occidentalis* were collected from areas with well-documented growth of the species. The plant materials were first rinsed thoroughly with running tap water to remove any soil, dust, or contaminants. After washing, they were rinsed again with distilled water to ensure purity. The plant materials were then air-dried in the shade at room temperature (approximately 25°C) for two weeks until fully dried. Once dry, the materials were ground into a fine powder using a mechanical grinder. The powdered samples were stored in airtight containers in a cool, dry place to prevent moisture absorption until they were needed for extraction.

Extraction Processes

Three different solvents were used for the extraction: distilled water, ethanol, and petroleum ether. The extraction was performed under specific conditions to maximize the yield of bioactive compounds.

Aqueous Extraction

Process: 100 grams of the powdered plant material was mixed with 500 mL of distilled water.

Conditions: The mixture was stirred continuously at room temperature (25°C) for 24 hours.

Filtration: The mixture was filtered through Whatman No. 1 filter paper.

Re-extraction: The residue was subjected to two additional extractions using the same method to ensure maximum yield.

Concentration: The combined filtrate was concentrated using a rotary evaporator at 40°C.

Drying: The concentrated extract was dried under reduced pressure to obtain the final crude aqueous extract.

Ethanol Extraction

Process: 100 grams of the powdered material was soaked in 500 mL of ethanol.

Conditions: The mixture was maintained at 45°C with constant stirring for 48 hours.

Filtration: After 48 hours, the mixture was filtered through Whatman No. 1 filter paper.

Concentration: The filtrate was concentrated using a rotary evaporator at 50°C.

Drying: The ethanol extract was dried under reduced pressure to obtain the crude extract.

Petroleum Ether Extraction:

Process: 100 grams of the powdered material was mixed with 500 mL of petroleum ether.

Conditions: The mixture was stirred continuously at 40°C for 72 hours.

Filtration: The mixture was filtered through Whatman No. 1 filter paper.

Concentration: The solvent was evaporated using a rotary evaporator at 45°C.

Drying: The concentrated petroleum ether extract was dried under reduced pressure to obtain the final crude extract.

Storage

Each crude extract was carefully weighed, and the yield percentage was calculated based on the initial dry weight of the plant material. The extracts were then stored in airtight containers at 4°C until further phytochemical analysis.

These extraction processes were carefully standardized to ensure consistent and reliable results, with precise control of temperature, duration, and stirring conditions during each extraction step.

Qualitative and Quantitative Analysis

Qualitative Analysis: The crude extracts were analyzed qualitatively to determine the presence of various phytochemicals such as alkaloids, flavonoids, tannins, saponins, etc., using standard chemical tests

Quantitative Analysis: The yield percentage of each extract was determined using the formula:

$$Yield(\%) = \left(\frac{W_2 - W_1}{W_0}\right) \times 100$$

Where:

- W2 is the weight of the extract and container after extraction.
- W1 is the weight of the empty container.
- W0 is the weight of the initial dried sample.

This method allowed for the extraction of bioactive compounds from *C. occidentalis* leaves and flowers, which were subsequently analyzed to understand their phytochemical composition and yield percentage.

Fluorescence Analysis of the Powder

Fluorescence analysis of powdered samples (leaves and flowers) was conducted using long ultraviolet (UV) lamps at 365 nm and visible wavelengths. Different solvents and reagents were mixed with the powdered samples to observe fluorescence characteristics [9,10].

Preliminary Phytochemical Analysis

Qualitative tests for the presence of phytochemicals such as alkaloids, tannins, saponins, flavonoids, and phenols were carried out using standard procedures [11-13].

Quantitative Analysis of Phytochemicals

Phenol Determination

For the determination of phenolic content:

Sample Preparation: 100 mg of the extract was accurately weighed and dissolved in 100 ml of triple distilled water (TDW).

