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Butea Monosperma's Phytochemical Properties and its Antibacterial, Antioxidant, and Hypoglycemic Effects

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ABSTRACT

The medicinal traditions of *Butea monosperma* (flame of the forest) are supported by its diverse phytochemical profile and multiple biological activities. This study investigates the antibacterial, antioxidant, and hypoglycemic properties of ethanol, methanol, ethyl acetate, and chloroform extracts from the leaves, flowers, bark, and seeds of the plant. Phytochemical screening revealed the presence of alkaloids, tannins, flavonoids, sterols, and glycosides, with methanolic extracts showing the highest abundance. Antibacterial activity, assessed via the disk diffusion method, showed significant inhibition of both Gram-positive and Gram-negative bacteria, with methanolic leaf extract demonstrating the largest inhibition zones against *Pseudomonas aeruginosa* and *Staphylococcus aureus*. Antioxidant activity, evaluated using the DPPH free radical scavenging assay, was most potent in methanolic leaf and flower extracts. Furthermore, methanolic flower extract exhibited a pronounced hypoglycemic effect in alloxan-induced diabetic rabbits, reducing blood glucose by 44% over three weeks and stabilizing body weight. These findings reinforce the therapeutic potential of *Butea monosperma* as a natural source of antibacterial, antioxidant, and hypoglycemic agents, validating its use in traditional medicine and highlighting its promise for pharmaceutical applications.

INTRODUCTION

Medicinal plants have assumed vital roles regarding human health care for millennia and are a renowned source of restorative chemicals..We know that traditional plant-based remedies have been used widely to treat many types of health conditions. Medicinal plants still have an important role to play in modern as well as traditional medicine since an estimated 80% of the world population rely on herbal medicine as their main form of healthcare [1]. In particular, Butea monosperma (Fabaceae) is famous in Ayurveda, Unani and folk medicine for its folklore use on antimicrobial, antioxidant and hypoglycaemic properties. Often called the 'flame of the forest' because of its orange flowers, the Butea monosperma is a South Indian tree which is commonly used in herbal formulations.

Medicinal Plants Importance in Antimicrobial and Antioxidant Research: Interest in natural antimicrobial agents, and those from plant sources in particular, as potential alternatives to synthetic antibiotics has increased with the rapid emergence of antibiotic resistance. Staphylococcus aureus, Escherichia coli and Pseudomonas aeruginosa, many bacterial pathogens, have shown resistance to common antibiotics, which is a great challenge in healthcare worldwide [2]. Plant based antimicrobial agents thus present a promising solution in the fight against antibiotic resistance, drawing upon entirely natural, biologically active phytochemicals known to be protective in nature.

Besides the antimicrobial property, the antioxidants of plant origin are being widely studied for their potential oxidative stress fighting property [3]. Production of reactive oxygen species (ROS) is part of normal metabolism of the body and ROS can become a source of oxidative stress if there are more ROS produced than can be managed by body's antioxidant defense [4] Antioxidants prevent the oxidative damage that can lead to cardiovascular disease, cancer and diabetes. Synthetic antioxidants are available, though there are questions about their carcinogenic effects. For this reason, plant based antioxidants (often safer and more effective) are being used more and more in both research and industry.

Diabetes is a chronic metabolic disorder marked by elevated blood glucose levels that affects millions of people worldwide and whose incidence is increasing rapidly. Though insulin and other medications are used to manage diabetes widely, side effects and cost can be prohibitive. Medical plants can help regulate blood glucose levels through little to no adverse effects. Studies on Butea monosperma have been promising in reducing blood glucose levels and the possibility as a hypoglycemic agent in diabetes management [5].

Butea monosperma: A Versatile Medicinal Plant: Butea monosperma is traditionally used as flowers, leaves, and bark in treating skin infections, ulcers, inflammation and even diabetes [6]. Properties attributed to the plant are due to its rich phytochemical profile consisting of flavonoids, saponins, tannins and alkaloids. There has been the belief that each one of the plant's part has been believed to have its own specific bioactive compounds, elements which contribute to the plant's medicinal efficacy. For example, flowers contain flavonoids and tannins as antioxidant substance, leaves and seeds saponins and alkaloids as antibacterial. Furthermore, the flowers contain compounds which exhibits hypoglycemic effects potentially to be used for diabetes treatment [7].

Studies on Butea monosperma in recent years have shown that it has broad spectrum biological activity. The antibacterial activity of the plant against both gram positive and gram negative bacteria. Another study, antibacterial activity in leaf extracts of the plant and rationalized its traditional uses as an agent for infection control. Such results point to the possibility of using Butea monosperma as a source of natural antibacterial agents as an alternative to synthetic antibiotics in the treatment of resistant bacteria infections [8].

