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Original article

Phytochemical and antimicrobial properties of different plants and *in silico* investigation of their bioactive compounds in wound healing and rheumatism

Roheena Abdullah *, Qamar Younas, Afshan Kaleem, Mehwish Iqtedar, Mahwish Aftab, Faiza Saleem

Department of Biotechnology Lahore College for Women University, Lahore, Pakistan

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ABSTRACT

In the current study the assessment of the antimicrobial and phytochemical properties of *Cassia fistula, Musa paradisiaca, Ficus religiosa* and *Murraya koenigii* plants extracts was carried out. The antibacterial potential of these plants extracts was tested against *S. aureus* and *E. coli*. The *Cassia fistula* and *Ficus religiosa* leaves showed the larger zone of inhibition in aqueous and butanolic extract respectively against *Escherichia coli. Musa paradisiaca* and *Murraya koenigii* leaves showed larger zone of inhibition in ethanolic extract against *S. aureus*. Qualitative phytochemical analysis showed the presence of alkaloids, flavonoids, phenols, terpenoids, steroids, glycosides, saponins, carbohydrates, proteins and tannins in all extracts while phylobatannins, emodins, anthocyanins and leucoanthocyanins were not present in these extracts. Quantitative phytochemical analysis showed the highest alkaloid content in the *Murraya koenigii* leaves. Highest tannin content and flavonoid content was found in *Ficus religiosa* leaves, while highest phenolic content was found in case of *Cassia fistula*. In addition to this antioxidant potential of all the extracts was determined. *Musa paradisiaca* leaves showed highest antioxidant potential as compared to other plant extracts. *In silico* analysis of bioactive components present in plant extracts was performed by molecular docking. The rutin and Glu from *Musa paradisiaca* and *Murraya koenigii* respectively, were docked with Glycogen Synthase Kinase 3 beta (1GSK-3beta) protein. Quercetin and rutin from *Cassia fistula* and *Ficus religiosa* respectively, were docked with C- reactive protein (CRP). The tested bioactive compounds showed good binding affinity with significant number of hydrogen bonds and can be used as a good alternative of synthetic drugs to treat rheumatism and wounds.

1. Introduction

The production of antibiotics is one of the most effective weapons against microbial illnesses. The need for new medicines has arisen from the evolution of antibiotic resistance by harmful microorganisms. It is important for the production of novel medications with fewer adverse impacts and resistance-building properties. Since ancient times, the plants have been used medicinally, especially in Asia (Seyyednejad et al., 2014).

Any chemical that destroys microbes including bacteria or prevents their proliferation is said to have antibacterial effect. Numerous chemical elements found in medicinal plants have antibacterial properties. These plants are abundant in bioactive molecules, which can be converted into valuable medicines and other bio-reactive compounds that treat a wide range of ailments. Many compounds found in plant parts are the cause of antibacterial properties (Mamta et al., 2021).

Cassia fistula generally regarded as golden shower tree belongs to the family Leguminosae. To cure rhinosinusitis disease, the *Cassis fistula* is utilized by many tribes. It aids in the management of rheumatism, hemoptysis, itching, leukoderma and gastrointestinal issues. A huge number of investigators from all around the globe have investigated how plant extracts influence microorganisms. Numerous secondary metabolites found in plant including tannins, terpenes, flavones, carbohydrates and others, have been reported to show antimicrobial effects (Satpute et al., 2014).

There is evidence that the leaves of *Cassia fistula* have anti-

* Corresponding author.
E-mail addresses: roheena.abdullah@lcwu.edu.pk (R. Abdullah), qamar.younas@lcwu.edu.pk (Q. Younas), afshan.kaleem@lcwu.edu.pk (A. Kaleem), mehwish.iqtedar@lcwu.edu.pk (M. Iqtedar), mahwish.aftab@lcwu.edu.pk (M. Aftab), faiza.saleem@lcwu.edu.pk (F. Saleem).

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inflammatory and wound-healing effects. The leaves of *Cassia fistula* indicate strong antiseptic properties and possess qualities that suggest their traditional use as wide-range of antibacterial agents to prevent various infections. It has also been reported to have anti-inflammatory and glycemic effects (Panda et al., 2011).

Ficus religiosa belongs to the family Moraceae. It is one of the most well-known members of the *Ficus* genus. It is commonly known as a peepal.. Various plant elements like bark, fruit, leaves and stem use in number of medication. In conventional and folk healthcare, its therapeutic benefits have been reported widely. Studies on antibacterial, antimutagenic, antithrombotic, antioxidative, anti-inflammatory, wound healing, cardioprotective and anti-amnesic medications have been reported traditionally. Astringent, antiparasitic, antiulcer and antiviral, antifungal actions are all also well recognized properties. It is efficacious in the management of a number of illnesses, including tumors, dermatitis and other skin problems (Chavan et al., 2019).

Murraya koenigii, generally referred as curry leaves, is a member of the Rutaceae family and is recognized for its distinctive aroma and therapeutic properties. Several bioactive substances, including opioids, phenols, quercetin, saponins, polypeptides and steroids are abundant in *Murraya koenigii*. Traditional medicines employ various portions of this plant to treat a wide range of diseases. It is used as an antispasmodic, antidiarrheal, gastroenteritis, purgative, blood cleanser and seasoning agent in chilies and chetneys in the folk system of medication (Mbachu et al., 2018).

Musa paradisiaca is commonly referred as banana belongs to Musaceae family. Different parts of this plant contain a variety of bioactive substances, including quercetin, tannins, polyphenols, opioids and carbohydrates. *Musa paradisiaca* extracts possess antidiarrheal, reactive hypoglycemia, antioxidants, cardiovascular, wound-healing, anti-allergic, antiseptic, antimalarial and anti-snake venom properties (Naikwade et al., 2015).

