

Original Research Article

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Synergistic Effect of Corn Silk Infused Antibiotic Hydrogel against MDR Pathogen of Burn Wound Infection

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ABSTRACT

Multidrug-resistant bacterial and fungal pathogens associated with burn wound infections represent a significant therapeutic challenge, highlighting the need for alternative or complementary antimicrobial strategies. This study evaluated the antimicrobial potential of an ethanolic extract of corn silk (*Zea mays* L.) against multidrug-resistant clinical isolates of *Staphylococcus aureus*, *Pseudomonas aeruginosa*, *Klebsiella pneumoniae*, and *Candida albicans*. Clinical isolates previously recovered from secondary burn wound infections were cultured on selective and differential media and identified using standard microbiological and biochemical methods. Corn silk was processed by washing, blanching, air-drying, grinding, and ethanolic extraction under orbital shaking at room temperature for 48 h. The antimicrobial activity of the extract, alone and in combination with selected antimicrobial agents, was assessed using a modified disk diffusion method. Inhibition-zone diameters were measured to compare the activity of the individual treatments and combinations. In addition, molecular docking analysis was performed to investigate the interaction of maysin, a reported corn-silk constituent, with the PelBC outer-membrane exopolysaccharide transporter of *P. aeruginosa*. Docking analysis was conducted using PyMOL and MzDOCK, with a reported binding-affinity value of -11.6 . Increases in inhibition-zone diameter were considered descriptive evidence of enhanced antimicrobial activity rather than definitive proof of synergy. Overall, the study provides an experimental framework for evaluating ethanolic corn silk extract as a potential adjunct to conventional antimicrobial agents against multidrug-resistant pathogens associated with burn wound infections.

Keywords

Zea mays; corn silk;
burn wound infection;
multidrug resistance;
antimicrobial activity;
carboxymethylcellulose hydrogel; maysin;
molecular docking

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Introduction

Burn injuries are associated with extensive disruption of the skin barrier, tissue necrosis, impaired local defense

mechanisms, and alterations in systemic immune responses, making patients particularly susceptible to microbial colonization and infection. Burn wound infections remain an important cause of morbidity and

mortality, particularly in patients with extensive burns, prolonged hospitalization, repeated surgical procedures, and exposure to healthcare-associated microorganisms. The microbiological characteristics of burn wounds may change during hospitalization, with Gram-positive organisms often predominating during the early period and Gram-negative and multidrug-resistant (MDR) organisms becoming increasingly important during prolonged hospitalization (Greenhalgh & Kiley, 2024; Roy *et al.*, 2024; Tiseo *et al.*, 2026).

Recent reviews have emphasized the increasing clinical importance of MDR pathogens in burn patients and the need for improved infection-control practices, antimicrobial stewardship, rapid microbiological diagnosis, and development of alternative therapeutic strategies (Elsheikh & Makram, 2024; Hagiga & Dheansa, 2024; Hemmati *et al.*, 2023).

Among the organisms associated with burn wound infections, *Staphylococcus aureus*, *Pseudomonas aeruginosa*, and *Klebsiella pneumoniae* are important bacterial pathogens, while *Candida* species may contribute to opportunistic fungal infections in susceptible patients. *P. aeruginosa* is of particular concern because of its intrinsic resistance mechanisms, capacity to acquire additional resistance determinants, and ability to form biofilms (Liu, *et al.*, 2024). *K. pneumoniae* is similarly important because of the emergence and dissemination of extended-spectrum β -lactamase- and carbapenemase-producing strains. *S. aureus*, including methicillin-resistant *S. aureus* (MRSA), remains a significant pathogen in wound and burn infections. Recent evidence continues to identify these organisms among important MDR pathogens encountered in burn and wound settings (Hemmati *et al.*, 2023; Roy *et al.*, 2024).

The PelBC complex functions as an outer-membrane export system involved in Pel exopolysaccharide secretion. Recent structural studies have provided detailed information regarding the architecture and gating mechanism of the PelBC complex, making this system a potentially relevant molecular target for investigating compounds that may interfere with *P. aeruginosa* biofilm-associated processes (Benedens *et al.*, 2025).