LITERATURE REVIEW

The medicinal plants serve as an important source for drug discovery and traditional healing systems with a significant number of bioactive compounds which are responsible for their therapeutic effects [9]. Pharmacological exploration of these plants has been undertaken by numerous studies, including the potential of the plants as antibacterial, hypoglycemic, and antioxidant. Of these, the most important is Butea monosperma, due to its extensive medicinal usage and strong biological activities [10].

Plant derived chemical compounds are known as phytochemicals and key to plants' medicinal properties. Secondary metabolites such as alkaloids, flavonoids, saponins, tannins, and terpenoids are each important in protecting plants against pathogens and other environmental stresses. Therapeutic effects of these compounds range, from being antimicrobial to anticancer and also demonstrating antioxidant activity [11].

Studies demonstrate the phytochemical composition of Butea monosperma to be diverse bioactive compounds [12] and, e.g., flavonoids, saponins and tannins in the plant. Frozen phytomed plants are also useful materials for phytochemical screening that can furnish valuable information on the medicinal potential of the plants because they contain different chemical constituents presenting different therapeutic effects. For example, alkaloids are widely known to possess pharmacological effect in pain relief as well as being antibacterial agents, flavonoids and tannins are used as an antioxidant and antimicrobial substance [13].

As the rising resistances of pathogens to conventional antibiotics have intensified the research on natural antibacterial agents derived from medicinal plants [14]. A large amount of antimicrobial compounds are produced by plants as a defens mechanism against microbial infection Medicinal plants that possess the antibiotic properties were due to secondary metabolites such as flavonoids, alkaloids, and tannins that destroy microbial cell membranes, affect protein synthesis or hamper bacterial DNA replication [15].

Evidence has been shown that Butea monosperma has the antibacterial activity, and has been used traditionally to treat infections. The leaves, bark, and flowers of the plant were evaluated for their antibacterial efficacy against different strains of bacteria and significant differences between activity of different extracts were established.The antibacterial effects were greater in methanolic extracts of flowers against gram positive bacteria such as Staphylococcus aureus and the gram negative reported that Butea monosperma leaf extracts were effective against nine bacterial strains (gram positive and Gram negative), this validated Butea monosperma leaf extract as a source of natural antibiotics [16].

Plants as Antioxidant Agents

Reactions with oxygen free radicals are kept in balance by antioxidants to keep oxidative stress from doing cellular damage to generate various diseases, including cancer, cardiovascular conditions, and neurodegenerative disorders. Synthetic antioxidants are preferred to natural antioxidants because they are safer and more effective. Antioxidants in plants such as polyphenols, flavonoids and tannins such as these phytochemicals help protect cells from oxidative damage [8].

We found that Butea monosperma has potent antioxidant properties. The antioxidant activity of plant's leaf extract was investigated using DPPH assay to which it showed much free radical scavenging activity similar to that of ascorbic acid (a standard antioxidant).The findings support prior studies, showing that polyphenols, rich in Butea monosperma, have antioxidant potential that can inhibit the process by which saba fasts. Further the antioxidant properties of flavonoids and tannins of the plant suggest the possibility of natural antioxidant source as such in the development of therapeutic formulations [17].

Medicinal Plants with Hypoglycemic Effects

Diabetes mellitus is a chronic metabolic disorder marked by markedly elevated blood glucose levels, known to be increasingly common.For diabetes, many people use synthetic drugs to control diabetes, but they may have unwanted side effects and are expensive. Thus plant based treatment for diabetes is of high interest as the results of these are effective, safe and cost effective [18].

Promising hypoglycemic properties have been shown by many medicinal plants as in Butea monosperma, indicating their use in traditional diabetes management [19]. The authors attributed the lower blood glucose levels

in diabetic animal models following Butea monosperma flower extract, respectively, to its flavonoid content. These compounds have been thought to stimulate insulin secretion, increase glucose uptake in tissues and inhibit carbohydrate metabolism by inhibiting enzymes activities involved in metabolism of carbohydrates, which leading to better blood glucose control.

Butea monosperma's efficacy in reducing the blood glucose levels is in agreement with the broader research of plant based hypoglycemic agents [20]. Studies have shown that many flavonoid rich plants have anti diabetic properties that may target insulin secretion and/or glucose absorption. For Butea monosperma, the plant's flower body extracts have been found particularly promising because they have shown hypoglycemic activity that could be used for the development of alternative treatments of diabetes [21].