Musa paradisiaca is used medicinally in a number of different ways. For instance, the leaf decoction is employed to cure wounds, scratches and bug stings. Traditional healers in Nigeria have utilized banana leaf extract to treat infectious diseases, gastroenteritis, malaria, abdominal discomfort and ulcers. *Musa paradisiaca* leaves contain a lot of fibre, which lowers cholesterol, eases constipation and prevents colorectal cancer by preventing bowel obstruction (Asuquo and Udobi, 2016).

Systemic inflammation in the peripheral joints is a characteristic of the systemic inflammatory disease known as rheumatoid arthritis (RA). One of the biomarkers for the identification of clinical symptoms in rheumatoid arthritis is C-reactive protein (CRP). The processes of inflammation, matrix formation, cell proliferation, and tissue regeneration are all part of the well-coordinated and ordered process of wound healing. It has been demonstrated that the Wnt/b-catenin pathway inhibits the 1GSK-3beta protein to promote wound healing (Ahamed et al., 2013). There is a need to look for alternatives to synthetic medications because they have a lot of adverse effects when used to treat rheumatoid arthritis and wounds (Kim et al., 2015). For the development of new drugs, molecular docking simulation study has become a crucial technique. A bioinformatics technique called molecular docking is employed to assess the effectiveness of different compounds' ability to bind to specific proteins. Phytochemicals present in *Cassia fistula*, *Musa paradisiaca*, *Murraya koenigii* and *Ficus religiosa* extracts can help in preventing the rheumatoid arthritis and wounds by targeting CRP protein and 1GSK-3beta protein.

2. Materials and methods

2.1. Sample collection and preparation of extracts

The leaves of *Cassia fistula*, *Musa paradisiaca*, *Murraya koenigii* and *Ficus religiosa* were collected from Botanical garden of GCU Lahore, Pakistan. All of the leaves were washed, dried in the shade, and ground into a powder in order to prepare the extract. 6 g of each leaf powder was dissolved in 60 ml of each solvent (water, methanol, ethanol and butanol) and kept at 160 rpm for 24 h in case of *Cassia fistula* and *Ficus religiosa*. However, in case of *Musa paradisiaca* and *Murraya koenigii* left for 48 h at room temperature. Then extracts were centrifuged at 4000 rpm for 20 min, the supernatant obtained was used for further testing (Al-Harbi et al., 2016; Asuquo and Udobi, 2016; Prakash et al., 2017; Rana et al., 2017).

2.2. Antimicrobial analysis

Using the disc diffusion method, the antimicrobial potential of all the extracts was assessed against *E. coli* and *S. aureus* (Kulkarni et al., 2015).

2.3. Qualitative phytochemical analysis

Qualitative phytochemical analysis including alkaloids, anthraquinones, protein, flavonoids, saponins, carbohydrates, coumarins, terpenoids, emodins, anthocyanins, leucoanthocyanins, tannins, phlobatannins, phenolic compound and cardiac glycosides test were performed (Anitha and Miruthula, 2014; Rashmi and Naveen, 2016; Prakash et al., 2017; Kumari et al., 2017; Kumaresan et al., 2018; Jyothisree and Umadevi, 2021).

2.4. Quantitative phytochemical analysis

2.4.1. Determination of total alkaloid content

50 ml of 10 % acetic acid was poured to a beaker containing 1.25 g of powder from each plant sample. The mixture was covered and left for 4 h. Following the filtering of the mixture, the extract was concentrated on a water bath until it reached one-quarter of its initial volume. NH_4OH was poured drop by drop until completion of the precipitation. After allowing the solution to settle, the precipitates were collected (Soni and Sosa, 2013).

Using the following formula, the percentage of alkaloid was obtained.

% Alkaloid = Weight of Alkaloid / Weight of Sample × 100.

2.4.2. Determination of flavonoids

In a test tube with 1 ml of distilled water, 0.5 ml of each plant extract was added. 75 µl of 5 % sodium nitrite was added in this solution and left it for 5 min. After five minutes, 75 µl of 10 % aluminum chloride was added. After leaving the mixture for five minutes, 0.5 ml of 1 M NaOH was added, and it was left for fifteen minutes. At 510 nm, the sample's absorbance was measured (Salama et al., 2020).

2.4.3. Determination of total phenolic content

0.6 ml of Folin-Ciocalteu reagent was poured in the test tubes containing 0.5 ml of each plant extract. For five minutes it was left at room temperature. After 5 min 2 ml of 20 % Na_2CO_3 was added and distilled water was used to get the overall volume up to 10 ml. For 90 min the test tubes were placed in dark. After this absorbance was measured at 765 nm (Kulkarni et al., 2015).

2.4.4. Determination of tannins

0.5 ml of the Folin-Ciocalteu reagent and 1 ml of 35 % sodium carbonate were added to 0.1 ml of each plant extract. Distilled water was used to increase the overall volume to 10 ml. The solution was mixed well and left it at room temperature for 30 min. Absorbance of sample was taken at 725 nm by spectrophotometer. Blank was run parallel (Salama et al., 2020).

2.5. Determination of antioxidant activity

Antioxidant potential of each plant sample was evaluated by DPPH free radical scavenging assay (Joshi et al., 2011). The formula used for calculating DPPH radical scavenging activity, which is given as a

percentage of scavenging ability, is as follows:

$$\text{Radical Scavenging Activity}\,(\%) = \frac{(\text{OD of Control} - \text{OD of Sample}}{\text{OD of Control}} \times 100$$

2.6. FTIR analysis

FTIR analysis of aqueous extracts of *Cassia fistula*, *Musa paradisiaca*, *Ficus religiosa* and *Murraya koenigii* was performed to identify different functional groups in these plant extracts (Manisha et al., 2011).

2.7. In silico analysis of plants extracts

Molecular docking of various bioactive compounds existing in *Cassia fistula*, *Musa paradisiaca*, *Murraya koenigii* and *Ficus religiosa* was performed against GSK-3beta (PDB ID; 1H8F) and CRP (PDB ID; 1GNH) proteins. Molecular docking was performed using Galaxy web to check the interaction between proteins and ligands.