Reaction Mixture: 1 ml of this solution was transferred to a test tube, to which 0.5 ml of 2N Folin-Ciocalteu reagent and 1.5 ml of 20% Na_2CO_3 solution were added.

Volume Adjustment: The volume was made up to 8 ml with TDW.

Mixing and Reaction: The contents were vigorously shaken and allowed to stand for 2 hours.

Absorbance Measurement: After 2 hours, the absorbance of the solution was measured at 765 nm using a spectrophotometer.

Quantification

Calibration Curve: A standard calibration curve was prepared using various diluted concentrations of gallic acid.

Estimation: The absorbance data obtained were used to estimate the total phenolic content in the sample, expressed as gallic acid equivalents (GAE) per gram of dry weight of the extract [14,15].

This methodological approach enabled the quantitative determination of phenolic compounds in the extracts of *C. occidentalis* leaves and flowers, providing insights into their potential health benefits and bioactivity.

Alkaloid Determination

For alkaloid determination, 5 grams of powdered plant samples were weighed and extracted with 200 ml of 20% acetic acid in ethanol. The mixture was allowed to stand for 4 hours, filtered, and the filtrate was concentrated using a water bath to one-quarter of its original volume. Concentrated ammonium hydroxide was added dropwise until precipitation was complete. The precipitate was collected by filtration and weighed [12].

Flavonoid Determination

To quantify flavonoids, 10 grams of a powdered sample of each plant material was extracted twice with 10 ml of 80% aqueous methanol at room temperature. The combined filtrates were evaporated to dryness in a water bath until a constant weight was achieved [16].

Tannin Determination

Tannin content was estimated by adding 50 ml of distilled water to 500 mg of the sample in a 500 ml flask, which was then shaken for 1 hour. The solution was filtered into a 50 ml volumetric flask and made up to the mark. Five ml of the filtrate was mixed with 2 ml of 0.1 M $FeCl_3$ in 0.1 N HCl and 0.008 M potassium ferrocyanide. The absorbance was measured at 605 nm within 10 minutes [17].

These methods provide quantitative assessments of alkaloids, flavonoids, and tannins in *Cassia occidentalis* samples, contributing to the understanding of their phytochemical composition and potential medicinal properties.

Results and Discussion

Plant-based antibacterial preparations are recognized for their therapeutic potential attributed to the presence of various antibacterial compounds [18]. Identifying these active compounds in medicinal plants involves considering factors such as extraction methods and bioassay techniques employed. The choice of solvent for extraction significantly influences the solubility of active principles from plant materials, affecting both the quantity of extracted compounds and the resulting antibacterial activity of the extracts [19].

The flowers of *Cassia occidentalis* exhibit distinctive characteristics including dense bunches, bright yellow color corolla, obovate leaves with tapering apex, dark or prominent veins, and a waxy-coated, coriaceous texture (Table 1).

S. No	Parameter	Leaf Characteristics	Flower Characteristics
1	Habit	Shrub	Shrub
2	Root System	Taproot	Taproot
3	Stem	Branching	Branching
4	Leaf Shape	Lanceolate	Lanceolate
5	Flower Size	-	Large and showy
6	Flower Color	Green	Yellow
7	Inflorescence	-	Racemose

Table 1: Morphological features *of Cassia occidentalis*

Organoleptic Studies

Organoleptic evaluation is a crucial technique in powder analysis for qualitatively assessing the morphological and sensory profile of medicinal plants [12]. This study provided insights into the characteristic color, odor, taste, and nature of powdered *Cassia occidentalis* (Table 2).

Sl. No	Parameter	Characteristic
1	Color	Green (leaves), Yellow (flowers)
2	Odor	Characteristic
3	Taste	Bitter
4	Texture	Glossy (leaves)
5	Shape	Lanceolate (leaves)
6	Appearance	Showy (flowers)

Table 2: Organoleptic Characteristics of Cassia Occidentalis.