MATERIAL AND METHODS

Study Area and Plant Collection

This study was conducted in 2023 at the Department of Biotechnology, Mirpur University of Science and Technology (MUST), Mirpur, Pakistan. *Butea monosperma* plant parts (leaves, flowers, bark, seeds) were collected from different areas of District Mirpur, Azad Jammu and Kashmir. The samples were authenticated by a botanist at MUST, washed with distilled water, air-dried in shade, ground into fine powder, and stored at 4°C.

Preparation of Plant Extracts

Each powdered plant part (50 g) was macerated in 300 mL of methanol, ethyl acetate, or chloroform for seven days at room temperature in the dark. The mixtures were filtered using Whatman No. 2 filter paper, and the solvents were evaporated under reduced pressure using a rotary evaporator. Extracts were stored in airtight containers at 4°C for further analysis.

Phytochemical Screening

Standard qualitative tests were used to detect major phytochemical groups, including alkaloids, tannins, saponins, flavonoids, sterols, glycosides, terpenoids, and carbohydrates. The presence of these compounds was confirmed by specific color reactions or precipitate formation using established protocols.

Antibacterial Activity

Antibacterial activity was evaluated using the disk diffusion method against five bacterial strains: *Bacillus subtilis*, *Bacillus pumilus*, *Staphylococcus aureus* (Gram-positive) and *Escherichia coli*, *Pseudomonas aeruginosa* (Gram-negative). Nutrient agar plates were inoculated with bacterial cultures, and sterile filter paper disks soaked with 20 µL of each extract were placed on the surface. After diffusion at 4°C for 1 hour, plates were incubated at 37°C for 24 hours. Inhibition zones were measured in millimeters.

Antioxidant Activity (DPPH Assay)

The antioxidant potential was assessed using the DPPH (2,2-diphenyl-1-picrylhydrazyl) free radical scavenging assay. Extracts were mixed with DPPH solution and distilled water, shaken, and left to react at room temperature. Absorbance was measured at 517 nm, and percentage inhibition was calculated to determine antioxidant capacity.

Hypoglycemic Activity

Alloxan-induced diabetic rabbit models were used to evaluate the hypoglycemic effect of *Butea monosperma* methanolic flower extract. Nine rabbits (1.2–1.8 kg) were divided into three groups: normal control, diabetic control, and diabetic treated. Diabetes was induced using alloxan monohydrate (75 mg/kg body weight), followed by extract administration for three weeks. Blood glucose levels and body weights were recorded weekly using a glucometer and digital scale.

Statistical Analysis

All data were expressed as mean ± standard error (SE). One-way analysis of variance (ANOVA) was applied to compare group differences, and p-values < 0.05 were considered statistically significant.

RESULTS

Phytochemical Composition

Phytochemical screening of Butea monosperma showed a variety of bioactive compounds from different parts of the plant (leaves, flowers, seeds and bark), as well as different solvents (methanol, ethyl acetate and chloroform). In almost all parts, phytochemical contents were found to be highest in methanolic extracts which contained alkaloids, tannins, flavonoids, sterols and carbohydrates. The high amount of bioactive compounds in methanolic extracts may be attributed to the potency of the solvent in extracting polar compounds.

Leaf extracts had a good profile of phytochemicals and methanol and ethyl acetate extracts showed strong presence of alkaloids, tannins, flavonoids, sterols and terpenoids. The chloro form extract however, exhibited only marginally phytochemical activity thus suggesting it is inadequate for polar compounds. Flavonoids, tannins and sterols were also present in flower extracts, especially in methanol and were also potential therapeutic agents. Sterols and glycosides were well represented in both bark and seed extracts, and methanol was the most efficient solvent for extraction.

Table 1

Phytochemical Composition of Butea monosperma Extracts

Part	Solvent	Alkaloids	Tannins	Glycosides	Flavonoids	Saponins	Sterols	Carbohydrates	Terpenoids
Leaf	Methanol	++	++	+	++	-	+	+	+
	Ethyl Acetate	+	+	-	+	-	+	+	+
	Chloroform	-	-	+	-	-	+	+	-

	Methanol	-	++	+	++	-	+	+	-
Flower	Ethyl Acetate	-	+	-	+	-	+	+	-
	Chloroform	-	+	+	-	-	+	-	-
	Methanol	-	+	+	-	-	+	+	-
Bark	Ethyl Acetate	-	+	+	+	-	+	+	-
	Chloroform	-	-	+	-	-	+	+	-
	Methanol	-	+	+	+	-	+	+	-
Seed	Ethyl Acetate	-	+	+	+	-	+	+	-
	Chloroform	-	-	+	-	-	-	+	-

Note: Symbols indicate presence and abundance: "++" = strongly present, "+" = moderately present, "-" = absent.