3. Results

3.1. Physical properties of plant extracts

The physical properties of various extracts such as *Cassia fistula*, *Musa paradisiaca*, *Murraya koenigii* and *Ficus religiosa* leaves, in different solvents were assessed. Aqueous extract of *Cassia fistula* leaves was dark brown in colour while, ethanol, methanol and butanol extracts of *Cassia fistula* leaves were dark green in color. All the extracts of *Musa paradisiaca* leaves were pine green in color. Aqueous extract of *Murraya koenigii* leaves was brown in colour while ethanol, methanol and butanol extracts were olive green in colour. All *Ficus religiosa* leaves extracts were dark green in color. All the plant extracts were non-viscous in nature (Table S1).

3.2. Antimicrobial activity of extracts

The antibacterial potential of all each extracts was evaluated against *S. aureus* and *E. coli* (Fig. 1&2). All the extracts showed antimicrobial activity against tested bacterial strains. In case of *Cassia fistula* leaves the aqueous extract showed the larger zone of inhibition against *Escherichia coli* (Fig. 1a). However, both *Musa paradisiaca* and *Murraya koenigii* leaves extracts showed larger zone of inhibition in ethanolic extract against *Staphylococcus aureus* (Fig. 2b &c). In case of *Ficus religiosa* leaves extracts the larger zone of inhibition was observed in butanolic extracts against *Escherichia coli* (Fig. 1d).

3.3. Qualitative phytochemical analysis

In the present study qualitative phytochemical analysis of *Cassia fistula*, *Musa paradisiaca*, *Murraya koenigii* and *Ficus religiosa* leaves was carried out. Extracts showed that alkaloids, flavonoids, phenols, terpenoids, steroids, glycosides, saponins, carbohydrates, proteins and tannins were mostly present in these extracts while, phylobatannins, emodins, anthocyanins and leucoanthocyanins were not present in these extracts (Table S2-S5).

3.4. Quantitative phytochemical analysis

In the present study quantitative phytochemical analysis of *Cassia fistula*, *Musa paradisiaca*, *Murraya koenigii* and *Ficus religiosa* leaves extract was performed. Total phenolic, flavonoid, tannin and alkaloid contents of each extract were calculated. The results showed that among leaves of the above plants the highest alkaloid content was present in *Murraya koenigii* leaves and lowest alkaloid content was found in *Cassia fistula* leaves as compared to other extracts (Fig. 3a). Maximum tannin content (0.76 mg TAE/ml) was found in *Ficus religiosa* leaves and minimum tannin content (0.26 mg TAE/ml) was found in *Musa paradisiaca* leaves (Fig. 3b). Maximum phenolic content was found in *Cassia fistula* leaves (0.86 mg GAE/ml) and minimum phenolic content (0.1 mg GAE/ml) was found *Murraya koenigii* leaves (Fig. 3c). Highest flavonoid content (6.92 mg QE/ml) was present in *Ficus religiosa* leaves and lowest flavonoid content (2.96 mg QE/ml) was found in *Musa paradisiaca* leaves (Fig. 3d).

3.5. Determination of antioxidant activity of extracts

In present study antioxidant activity of aqueous extracts of *Cassia fistula* leaves, *Musa paradisiaca* leaves, *Murraya koenigii* leaves and *Ficus religiosa* leaves was determined by DPPH assay. All the extracts possessed antioxidant potential. *Musa paradisiaca* leaves showed highest antioxidant potential in contrast to other plant extracts (Fig. 4).

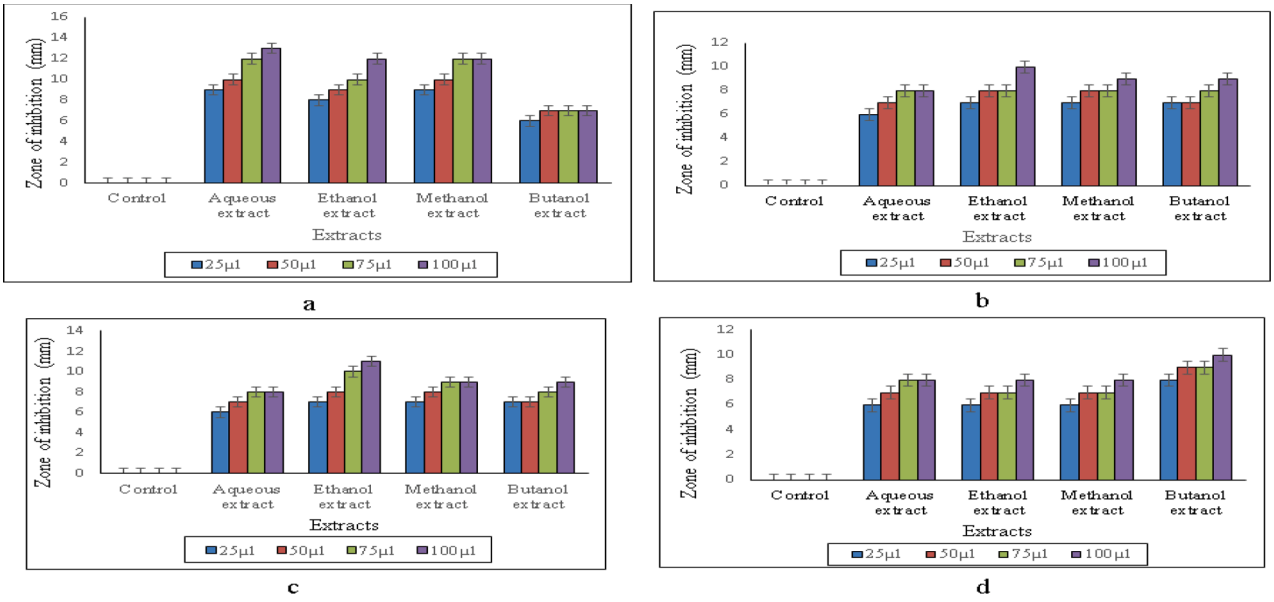


Fig. 1. Determination of antibacterial activity of different extracts of leaves against *Escherichia coli* (a) *Cassia fistula* (b) *Musa paradisiaca* (c) *Murraya koenigii* (d) *Ficus religiosa.*