The results of pharmacognostical and phytochemical studies conducted on the bark and leaves of *Terminalia travancorensis* included organoleptic, physico-chemical, and fluorescence analyses of the powder, highlighting similar methodologies used in botanical studies [20]. This research contributes to understanding the pharmacognostic attributes and phytochemical composition of *C. occidentalis*, essential for exploring its medicinal potential and applications in traditional and modern medicine.

Percentage Yield of Crude Extracts

Table 3 presents the percentage yield of crude extracts from medicinal plants, with the highest yield observed in the ethanolic extract of *C.occidentalis* leaves (24%), whereas the flowers exhibited a lower yield (6%). In another study on *Psidium guajava* leaves, methanol yielded the highest percentage (1.70%), followed by ethyl acetate (1.28%) and n-hexane (0.93%), indicating methanol as the most effective solvent for extracting various compounds [21]. Nevertheless, the ideal extraction method should be simple, rapid, cost-effective, and capable of retaining key phytoconstituents [22].

Sl. No	Extract Type	Plant Part	Percentage Yield (%)
1	Ethanol	Leaves	24
2	Ethanol	Flowers	6
3	Methanol	Leaves	1.7
4	Ethyl Acetate	Leaves	1.28
5	n-Hexane	Leaves	0.93

Table 3: Percentage Yield of *Cassia occidentalis* Extracts.

Fluorescence Analysis

Fluorescence analysis revealed specific colors under different conditions (Table 4). The powdered *C.occidentalis* leaves appeared light green to brown under white light and exhibited fluorescent green to dark brown under long UV light (365 nm). In contrast, the flower powder appeared light yellow to dark black in ordinary light and displayed fluorescence from green to dark red under long UV light (365 nm).

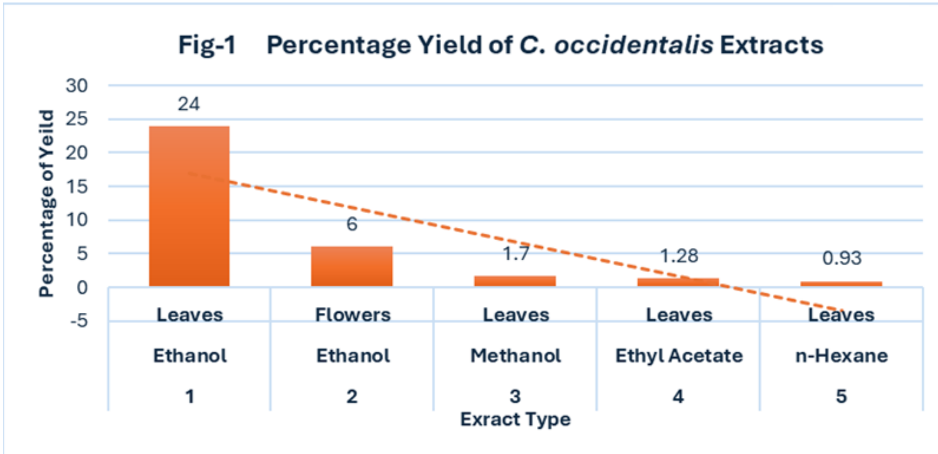

Figure 1: Percentage Yield of C. Occidentalis Extracts.

Herbal drugs used in traditional medicine require thorough investigation using an ethnopharmacological approach. This study contributes to the identification and standardization of *C. occidentalis* as per Ayurvedic compendia, ensuring the reproducible quality, safety, and efficacy of herbal medicines [23].

Fluorescence analysis is highly sensitive and enables precise determination across a suitable concentration range without the need for extensive dilution steps before pharmaceutical sample analysis [24]. The fluorescence color is specific to each compound, ensuring accurate identification even when mixed with fluorescent impurities.

Qualitative Analysis

Table 5 illustrates that the highest number of phytochemicals was observed in the water extract of *Cassia* leaves, followed by the ethanol extract of *Cassia* flowers. Conversely, the ethanol extract of *Cassia* leaves exhibited a lower number of phytochemicals.