Antibacterial Activity

Antibacterial properties were assessed from the disk diffusion method and the results clearly showed that the methanol extracts of Butea monosperma possessed strong antibacterial activity. Highest inhibition against Pseudomonas aeruginosa (33.33 ± 0.88 mm) and Staphylococcus aureus (31.33 ± 0.33 mm) was recorded with the methanolic leaf extract. The methanolic flower extract exhibited considerable inhibition against Staphylococcus aureus (15.66 ± 0.33) and Escherichia Coli (11.33 ± 0.33), thus indicating the presence of potent antibacterial compounds in them. Moderate antibacterial activity was observed in ethyl acetate extracts particularly against Bacillus subtilis and Pseudomonas aeruginosa. Nevertheless, only chloroform extracts had no effects on antibacterial, which might be attributed to poor extraction efficiency for antibacterial compounds.

Table 2

Antibacterial Activity of Butea monosperma Extracts (Zone of Inhibition in mm)

Part	Solvent	B. subtilis	B. pumilus	S. aureus	P. aeruginosa	E. coli
Leaf	Methanol	25.00 ± 0.57	21.83 ± 0.44	31.33 ± 0.33	33.33 ± 0.88	31.00 ± 0.77
	Ethyl Acetate	21.00 ± 0.57	10.16 ± 0.16	10.66 ± 0.66	10.33 ± 0.33	9.83 ± 0.44
	Chloroform	0.00	0.00	0.00	10.00 ± 0.57	8.33 ± 0.33
Flower	Methanol	11.66 ± 0.33	14.33 ± 0.33	15.66 ± 0.33	13.33 ± 0.82	11.33 ± 0.33
	Ethyl Acetate	11.00 ± 0.57	13.33 ± 0.88	22.16 ± 1.6	26.66 ± 0.66	14.00 ± 0.57
	Chloroform	0.00	0.00	0.00	0.00	13.00 ± 0.57
Seed	Methanol	8.50 ± 0.50	8.33 ± 0.33	9.66 ± 0.33	11.33 ± 0.33	11.66 ± 0.33
	Ethyl Acetate	22.00 ± 0.57	18.33 ± 0.82	25.66 ± 0.33	19.00 ± 0.57	10.50 ± 0.28
	Chloroform	0.00	11.66 ± 0.33	0.00	0.00	12.66 ± 0.33
Bark	Methanol	8.00 ± 0.57	9.00 ± 0.57	8.66 ± 0.88	9.33 ± 0.66	8.00 ± 0.00
	Ethyl Acetate	16.16 ± 0.44	18.16 ± 0.44	17.16 ± 0.44	19.33 ± 0.33	11.00 ± 0.57
	Chloroform	0.00	0.00	0.00	0.00	0.00

Note: Values are means ± standard error (SE).