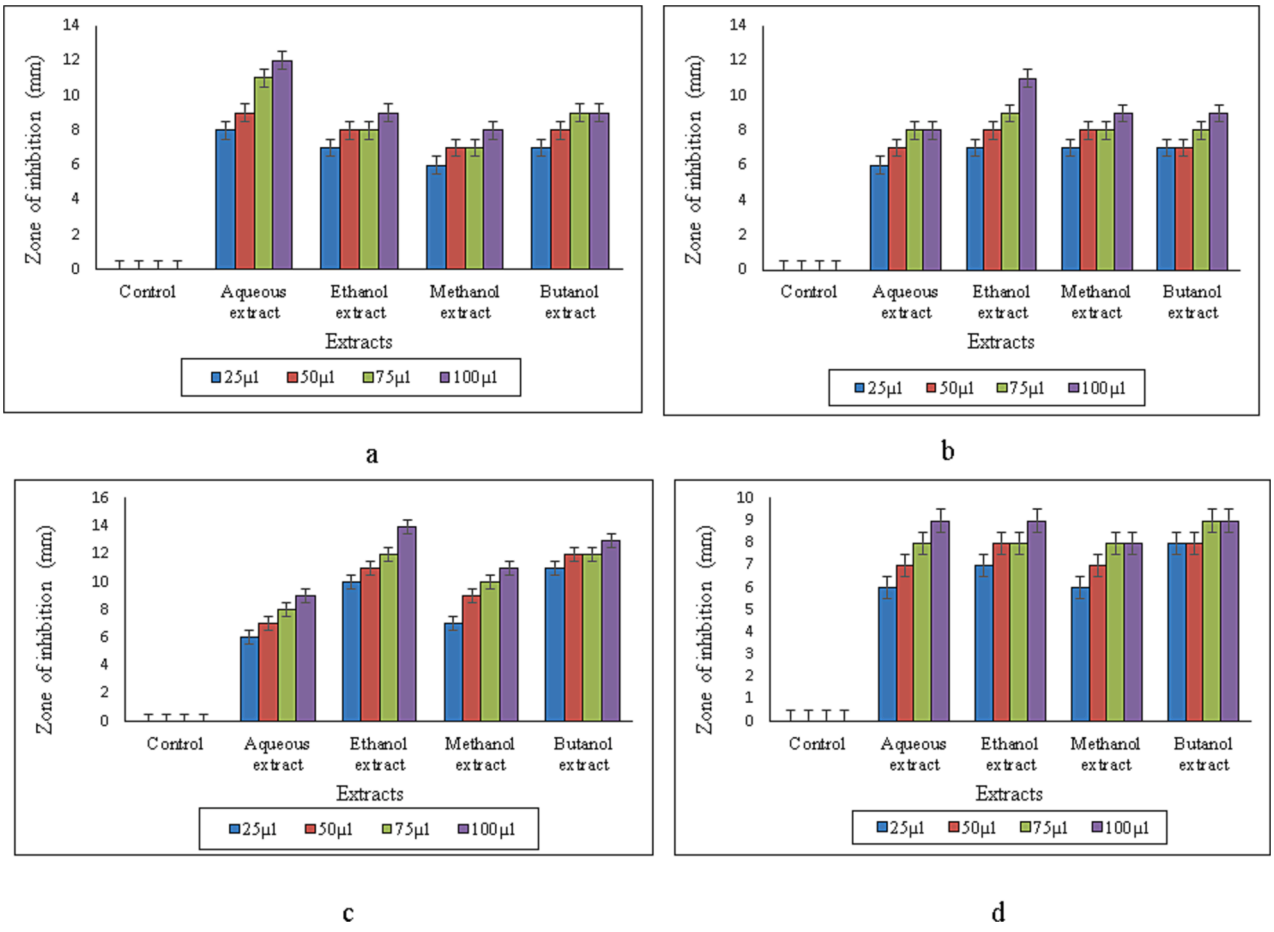


Fig. 2. Determination of antibacterial activity of different extracts of leaves against *Staphylococcus aureus* (a) *Cassia fistula* (b) *Musa paradisiaca* (c) *Murraya koenigii* (d) *Ficus religiosa.*

3.6. FTIR analysis of extracts

FTIR analysis of an aqueous leaf extract revealed a number of peaks that corresponded to distinct functional groups in the extracts (Fig. 5a-d).

3.7. In silico analysis

Molecular docking of the bioactive compounds Rutin, quercetin and Glu of *Cassia fistula, Musa paradisiaca, Murraya koenigii* and *Ficus religiosa* was performed with 1GSK-3beta protein (PDB ID; 1H8F) and CRP protein (PDB ID; 1GNH).

3.7.1. Binding of ligands to 1GSK-3beta protein

Interactions of ligands rutin and glutamic acid with 1GSK-3beta protein (PDB ID; 1H8F) are shown in Figs. 6&7. Various hydrophobic interactions and hydrogen bonds were established between ligands and proteins. Rutin and glutamic acid were shown to form 2 and 1 hydrogen bonds, respectively. Table1 explains the amino acids involves in interaction with 1GSK-3beta protein, type of bonding, length of hydrogen bond and binding site of protein and ligands. The structure of protein was downloaded from Protein data bank (https://www.rcsb.org/). The different compounds were selected with the help of FTIR. The spectra were compared with compounds retrieved from the PubChem database (https://pubchem.ncbi.nlm.nih.gov/). The compound which showed the peaks of their functional groups were selected for docking.

3.7.2. Binding of ligands to CRP protein

Interactions of ligands quercetin and rutin with CRP protein (PDB ID; 1GNH) are shown in Figs. 8 & 9 Various hydrophobic interactions and hydrogen bonds were established between ligands and proteins. It was observed that only 1 hydrogen bond was formed with quercetin and rutin. Table1 explains the amino acids involves in interaction with CRP protein, type of bonding, length of hydrogen bond and binding site of protein and ligands. The structure of protein was downloaded from Protein data bank (https://www.rcsb.org/) and ligands structures were downloaded from PubChem (https://pubchem.ncbi.nlm.nih.gov/).