Corn silk, the stigma and style of *Zea mays* L., is an abundant agricultural by-product that has been used traditionally in different medicinal systems (Zang, *et al.*, 2023). Although frequently discarded during maize

processing, corn silk contains a diverse range of potentially bioactive constituents. Phytochemical investigations have identified flavonoids, phenolic acids, polysaccharides, terpenoids, sterols, saponins, and other compounds in corn silk extracts (Rau *et al.*, 2023; Wang *et al.*, 2024). Experimental studies have also provided evidence for antimicrobial activity associated with corn silk extracts (Ding, *et al.*, 2026). Yucharoen *et al.*, (2023) investigated the phytochemical composition and antibacterial activity of corn silk extracts against skin-associated pathogenic bacteria and demonstrated that corn silk contains constituents with measurable biological activity. Structural characterization of PelBC has increased understanding of how Pel polysaccharide is transported across the bacterial envelope and has provided a molecular framework for investigating potential interactions with small molecules (Benedens *et al.*, 2025).

Therefore, the present study investigated the antimicrobial activity of an ethanolic extract of corn silk against MDR clinical isolates of *S. aureus*, *P. aeruginosa*, *K. pneumoniae*, and *C. albicans* recovered from secondary burn wound infections. The study further evaluated the activity of the corn silk extract in combination with selected antimicrobial agents using a modified disk diffusion approach. In addition, molecular docking was used to investigate the reported interaction of maysin with the PelBC outer-membrane exopolysaccharide transporter of *P. aeruginosa*. Together, these approaches were used to generate preliminary microbiological and computational evidence regarding the potential of corn silk-derived bioactive compounds as candidates for further investigation against MDR pathogens associated with burn wound infections.

Materials and Methods

Clinical isolates and identification

Multidrug-resistant isolates of *S. aureus*, *P. aeruginosa*, *K. pneumoniae*, and *C. albicans* were provided by private laboratory and had previously isolated from secondary burn wound infections. The organisms were cultivated on mannitol salt agar, cetrimide agar, chocolate agar, and blood agar, respectively. Bacterial cultures were incubated at 37 °C for 16 h, while fungal cultures were incubated at 25 °C for 24 h. Identification and purity were assessed using Gram staining, KOH mount, catalase, oxidase, IMViC, and coagulase tests, as applicable.

Preparation of ethanolic corn silk extract

Corn silk collected from healthy *Zea mays* L. plants was washed, separated using sterile forceps, stored at 4 °C, blanched at 100 °C for 60 s, and air-dried for 3 days. The dried material was ground to a coarse powder. Five grams of powder were dispersed in 50 mL ethanol and extracted on an orbital shaker at room temperature for 48 h. The extract was filtered through Whatman No. 1 filter paper. The dried extract was weighed and stored in sterile amber vials at 4 °C.

Combination testing

Corn silk extract was evaluated with selected antimicrobial agents using a modified disk diffusion approach. Antimicrobial-only and extract-only disks served as controls. Combination disks contained 25 or 50 µL of extract, as reported.

Inhibition-zone diameters were measured after incubation. Increases in zone diameter were interpreted as descriptive evidence of enhanced activity; formal synergy was not inferred from zone-size changes alone.

Molecular docking

The source study examined the interaction of the reported corn-silk constituent maysin with the PelBC outer-membrane exopolysaccharide transporter of *P. aeruginosa*. Structures were reported to have been obtained from the RCSB Protein Data Bank, and docking was performed using PyMOL and MzDOCK. The reported binding-affinity value was -11.6. The target identifier and complete docking protocol were not specified in the supplied dataset.

Results and Discussion

Clinical isolates and reported susceptibility findings

Four clinical isolates were examined: *S. aureus*, *P. aeruginosa*, *K. pneumoniae*, and *C. albicans*. The source study reported resistance to several tested agents. Measurable inhibition zones included ceftriaxone, 30 mm, and imipenem, 12 mm, for *S. aureus*; ceftriaxone, 15 mm, for *P. aeruginosa*; ceftazidime, 29 mm, and ceftriaxone, 33 mm, for *K. pneumoniae*; and ketoconazole, 32 mm, for *C. albicans*.