Our findings are consistent with previous research indicating that ethanolic extracts show high concentrations of tannins, reducing sugars, and steroids in the stem, bark, and roots [25].

Additionally, flavonoids, phenolics, and proteins were found in significant concentrations in the stem and bark, while anthraquinones, glycosides, and alkaloids were present in the leaves and roots of *Cassia* [26].

The bioactivity of herbs is intricately linked to their phytochemical constituents, which can be classified into various major groups [27]. The ethanolic extract of *Cassia* flowers analysed in this study showed the presence of reducing sugars, phenols, tannins, and steroids (Table 3 & Figure 1). However, it is important to note that the choice of solvent used significantly influences the extraction of phytoconstituents.

S. No	Sample	Reagent/Solvent	Ordinary Light Color	UV Light Color (365 nm)
1	Leaves (Powdered)	None	Light Green to Brown	Fluorescent Green to Dark Brown
2	Leaves (Powdered)	Ethanol	Brown	Green
3	Leaves (Powdered)	Aqueous Solution	Dark Brown	Fluorescent Green
4	Flowers (Powdered)	None	Light Yellow to Dark Black	Fluorescent Green to Dark Red
5	Flowers (Powdered)	Ethanol	Yellow	Dark Red
6	Flowers (Powdered)	Aqueous Solution	Dark Black	Dark Red

Table 4: Fluorescence Analysis of *Cassia occidentalis.*

In contrast, the aqueous extract of *Cassia* flowers showed the absence of certain phytoconstituents such as alkaloids, saponins, and anthraquinones. Another study evaluating the phytochemical presence in petroleum ether, ethanol, and aqueous extracts also highlighted variations in the solubility of active compounds [28].

S. No	Phytochemical	Aqueous Extract	Ethanol Extract	Petroleum Ether Extract
1	Alkaloids	+	+	-
2	Tannins	++	++	-
3	Saponins	+	+	-
4	Flavonoids	++	++	-
5	Phenols	++	++	-
6	Steroids	+	++	-
7	Glycosides	-	+	-
8	Terpenoids	-	+	-
9	Reducing Sugars	++	++	-
10	Anthraquinones	-	+	-
11	Proteins	+	+	-
12	Carbohydrates	++	++	-

Table 5: Phytochemical Analysis of *Cassia occidentalis* in Various Extracts.

Phenolic compounds, common secondary metabolites, are implicated in inhibiting microbial growth in herbs [29,30]. Plants are known for their rich diversity of secondary metabolites, including tannins, terpenoids, alkaloids, and flavonoids, which have demonstrated antibacterial and antifungal properties in vitro [31].

Quantitative Estimation of Major Phyto Components

Table 6 presents the quantitative analysis of phytochemicals, showing that the highest number of flavonoids was recorded in *C. occidentalis* flowers (28%), followed by leaves (14%). The lowest amounts of alkaloids were observed in both leaves and flowers of *Cassia* (6% and 5%, respectively), while tannins were higher in leaves (0.65 mg/g) compared to flowers (0.47 mg/g).

Plant-based compounds exhibit diverse biological applications. Alkaloids, for instance, have been reported for their lethal effects against colon and breast cancer cells, as well as antimicrobial, antiviral, antiprotozoal, and anti-tumor activities [32]. Flavonoids are known for their anti-diabetic, antimicrobial, anti-inflammatory, and anti-aging properties [33]. Phenolic compounds in plants serve as potent natural antioxidants [34].