4. Discussion

Medicinal plants are generally source of various phytochemicals; few of them are usually cause of biological activities. Many different types of constituents are present in plant extracts that are used in natural remedies and cure a variety of microbial infections. Numerous chemical elements found in medicinal plants have antibacterial properties (Ugboko et al., 2020).

In this study, antibacterial potential of different extracts of *Cassia fistula, Musa paradisiaca, Murraya koenigii* and *Ficus religiosa* leaves was determined against *Escherichia coli* and *Staphylococcus aureus*. In case of *Cassia fistula* leaves the aqueous extract showed the larger zone of inhibition against *Escherichia coli*. Antibacterial activity showed by aqueous extract of *Cassia fistula* leaves was might be due to the presence of important secondary metabolites (Seyyednejad et al., 2014). Our study is in line with Rabha et al. (2021) who reported that the aqueous extract of *Cassia fistula* exhibited higher antimicrobial activity against Gram negative bacteria.

In case of *Musa paradisiaca* leaves ethanolic extract showed larger zone of inhibition against *Staphylococcus aureus*. The larger zone of

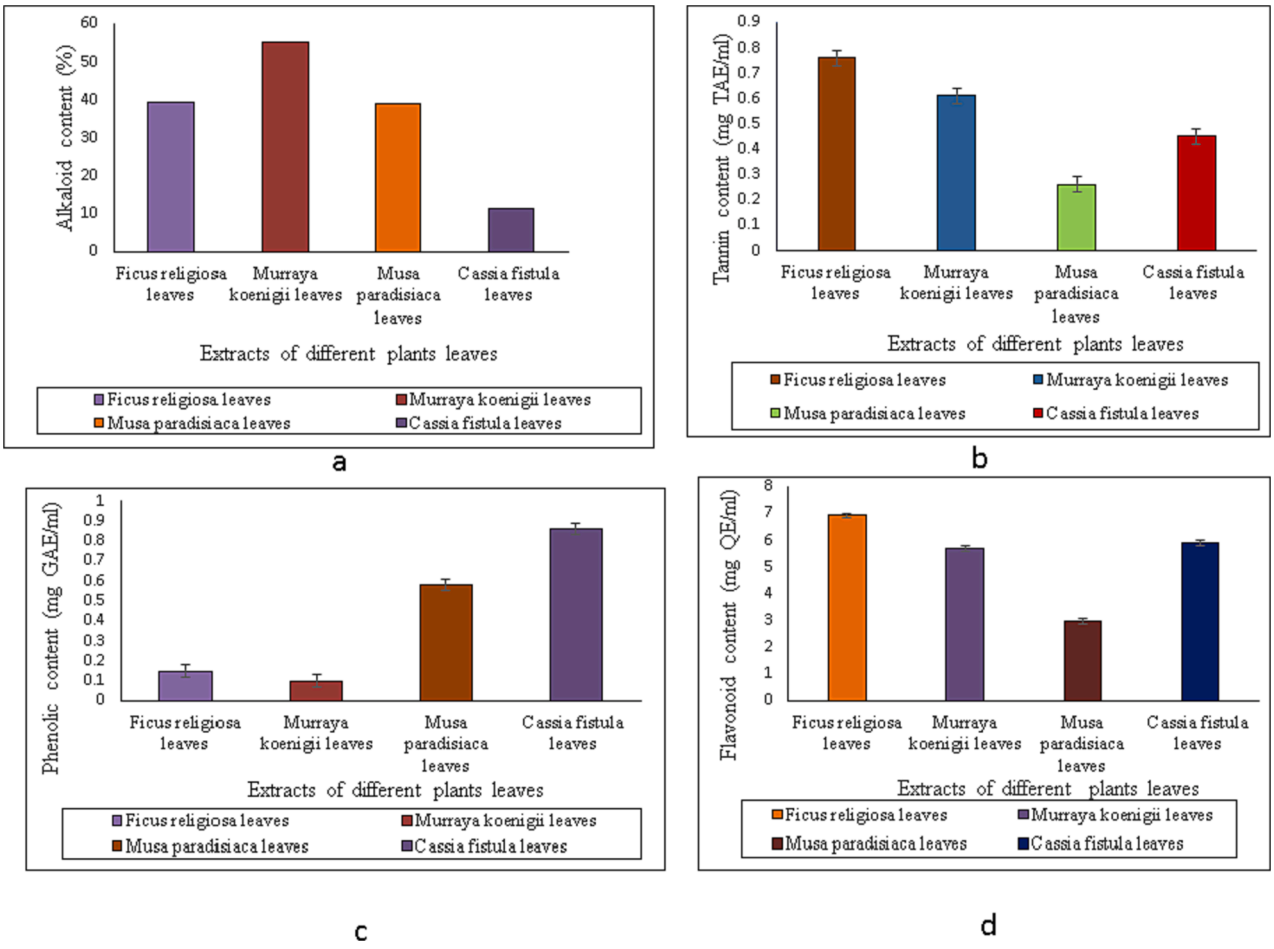


Fig. 3. Determination of different phytochemicals in aqueous extracts of *Ficus religiosa* leaves, *Murraya koenigii* leaves, *Musa paradisiaca* leaves and *Cassia fistula* leaves (a) alkaloid content (b) tannin content (c) phenolic content (d) flavonoid content.