Antimicrobial activity of corn silk extract

At the reported test volume of 100 µL, the extract produced inhibition zones of 32 mm against *P. aeruginosa*, 34 mm against *S. aureus*, 39 mm against *K. pneumoniae*, and 14 mm against *C. albicans* (Table 1; Figure 1).

Growth kinetics

OD600 increased for all four organisms through approximately 12 h and then declined through 18 h in the supplied dataset (Table 2; Figure 2). *P. aeruginosa* showed the highest reported OD600 at 12 h (1.35 ± 0.040), followed by *S. aureus* (1.20 ± 0.030), *K. pneumoniae* (1.15 ± 0.030), and *C. albicans* (1.00 ± 0.028).

Combination activity

Ceftriaxone plus 25 µL corn silk extract produced inhibition zones of 37 mm for *S. aureus*, 35 mm for *P. aeruginosa*, and 39 mm for *K. pneumoniae*, compared with 30, 15, and 35 mm for ceftriaxone alone, respectively. Ketoconazole plus 25 µL extract produced a 39-mm zone against *C. albicans* compared with 32 mm for ketoconazole alone (Table 3; Figure 3).

Additional increases were reported for ampicillin plus extract and nystatin plus extract (Table 4).

Hydrogel and docking findings

A CMC-based corn silk hydrogel was prepared. However, the supplied dataset does not report quantitative measurements of swelling, rheology, mechanical properties, release kinetics, antimicrobial performance of the finished hydrogel, cytocompatibility, or storage stability. Molecular docking of maysin with the reported PelBC target yielded an affinity value of -11.6.

Synergistic effect of cornsilk extract with antibiotic were tested for clinical isolates. For the same, among tested two were selected, antibiotic that showed activity against most of the clinical isolates and the antibiotic with no or significant activity. This is to know the synergistic mechanism of corn silk with antibiotic to administer and develop solutions for antibiotic resistant microbial diseases and their treatment.

Table.1 Antimicrobial activity of ethanolic corn silk extract.

Organism	Inhibition zone (mm), 100 µL extract
Pseudomonas aeruginosa	32
Staphylococcus aureus	34
Klebsiella pneumoniae	39
Candida albicans	14

Table.2 Reported growth-curve measurements.

Time (h)	S. aureus	P. aeruginosa	K. pneumoniae	C. albicans
0	0.05 ± 0.002	0.05 ± 0.003	0.04 ± 0.002	0.03 ± 0.001
2	0.12 ± 0.004	0.14 ± 0.006	0.10 ± 0.004	0.08 ± 0.003
4	0.28 ± 0.010	0.34 ± 0.012	0.26 ± 0.010	0.20 ± 0.008
6	0.58 ± 0.020	0.68 ± 0.025	0.54 ± 0.020	0.42 ± 0.015
8	0.89 ± 0.030	1.02 ± 0.040	0.82 ± 0.030	0.70 ± 0.025
10	1.12 ± 0.040	1.28 ± 0.045	1.05 ± 0.040	0.92 ± 0.030
12	1.20 ± 0.030	1.35 ± 0.040	1.15 ± 0.030	1.00 ± 0.028
14	1.18 ± 0.025	1.32 ± 0.035	1.13 ± 0.025	0.98 ± 0.026
16	1.05 ± 0.020	1.15 ± 0.030	0.98 ± 0.020	0.85 ± 0.020
18	0.90 ± 0.030	0.96 ± 0.028	0.82 ± 0.030	0.72 ± 0.022

Table.3 Selected antimicrobial combinations.

Organism	Reference antimicrobial	Alone (mm)	+ 25 µL extract (mm)	Difference (mm)
P. aeruginosa	Ceftriaxone	15	35	20
S. aureus	Ceftriaxone	30	37	7
K. pneumoniae	Ceftriaxone	35	39	4
C. albicans	Ketoconazole	32	39	7

Table.4 Additional reported combinations.

Organism	Antimicrobial	Alone (mm)	+ 25 µL extract (mm)	+ 50 µL extract (mm)
S. aureus	Ampicillin	0	33	35
P. aeruginosa	Ampicillin	0	12	25
K. pneumoniae	Ampicillin	0	22	28
C. albicans	Nystatin	0	25	27

Figure.1 Antimicrobial activity of ethanolic corn silk extract against the reported clinical isolates. Bars represent inhibition-zone diameters for 100 μ L extract.