Antibacterial Potential of Leaf Extracts of *Butea monosperma*

Figure 1

Potential of Flower Extracts of Butea monosperma

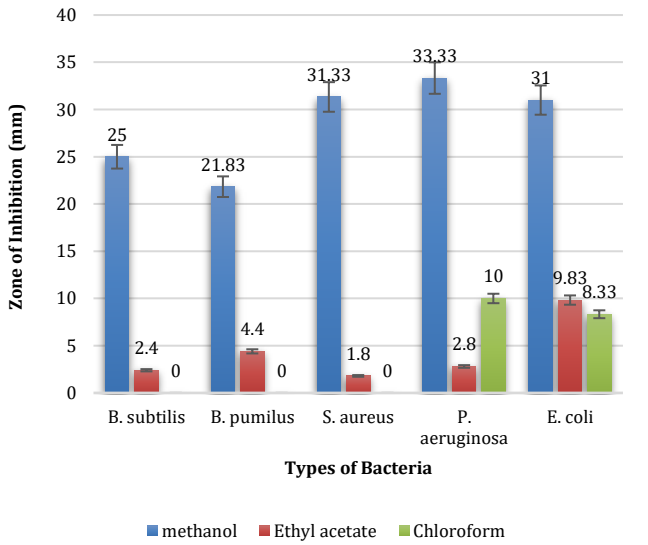


Figure 2

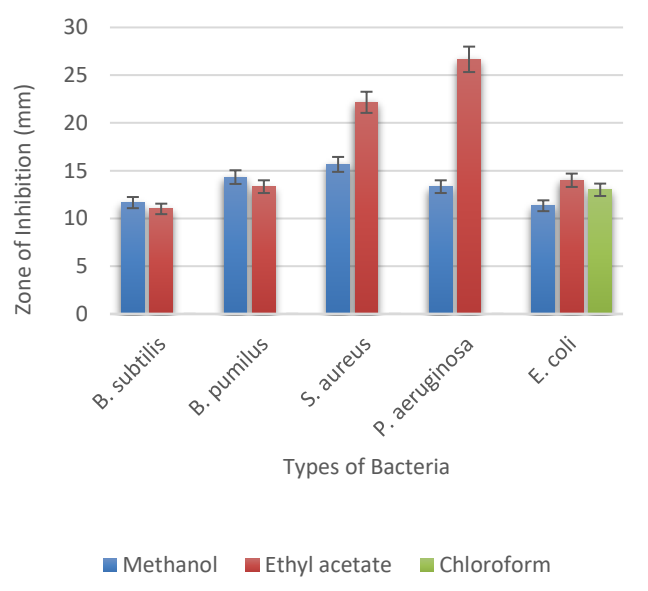
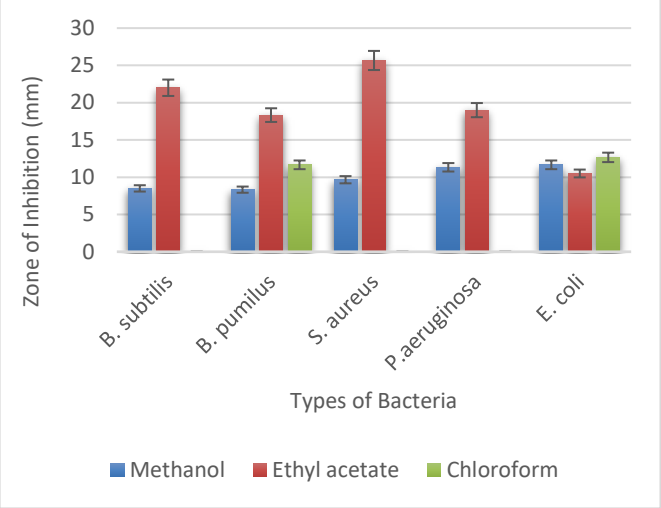