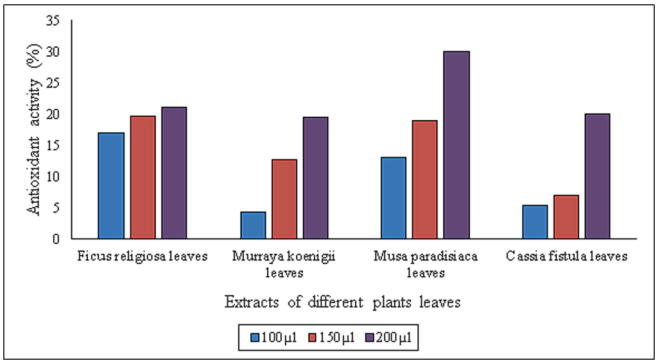


Fig. 4. Determination of antioxidant activity in aqueous extracts of *Ficus religiosa* leaves, *Murraya koenigii* leaves, *Musa paradisiaca* leaves and *Cassia fistula* leaves.

inhibition in ethanolic extract was might be due to its high polarity and also it is an ideal solvent (Ramli et al., 2017). Our results are in agreement with Egbuonu et al. (2016) who also reported that the ethanolic extract of *Musa paradisiaca* leaves showed larger zone of inhibition against *Staphylococcus aureus*. However, ethanolic extract of *Murraya koenigii* leaves showed the larger zone of inhibition against *Staphylococcus aureus*. Our study is in agreement with Kavitha (2017) who also reported that ethanolic extract of *Murraya koenigii* leaves showed larger zone of inhibition against *Staphylococcus aureus*. The larger zone of inhibition in ethanolic extract is might be due to its high polarity (Ramli et al., 2017). The *Ficus religiosa* leaves, butanolic extract exhibited the larger zones of inhibition against *Escherichia coli*. Our study is in agreement with Chavan et al. (2019) according to which butanolic extract showed larger zone of inhibition against *Escherichia coli*. The presence of significant bioactive compounds in butanolic extract as compared to other solvents may have contributed to the bigger zone in that extract (Vedulla et al., 2013).

The majority of plants are suppliers of several phytochemicals that are primarily responsible for their biological actions. Because of its analgesic, antispasmodic, and antibacterial effects, alkaloid is one of the most effective therapeutically significant bioactive substances in plants (Harriet et al., 2020). The presence of flavonoids in plant samples is responsible for biological functions such as anti-oxidation, and protection against allergies. In present study, qualitative phytochemical analysis of *Cassia fistula*, *Musa paradisiaca*, *Murraya koenigii* and *Ficus religiosa* leaves was performed. Extracts showed that alkaloids, flavonoids, phenols, glycosides terpenoids, saponins, steroids, carbohydrates, proteins and tannins were mostly present in these plant extracts while, phylobatannins, emodins, anthocyanins and leucoanthocyanins were not present in these extracts. Our results are compatible to Rashmi and Naveen (2016) and Panda et al. (2011) who also reported similar results.

In current study, quantitative phytochemical test including total tannin content, phenolic content, flavonoid content and alkaloids content of aqueous extracts of *Cassia fistula*, *Musa paradisiaca*, *Murraya koenigii* and *Ficus religiosa* were done. The results showed that highest alkaloid content was present in *Murraya koenigii* leaves as compared to other extracts. Our results are similar to Uraku and Nwankwo (2015) who reported maximum alkaloid content in *Murraya koenigii* leaves.

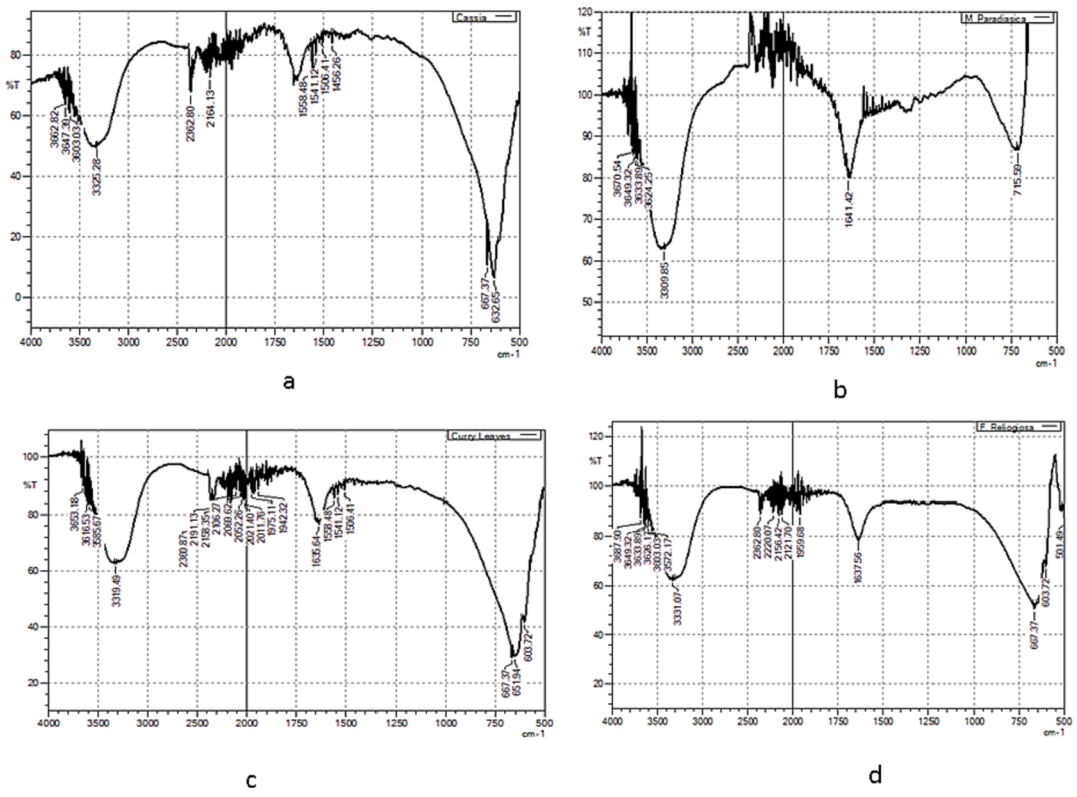


Fig. 5. FTIR analysis of aqueous extract (a) *Cassia fistula* leaves (b) *Musa paradisiaca* leaves (c) *Murraya koenigii* leaves (d) *Ficus religiosa* leaves.