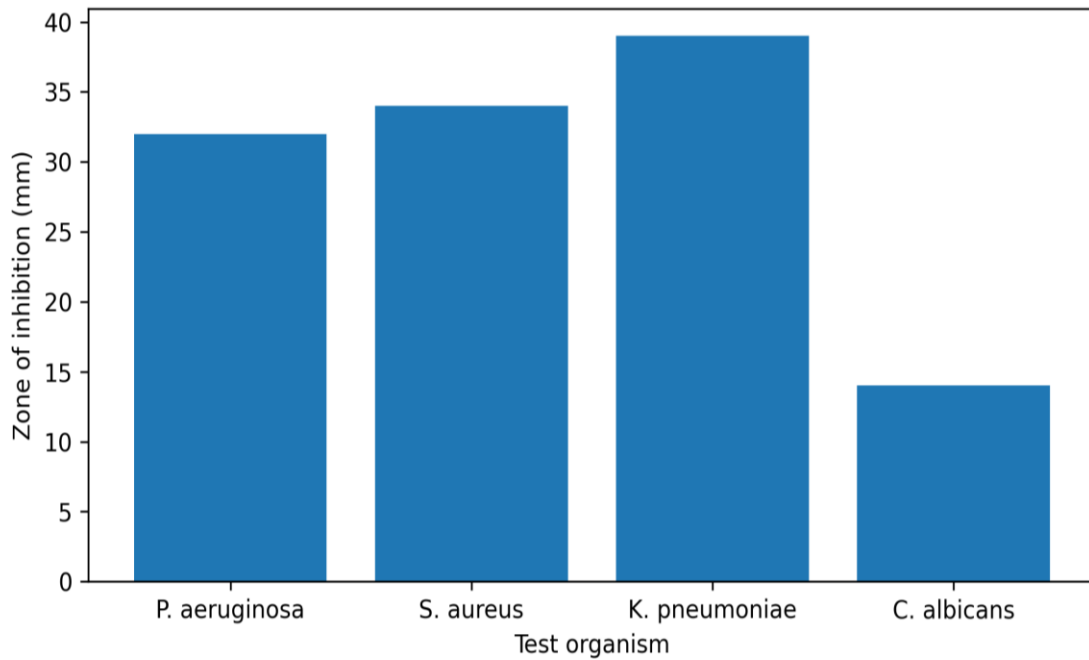


Figure.2 Growth kinetics of the reported clinical isolates measured by OD600 over 18 h. Values are reproduced from the supplied dataset.