Figure 3

Antibacterial Potential of Seed Extracts of Butea monosperma



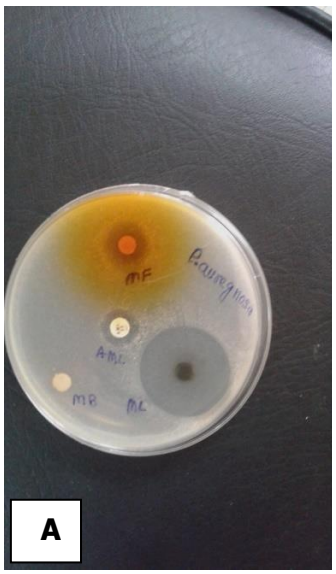


Plate A

Zone of inhibition of P. aeruginosa in methanolic extract

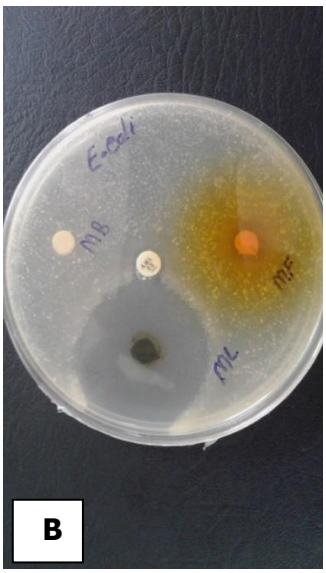


Plate B

Zone of inhibtion of E. coli in methanolic extract

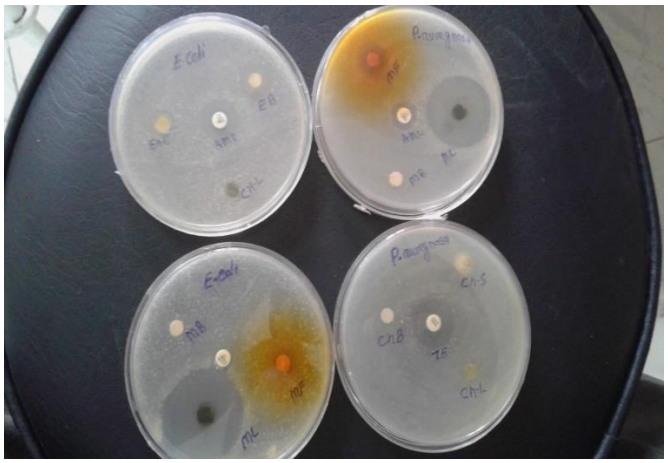


Plate C

Zone of Inhibition of P. aeruginosa and E. coli in Various Extracts

Antioxidant Activity

The antioxidant potential of Butea monosperma extracts was examined in terms of DPPH radical scavenging by methanolic flower and leaf extracts, which showed the highest scavenging activity. The ascorbic acid control and the DPPH inhibition percentage showed 78.6 ± 1.2 and 85.2 ± 0.9, respectively from methanol leaf extract, and methanol flower extract was also both similar. Moderate antioxidant potential was determined in ethyl acetate extracts with the leaf and flower extracts reaching 52.4 ± 1.8% and 60.3 ± 1.4% respectively. But chloroform extracts showed minimal antioxidant activity probably because of their poor ability to extract phenolic compounds that are responsible for the radical scavenging.

Table 3

Antioxidant Activity of Butea monosperma Extracts (DPPH Radical Scavenging Percentage)

Part	Solvent	DPPH Scavenging (%)
Leaf	Methanol	78.6 ± 1.2
	Ethyl Acetate	52.4 ± 1.8
	Chloroform	20.1 ± 1.3
Flower	Methanol	85.2 ± 0.9
	Ethyl Acetate	60.3 ± 1.4
	Chloroform	18.6 ± 1.1
Bark	Methanol	74.5 ± 1.0
	Ethyl Acetate	50.2 ± 1.7
	Chloroform	22.4 ± 1.5
Seed	Methanol	82.1 ± 0.8
	Ethyl Acetate	58.8 ± 1.3
	Chloroform	19.0 ± 1.4