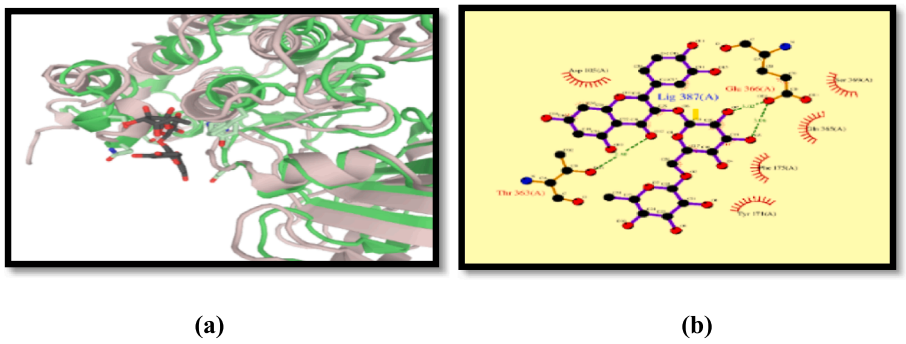


Fig. 6. Molecular docking of rutin ligand with 1GSK-3beta protein (a) 3D structure of interaction of rutin with 1GSK-3beta protein (b) Residues in contact of 1GSK-3beta protein with rutin.

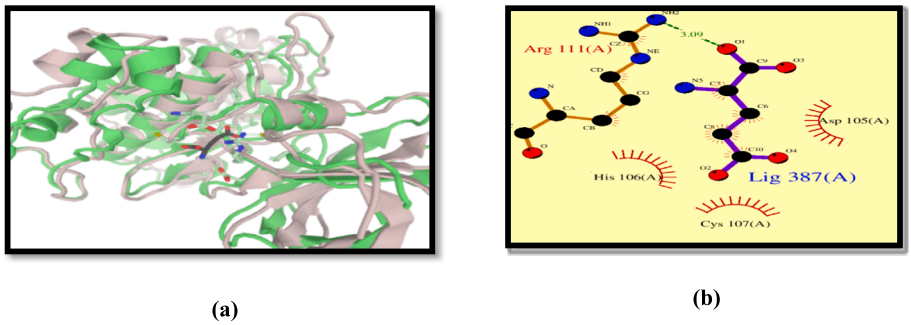


Fig. 7. Molecular docking of glutamic acid with 1GSK-3beta protein (a) 3D structure of interaction of glutamic acid ligand with 1GSK-3beta protein (b) Residues in contact of 1GSK-3beta protein with Glu.

Table 1
Binding of different ligands with 1GSK-3beta protein and CRP protein. (HB = hydrogen bond, HI = Hydrophobic interactions).

Ligand	1GSK-3beta	Types of bonds	Length (A)	Ligand AA binding sites
Rutin	Glu 366	HB	3.02, 3.06	OE2-O7, E2-O5
	Thr 363	HB	2.80	OG1-O12
	Ser 369	HI		
	Gln 365	HI		
	Phe 175	HI		
	Asp 105	HI		
	Tyr 171	HI		
Glutamic acid	Arg 111	HB	3.09	NH_2.O1
	Asp 105	HI		
	His 106	HI		
	Cys 107	HI		
Ligand	**CRP**	**Types of bonds**	**Length (A)**	**Ligand AA binding sites**
Quercetin	Asn 158	HB	3.07	OD1-O2
	Pro 182	HI		
	Trp 187	HI		
	Leu 190	HI		
	Asn 160	HI		
	Met 4	HI		
	Lys 7	HI		
	Phe 9	HI		
	Gly 157	HI		
Rutin	Thr 98	HB	2.87	OG1-O8
	Phe 33	HI		
	Phe 52	HI		
	Val 34	HI		
	Phe 109	HI		
	Met 161	HI		
	Leu 185	HI		
	Leu 26	HI		
	Leu 190	HI		
	Trp 187	HI		
	Leu 22	HI		
	Tyr 54	HI		
	Ile 133	HI		
	Val 159	HI		
	Leu 37	HI		
	Phe 75	HI		
	Ile 96	HI		
	Ile 65	HI		

Highest tannin content and flavonoid content was found in *Ficus religiosa* leaves. Our results are similar to Ghadigaonkar et al. (2021) who reported similar tannin, flavonoid content in *Ficus religiosa* leaves.

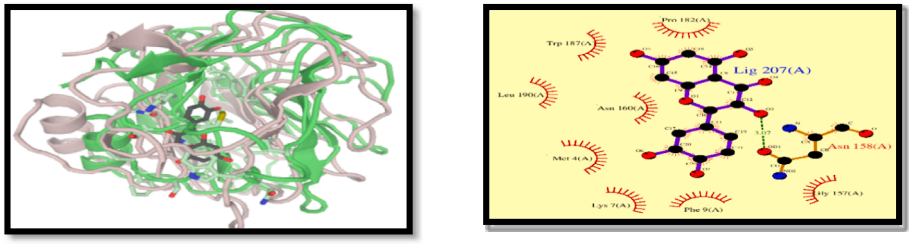
In current investigation antioxidant potential of aqueous extracts of *Cassia fistula*, *Musa paradisiaca*, *Murraya koenigii* and *Ficus religiosa* was evaluated using DPPH assay. The present findings indicated that antioxidant level of extracts increased with increase in their concentrations. This might be due to the occurrence of more antioxidant compounds such as phenols, flavonoids and terpenoids in greater concentrations of extracts. Results of the study indicated that *Musa paradisiaca* leaves showed highest antioxidant potential (30 %) in 200 µl of concentration. Our study is in agreement with the Karuppiah and Mustaffa (2013) who also reported similar results.

Functional groups present in *Cassia fistula*, *Musa paradisiaca*, *Murraya koenigii* and *Ficus religiosa* extracts was determined using FTIR analysis. FTIR spectra of all the extracts showed different peaks in the range between 500 and 4000 cm^{-1}. FTIR spectrum of *Cassis fistula* showed Quercetin and benzoic acid were present in this plant extract, rutin and quercetin were present in *Musa paradisiaca,* aspartic acid and vanillic acid were present in *Murraya koenigii* and rutin was present in plant extract of *Ficus religiosa.* Results of FTIR analysis of the extracts revealed the existence of several compounds that may be the responsible for the extracts' antibacterial, antioxidant, and other biological activities (Sujatha and Asokan, 2018).