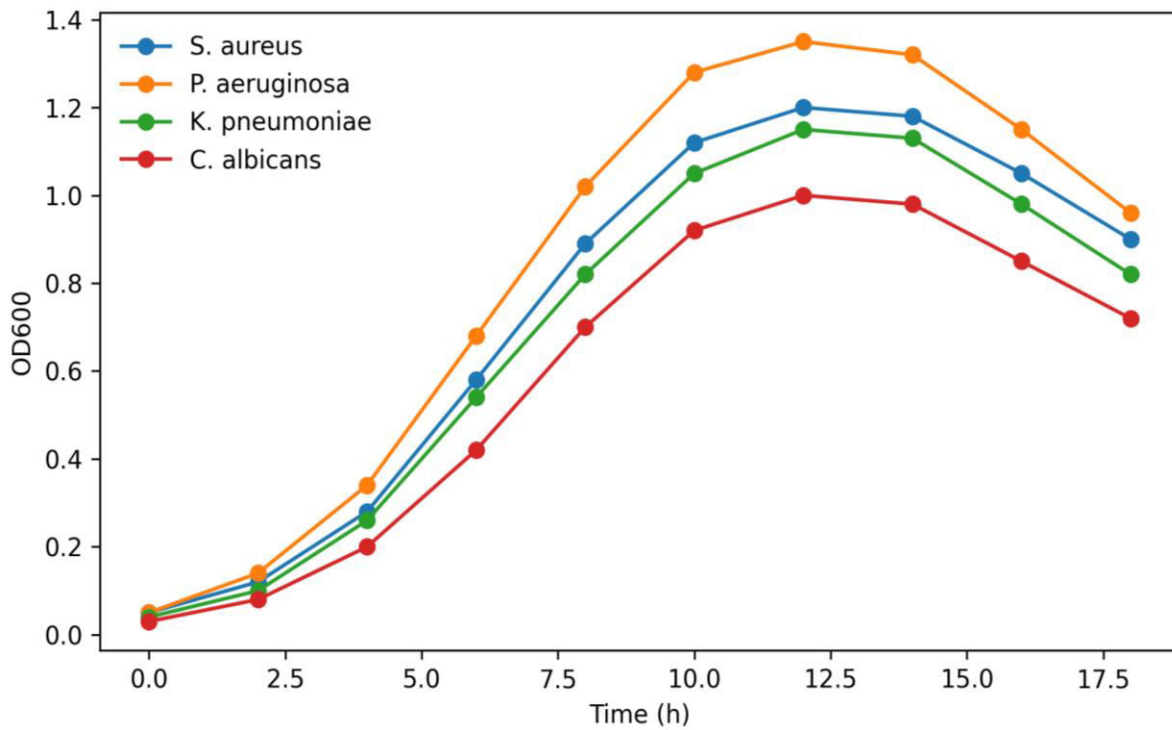


Figure.3 Selected combination activity. Comparison of antimicrobial-alone and antimicrobial plus 25 μ L corn silk extract inhibition zones using the reported values.

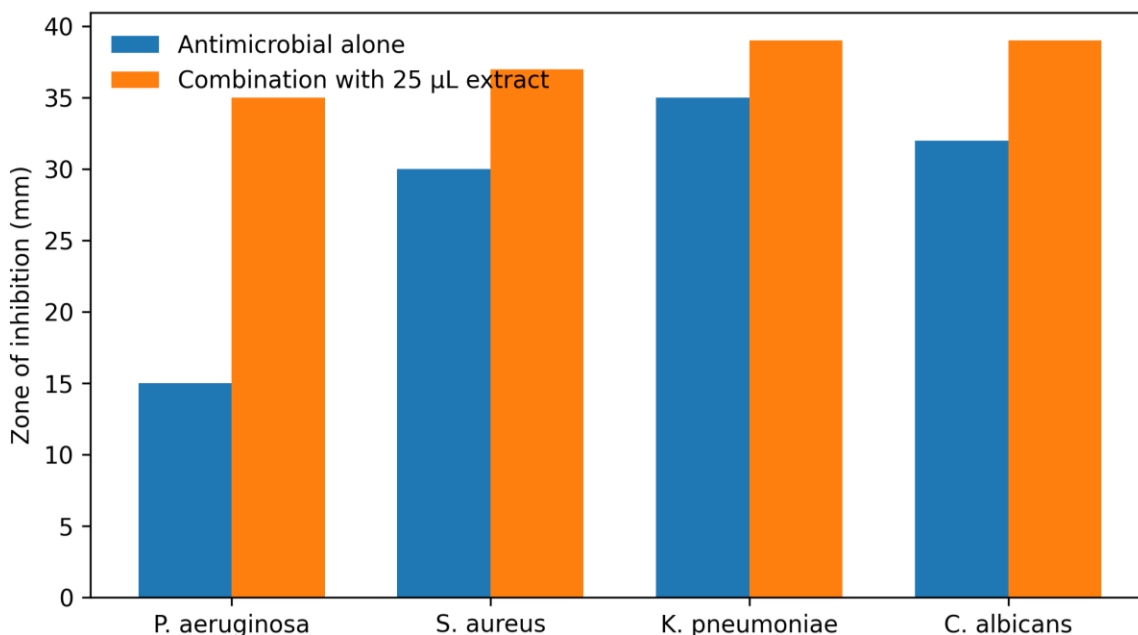
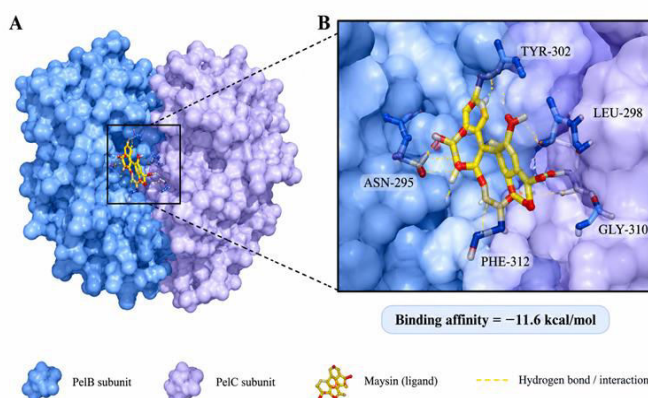