Figure 4

Antioxidant Activity of Leaf in Various Extracts

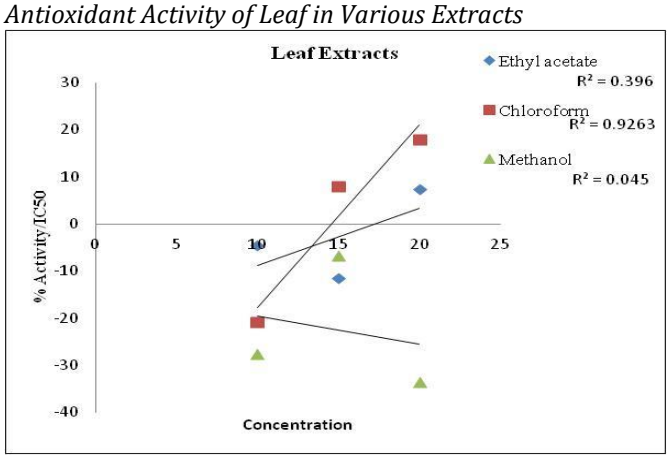


Figure 5

Antioxidant Activity of Flower of B. monosperma in Various Extracts

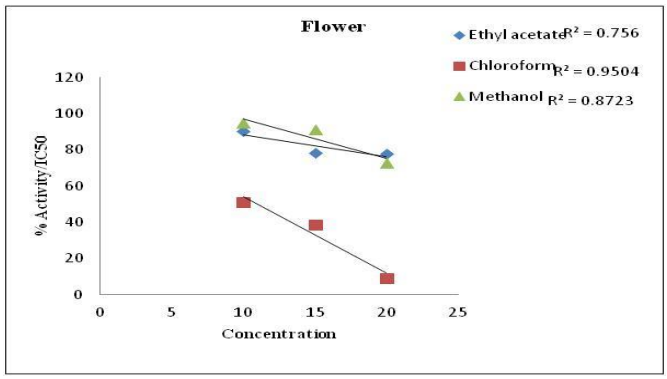


Figure 6

Antioxidant Activity of Bark of B. monosperma in Various Extracts

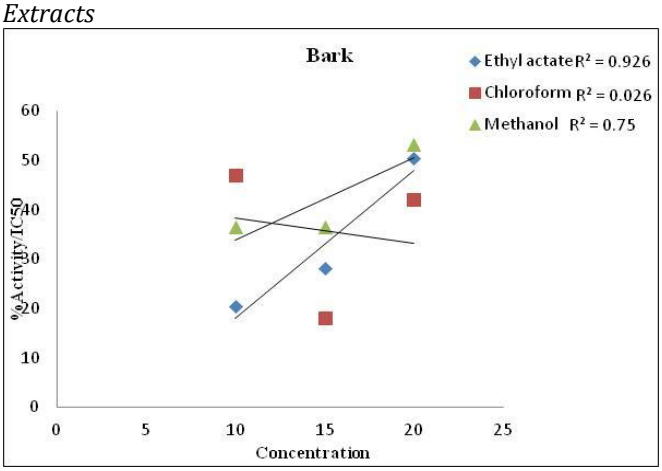
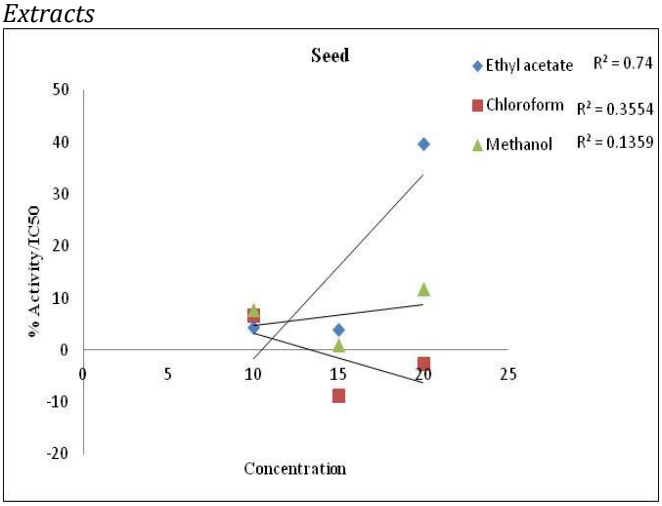


Figure 7

Antioxidant Activity of Seed of B. monosperma in Various Extracts



Hypoglycemic Activity

Ethanol extract of the flower extract of the Butea monosperma was tested for its hypoglycemic effect on alloxan induced diabetic rabbits. After three weeks, blood glucose levels in the treated rabbits were 44 percent lower than in the diabetic control group. Closer to the time these experiments were conducted, blood glucose levels averaged 250 mg/dL in the diabetic rabbits, reduced to approximately 140 mg/dL following treatment. This hypoglycemic potential is suggested by this significant reduction.

Secondly, body weight increased in the treated diabetic rabbits from a mean of 1115 grams to 1584 grams a sign of metabolic improvement and the untreated diabetic group demonstrated slight loss of body weight.

Table 4

Hypoglycemic Effect of Methanolic Flower Extract on Blood Glucose Levels in Diabetic Rabbits

Group	Initial Blood Glucose (mg/dL)	Final Blood Glucose (mg/dL)	Percentage Reduction (%)
Diabetic Control	250 ± 10	245 ± 12	2.0
Diabetic Treated	250 ± 10	140 ± 8	44.0
Normal Control	85 ± 5	85 ± 5	0.0

Figure 8

Effect of Extract of B. monosperma Flower on BGL of Diabetic Treated Group

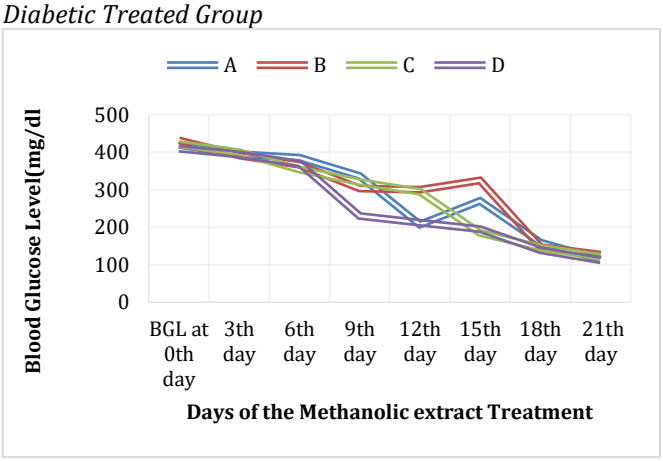


Figure 9

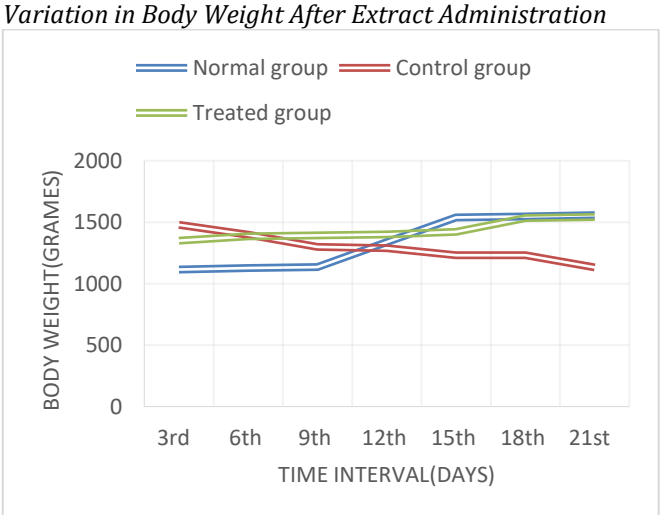
Table 5

Body Weight Changes in Rabbits Post-Treatment

Group	Initial Weight (g)	Final Weight (g)	Weight Change (%)
Diabetic Control	1150 ± 50	1120 ± 45	-2.6
Diabetic Treated	1115 ± 45	1584 ± 60	42.1
Normal Control	1200 ± 50	1205 ± 48	0.4