The rutin and glutamic acid from *Musa paradisiaca*, *Murraya koenigii* respectively, were docked with 1GSK-3beta (PDB ID; 1H8F) protein. By matching their FTIR peaks from PubChem with the FTIR spectra of the studied plant extracts, the ligands were chosen. 1GSK3 beta is important for Wnt signaling (Wingless related integrated site), and studies have indicated that blocking 1GSK-3beta protein can improve wound healing.

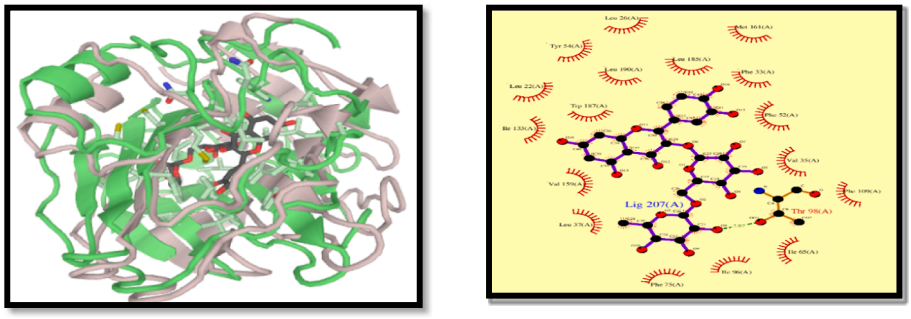
The process of wound healing is a well-coordinated and ordered sequence of events that involves inflammation, matrix deposition, cell proliferation, tissue modeling and epithelialization (Ahamed et al., 2013). It was shown that rutin and glutamic acid effectively bind with the target protein. Rutin showed hydrogen bonding and hydrophobic interaction with Glu 366, Thr 363, Asp 105, Arg 113, Asp 133, Glu 80, Lys 197, Cys 107, Arg 167, Ser 369, Gln 365, Phe 175, Tyr 171, Leu 359 and Arg 111. Whereas glutamic acid binds with hydrogen bonding and hydrophobic interactions with Arg 111, Asn 361, Arg 167, Asp 105, His 106 and Cys 107, which are the amino acids lie in the domain ranging from 56 to 370. The results showed that GSK-3β usually phosphorylates β-catenin on Ser and Thr residues, resulting in the targeting of β-catenin for degradation. Mesenchymal cells have significant levels of β-Catenin expression during the proliferative stage of wound healing, and it is overexpressed in fibroblast hyperproliferative conditions such as fibromatosis and hyperplastic scars. The results revealed that Glu and rutin inhibits the activity of protein binding with the catalytic site of domain, and promote the process of wound healing (Kapoor et al., 2008). Better stability with 1GSK-3beta protein is suggested by models that exhibit strong binding energy, establish hydrogen bonds, and interact hydrophobically with active sites.

Quercetin and rutin from *Cassia fistula* and *Ficus religiosa* respectively, were docked with C- reactive protein (PDB ID; 1GNH). The clinical use of CRP level as a sensitive marker of inflammation, such as in rheumatism, is widespread. Rheumatism is actually an inflammation in joints, muscles and surrounding soft tissue. The elimination of bacteria and of dying altered cells is aided by this protein. It was suggested that quercetin and rutin compounds efficiently bind with CRP protein with significant number of hydrogen bonds (Kim et al., 2015). Quercetin binds with Asn 158, Pro 182, Trp 187, Leu 190, Asn 160, Met 4, Lys 7, Phe 9 and Gly 157 with hydrogen and hydrophobic interactions. Rutin shows hydrogen and hydrophobic interactions with Thr 98, Phe 33, Phe



(a) (b)

Fig. 8. Molecular docking of quercetin ligand with CRP protein (a) 3D structure of interaction quercetin ligand with CRP protein (b) Residues in contact of quercetin with CRP protein.



(a) (b)

Fig. 9. Molecular docking of of rutin ligand with CRP protein (a) 3D structure of interaction of rutin ligand with CRP protein (b) Residues in contact of rutin ligand with CRP protein.

52, Val 34, Phe 109, Met 161, Leu 185, Leu 26, Leu 190, Trp 187, Leu 22, Tyr 54, Ile 133, Val 159, Leu 37, Phe 75, Ile 96 and Ile 65, these are the amino acids present in the domain range between 23 and 224. The results showed that quercetin and rutin inhibit the activity of protein binding with the active site of domain, and suppress the process of rheumatism (Alyan et al., 2009). It is concluded that the tested bioactive compounds show good binding affinity with significant number of hydrogen bonds and it may be effective substitute of synthetic drugs to treat rheumatism and wounds.

5. Conclusion

In current investigation the antibacterial, phytochemical and antioxidant potential of *Cassia fistula*, *Musa paradisiaca*, *Murraya koenigii* and *Ficus religiosa* leaves was evaluated. It was indicated that all the plant extracts possessed good antibacterial and antioxidant potential. Various important phytochemicals were found in these plant extracts that are responsible for several biological activities. FTIR analysis exhibited the occurrence of several functional groups in plant extracts. *In silico* analysis revealed that tested bioactive compounds found in all plant extracts possessed good binding affinity to target protein and could be an effective substitute of synthetic drugs to treat rheumatism and wounds. So, *Cassia fistula, Musa paradisiaca*, *Murraya koenigii* and *Ficus religiosa* leaves may be a useful source of secondary metabolites and possessed significant antibacterial and antioxidant potential that could substitute synthetic drugs to prohibit the wounds and rheumatism.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Appendix A. Supplementary material

Supplementary data to this article can be found online at https://doi.org/10.1016/j.sjbs.2024.103942.

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