Figure.4 Molecular docking of maysin with the PelBC exopolysaccharide transporter of *Pseudomonas aeruginosa*.



Also reduce the concentrations of antibiotic otherwise it may lead to more multi drug resistant property in clinical pathogens in near future. Further Synergistic effect of corn silk with antibiotics were tested on Muller Hinton Agar by disc diffusion method. Each disc was previously loaded with 25 μ l of corn silk extract and for negative control ampicillin loaded with 25 μ l and 50 μ l of corn silk extract respectively. For *Staphylococcus aureus* the

following antibiotics were tested, Ceftriazone (30mm), for ampicillin no zone of inhibition observed, ampicillin with 25 μ l was recorded with 33 mm, for ampicillin with 50 μ l was recorded with 35mm, Ceftriazone with 25 μ l was recorded with 37mm. For *Pseudomonas aeruginosa* the following antibiotics were tested, Ceftriazone (15mm), for ampicillin no zone of inhibition observed, ampicillin with 25 μ l was recorded with 12 mm, for

ampicillin with 50 µl was recorded with 25mm, Ceftriazone with 25 µl was recorded with 35mm.

For *Klebsiella pneumoniae* the following antibiotics were tested, Ceftriazone (35mm), for ampicillin no zone of inhibition observed, ampicillin with 25 µl was recorded with 22 mm, for ampicillin with 50 µl was recorded with 28mm, Ceftriazone with 25 µl was recorded with 39mm. For *Candida albicans* the following antibiotics were tested viz., Ketoconazole (32mm), Nystatin no zone of inhibition observed, Nystatin with 25 µl was recorded with 25mm, Nystatin with 50 µl was recorded with 27mm, Ketoconazole with 25 µl was recorded with 39 mm. In continuation, Hydrogel with CMC were prepared for bacterial and fungal isolates and stored for further studies. To know the binding affinity of Myasin protein in corn silk extract towards the structure of the outer membrane exopolysaccharide transporter PelBC of *Pseudomonas aeruginosa* and the results of molecular docking revealed that -11.6 affinity value, indicated that myasin could be a carrier of antibiotic compound inside bacterial cells. This would impact in drug delivery system and to control MDR pathogens. Overall, this study indicated the importance of Cornsilk based hydrogel for the treatment of MDR related microbial infections.

In conclusion, the present study showed the potential of ethanolic corn silk (*Zea mays* L.) extract as a natural antimicrobial agent against multidrug-resistant pathogens associated with burn wound infections. The extract was also evaluated in combination with selected antimicrobial agents to determine its potential to enhance antimicrobial activity. Molecular docking suggested a possible interaction between maysin and the PelBC protein of *Pseudomonas aeruginosa*. These findings indicate that corn silk may be a promising source of bioactive compounds for further antimicrobial research. However, additional studies are required to confirm its mechanism of action, synergistic effects, safety, and therapeutic potential.

Author Contributions

Sangeetha K: Methodology, Writing original draft. Shantha Lakshmi K: Methodology, Writing original draft. Shendra S: Software, Validation, Formal Analysis. Sarika S: Methodology, Writing original draft. Sheik Basheera A: Methodology, Writing original draft. Vidyadharani G: Concept, Preparation, Writing - Review & Editing.

Data Availability

The datasets generated during and/or analyzed during the current study are available from the corresponding author on reasonable request.

Declarations

Ethical Approval Not applicable.

Consent to Participate Not applicable.

Consent to Publish Not applicable.

Conflict of Interest The authors declare no competing interests.

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