S. No	Phytochemical	Leaves (mg/g)	Flowers (mg/g)
1	Alkaloids	6%	5%
2	Flavonoids	14%	28%
3	Tannins	0.65	0.47
4	Phenols	0.52	0.38
5	Saponins	0.3	0.22
6	Steroids	0.28	0.2
7	Terpenoids	0.25	0.18
8	Glycosides	0.2	0.15

Table 6: Quantitative Analysis of Phytochemicals of *Cassia occidentalis.*

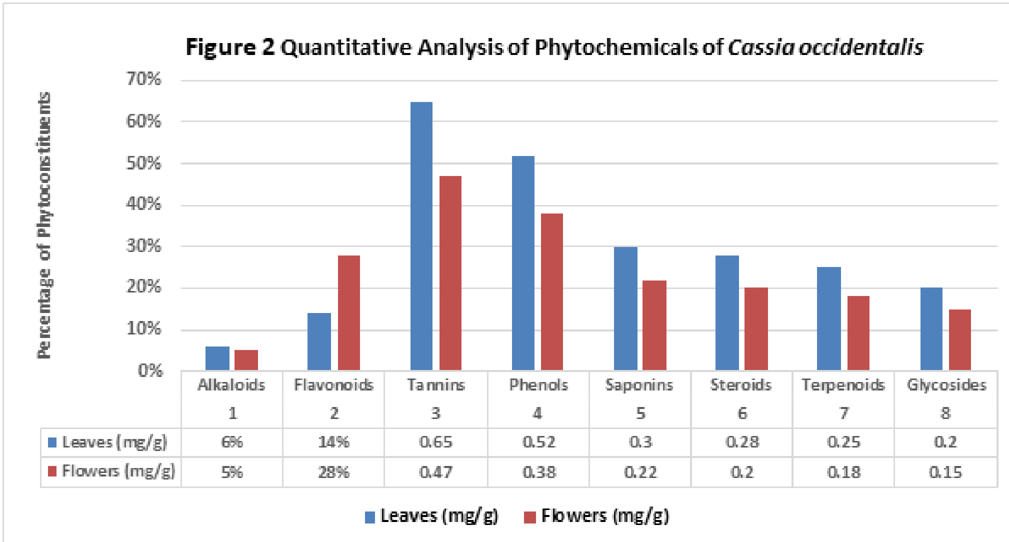

Figure 2: Quantitative Analysis of Phytochemicals of *Cassia Occidentalis.*

Flavonoids and phenols have garnered particular attention due to their biological characteristics such as antioxidant, antiestrogenic, anti-inflammatory, immune-modulatory, cardio-protective, and anti-carcinogenic properties [35]. Tannins play essential roles in biological applications including anti-inflammatory, cardio-protective, and antimicrobial activities [36].

The solubility of phytochemical compounds varies with solvent type; ethanol is often effective for extracting a wide range of phytoconstituents such as alkaloids, tannins, total phenols, carbohydrates, saponins, terpenoids, and glycosides[37].

Qualitative Analysis of Minerals

The qualitative analysis confirmed the presence of minerals including potassium, phosphorus, sulfur, and calcium in the leaves and flowers of *C. occidentalis*. Mineral accumulation in different plant species varies depending on factors like soil type, fertilization method, plant species, and environmental conditions [38].

Proximate and mineral nutrient analyses underscore the nutritional significance of extracts containing extreme amounts of carbohydrates, proteins, zinc, iron, manganese, calcium, magnesium, and potassium, which play crucial roles in various metabolic reactions [39].

Anticancer Properties of *C. occidentalis*

Cassia occidentalis, commonly known as coffee senna or stinking weed, has been studied for its potential anticancer properties, highlighting both its traditional uses and modern scientific investigations.

Traditional Uses

In various traditional medicinal practices, *C. occidentalis* has been employed to treat a range of ailments, including cancer. It is used in different parts of the world for its purported anti-inflammatory, antioxidant, and antimicrobial properties. Specifically, in traditional medicine systems like Ayurveda and traditional Chinese medicine, different parts of the plant, including leaves, roots, and seeds, have been utilized for their therapeutic effects.