Figure 10

Variation in Body Weight After Extract Administration



DISCUSSION

This study explored the phytochemical profile and the antibacterial, antioxidant, and hypoglycemic properties of

various extracts from the leaves, flowers, bark, and seeds of *Butea monosperma*. The results strongly support the plant's traditional use in herbal medicine and suggest promising pharmacological potential [22]. Methanol extracts, in particular, demonstrated significant bioactivity, which correlates with their higher content of bioactive compounds. These findings validate the ethnomedicinal uses of *Butea monosperma* and highlight its value as a natural therapeutic agent [23].

Phytochemical analysis revealed the presence of a wide range of compounds, including alkaloids, tannins, flavonoids, sterols, and glycosides, especially in the methanol extracts. These compounds are known for their diverse biological activities and are widely reported in literature for their roles in anti-inflammatory, antioxidant, antimicrobial, and antidiabetic functions. The strong presence of alkaloids may explain the notable antibacterial effects seen in leaf and bark extracts, while tannins and flavonoids contribute to the plant's potent antioxidant properties [24]. The presence of glycosides and sterols, which have been linked to cardioprotective and anti-inflammatory effects, further supports the therapeutic potential of this plant.

Antibacterial activity was most pronounced in the methanol extracts, particularly from the leaves and flowers, which showed significant inhibition against *Pseudomonas aeruginosa*, *Staphylococcus aureus*, and *E. coli*. These results align with earlier reports on the effectiveness of methanol as a solvent for extracting polar bioactive compounds with antimicrobial properties [25]. Ethyl acetate extracts exhibited moderate antibacterial effects, while chloroform extracts showed relatively weak activity, likely due to their inability to dissolve polar phytochemicals. Overall, these findings suggest that *Butea monosperma* is a promising natural source of antibacterial agents, particularly against resistant strains.

The antioxidant capacity of the extracts, measured using the DPPH assay, was highest in the methanolic extracts of leaves and flowers, with activity levels comparable to ascorbic acid [26]. This strong antioxidant potential is likely due to the presence of flavonoids, tannins, and other phenolic compounds, which are known for their radical-scavenging abilities. These findings are consistent with earlier studies that demonstrated the antioxidant potential of *Butea monosperma* leaf extracts. The lower antioxidant activity of ethyl acetate and chloroform extracts may be attributed to their reduced ability to extract these compounds. Given the role of oxidative stress in chronic diseases such as cardiovascular and neurodegenerative disorders, *Butea monosperma* could be explored as a natural antioxidant therapy [27].

The hypoglycemic activity observed in diabetic rabbits treated with *Butea monosperma* flower extract was particularly notable, with a 44% reduction in blood glucose levels over three weeks. This result supports the traditional use of the plant in managing diabetes and aligns with previous studies suggesting its antidiabetic effects [28]. The presence of flavonoids and tannins likely contributes to this effect by enhancing insulin secretion, improving glucose uptake in tissues, and modulating carbohydrate metabolism. Additionally, treated rabbits exhibited weight stabilization compared to the diabetic control group, indicating an overall improvement in metabolic health [29]. These findings underscore the potential of *Butea monosperma* as a complementary treatment for diabetes and its associated complications [30].

CONCLUSION

The findings of this study validate the traditional medicinal use of *Butea monosperma* by demonstrating its rich phytochemical composition and significant biological activities. Methanolic extracts, particularly from the leaves and flowers, were found to contain high concentrations of alkaloids, flavonoids, tannins, and glycosides—compounds known for their therapeutic properties [31]. These extracts exhibited strong antibacterial effects against both Gram-positive and Gram-negative bacteria, potent antioxidant activity comparable to standard antioxidants, and a marked hypoglycemic effect in diabetic rabbit models, confirming the plant's potential in managing infectious, oxidative, and metabolic disorders [32].

Overall, *Butea monosperma* shows promise as a natural source of pharmacologically active compounds. Its demonstrated antibacterial, antioxidant, and hypoglycemic properties support further research for the development of plant-based therapeutics. Future studies should aim to isolate and characterize specific bioactive compounds, evaluate their mechanisms of action, and assess their safety and efficacy through in vivo and clinical investigations [33].

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