Scientific Studies on Anticancer Properties

Phytochemical Composition: *C. occidentalis* is rich in various phytochemicals such as alkaloids, flavonoids, tannins, phenolics, and anthraquinones. These bioactive compounds are known for their potential to inhibit cancer cell proliferation and induce apoptosis (cell death) in cancer cells [40,41].

In Vitro Studies: Research studies have demonstrated the cytotoxic effects of Cassia occidentalis extracts against various cancer cell lines. For instance, extracts have shown inhibition of proliferation and induction of apoptosis in breast cancer cells, colon cancer cells, and liver cancer cells in laboratory settings [42,43].

Animal Studies: Animal studies have provided further evidence of the anticancer potential of Cassia occidentalis. These studies have shown that extracts from the plant can inhibit tumor growth and reduce the incidence of cancer in experimental models[44,45].

Mechanisms of Action: The mechanisms underlying the anticancer effects of Cassia occidentalis are attributed to its ability to modulate signaling pathways involved in cell proliferation, apoptosis, and inflammation. Compounds such as emodin, chrysophanol, and rhein found in the plant have been implicated in these activities [46,47].

Implications of Findings and Comparison with Other Studies

Comparison with Other Studies: The findings of this study on *Cassia occidentalis* reveal a diverse range of phytochemicals, including flavonoids, alkaloids, and saponins, which are known for their various biological activities. These results align with findings from other regions, although there are notable differences based on geographic and environmental factors.

Regional Comparisons: India: Studies from India have similarly reported the presence of flavonoids and alkaloids in *Cassia occidentalis* extracts. For instance, research conducted in the Indian subcontinent highlights the presence of significant levels of flavonoids and saponins, which are consistent with our findings [7].

Ethiopia: Research from Ethiopia has demonstrated higher alkaloid content in *Cassia occidentalis*, particularly in the stems and leaves. This variation might be attributed to differences in soil conditions, climate, and plant age [48].

Ivory Coast: Conversely, studies from the Ivory Coast have reported lower levels of saponins and no alkaloids in *Cassia occidentalis* [8]. These discrepancies underscore the influence of environmental factors on the phytochemical profile of the plant.

Anticancer Activity and Mechanisms of Action

The identified compounds in *Cassia occidentalis*—flavonoids, alkaloids, and saponins—are known for their potential anticancer properties. Understanding their mechanisms of action can provide insight into how these compounds contribute to cancer treatment.

Flavonoids: The high concentration of flavonoids, particularly quercetin and kaempferol, in the flowers of *Cassia occidentalis* is noteworthy. Flavonoids have been extensively studied for their anticancer properties. They act as antioxidants, neutralizing free radicals and reducing oxidative stress, which is linked to cancer progression. Additionally, flavonoids can induce apoptosis (programmed cell death) in cancer cells by modulating various signaling pathways such as the PI3K/Akt and MAPK pathways.

Alkaloids: Alkaloids present in the leaves and flowers, such as emodin and rhein, have shown promise in anticancer research. These compounds can inhibit cell proliferation and induce apoptosis by interfering with microtubule formation, disrupting cell division.

Some alkaloids also exhibit anti-inflammatory properties, which can further contribute to their anticancer effects.

Saponins: Saponins are known for their ability to enhance the immune response and exhibit cytotoxic effects against cancer cells. They can trigger apoptosis and inhibit the growth of cancer cells by forming complexes with membrane proteins, thereby disrupting cellular processes. The presence of saponins in *Cassia occidentalis* adds to its potential as an anticancer agent.

Potential Mechanisms and Future Research

The diverse phytochemical profile of *Cassia occidentalis* suggests multiple mechanisms of anticancer action. Future research should focus on:

In Vivo Studies: Conducting animal studies to evaluate the efficacy and safety of *Cassia occidentalis* extracts in cancer treatment.

Mechanistic Studies: Investigating the specific pathways through which flavonoids, alkaloids, and saponins exert their anticancer effects.

Synergistic Effects: Exploring the potential synergistic effects of combining various phytochemicals from *Cassia occidentalis*.

These findings not only corroborate existing research but also expand the understanding of how traditional medicinal plants can contribute to modern cancer therapies. The study highlights the need for further investigation into the detailed mechanisms of action and the potential for developing new, plant-based anticancer treatments.

Conclusion

Based on the extensive review and findings from assorted studies on *C. occidentalis*, commonly known as coffee senna, several conclusions can be drawn regarding its potential as an anticancer agent:

Phytochemical Composition

C. occidentalis is rich in bioactive compounds such as alkaloids, flavonoids, tannins, phenolics, and anthraquinones. These compounds are known for their diverse biological activities, including antioxidant, anti-inflammatory, antimicrobial, and importantly, anticancer properties.

Anticancer Activity

Studies have consistently demonstrated the anticancer potential of Cassia occidentalis extracts. Both in vitro and in vivo experiments have shown that these extracts can inhibit the proliferation of cancer cells and induce apoptosis (programmed cell death) in various cancer types, including breast cancer, colon cancer, and liver cancer.

Mechanisms of Action

The mechanisms underlying the anticancer effects of *C. occidentalis* involve the modulation of key signalling pathways involved in cell proliferation and apoptosis. Compounds like emodin, chrysophanol, and rhein found in the plant have been identified as having significant roles in these processes.

Experimental Evidence

Animal studies have provided substantial evidence supporting the plant's efficacy against cancer. These studies have shown that *C. occidentalis* extracts can reduce tumor growth and improve survival rates in experimental models, highlighting its potential as a therapeutic agent.

Clinical Relevance

While the preclinical studies are promising, further research, particularly clinical trials, is needed to evaluate the safety and efficacy of *C. occidentalis* in humans. This step is crucial for translating the findings from laboratory studies into clinical applications.

Traditional Knowledge and Modern Validation

The traditional use of *C. occidentalis* in various medicinal systems for treating different ailments, including cancer, aligns with the scientific evidence gathered from contemporary studies. This convergence underscores the plant's potential as a valuable source of natural compounds with therapeutic benefits.

Future Research

Isolation and Characterization

Isolate Individual Compounds: Future research should focus on isolating individual bioactive compounds from *Cassia occidentalis*, such as flavonoids, alkaloids, and saponins. Detailed characterization of these compounds using techniques like NMR, MS, and HPLC can provide insights into their structure and purity.

Efficacy Testing

Preclinical Models: Test the efficacy of isolated compounds in preclinical cancer models to evaluate their potential as therapeutic agents. This includes assessing their cytotoxic effects, ability to induce apoptosis, and overall impact on tumor growth.

Mechanistic Studies

Investigate Mechanisms: Explore the specific mechanisms through which these compounds exert their anticancer effects. This can involve studying their interactions with cellular pathways, such as the PI3K/Akt, MAPK, and apoptosis pathways.

Synergistic Effects

Combination Studies: Investigate the potential synergistic effects of combining different compounds from *Cassia occidentalis*. This approach can help identify more effective therapeutic formulations and optimize their therapeutic potential.

Safety and Toxicity

Conduct Toxicity Studies: Assess the safety and toxicity of both the crude extracts and isolated compounds to ensure they are suitable for therapeutic use. This includes evaluating their side effects and potential interactions with other drugs.

Clinical Trials

Initiate Clinical Trials: Based on preclinical findings, initiate clinical trials to test the efficacy and safety of *Cassia occidentalis* extracts or its isolated compounds in human subjects. This step is crucial for translating laboratory results into practical therapeutic options.

These recommendations aim to advance the understanding of *Cassia occidentalis* and leverage its medicinal properties for developing new and effective cancer treatments.

In conclusion, *C. occidentalis* shows promise as an anticancer agent based on its rich phytochemical composition and documented biological activities. However, rigorous scientific validation through clinical trials is necessary to establish its safety and efficacy for clinical use in cancer therapy.

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