



Research Article

Antimicrobial Activity Studies of Lupeol Isolated from *Crinum jagus* Rhizome

*Kabir Salsabilu¹, Abubakar Y. Galambi², and Abdulhakim Sani Lawal²

¹Department of Chemistry, Federal University of Petroleum Resources, Effurun, Delta State, Nigeria

²Department of Chemistry, Federal University of Dutsin-Ma, Katsina State, Nigeria

*Corresponding Author's email: kabir.salsabilu@fupre.edu.ng; Phone: +2348082255247

ABSTRACT

Rhizomes of *Crinum jagus* were pulverized and successively extracted with n-hexane, dichloromethane, and ethyl acetate, followed by concentration using a rotary evaporator, yielding 3.5 g, 5.0 g, and 7.0 g, respectively. Qualitative phytochemical screening of the ethyl acetate extract revealed the presence of steroids, terpenes, saponins, flavonoids, and alkaloids. The crude extract and the isolated compound were evaluated for antimicrobial activity against *Staphylococcus aureus*, *Staphylococcus epidermidis*, *Bacillus megaterium*, *Escherichia coli*, *Salmonella typhi*, *Pseudomonas aeruginosa*, *Candida albicans*, *Trichophyton rubrum*, and *Aspergillus niger*, with zones of inhibition ranging from 7 to 22 mm. Thin-layer chromatography (TLC) of the ethyl acetate extract revealed eight major spots, one of which exhibited fluorescence with an R_f value of 0.44. The isolated compound showed a single fluorescent spot with the same R_f value, indicating purity. Mass spectrometry revealed a molecular ion peak at m/z 462, consistent with a triterpenoid structure, while fragmentation patterns provided further structural insights. Comprehensive spectroscopic analyses (MS, IR, 1D and 2D NMR) confirmed the isolated compound as lupeol. Molecular docking studies demonstrated that lupeol binds effectively to the 7RJC protein of *S. epidermidis*, with binding energies of -9.0, -8.6, -7.6, and -7.1 kcal/mol, suggesting strong inhibitory potential. The docking results of lupeol, alongside other secondary metabolites identified in the rhizome, correlate with the observed antimicrobial activity, indicating that *Crinum jagus* is a promising natural source of antimicrobial agents for the treatment of various infectious diseases.

Keywords: *Crinum jagus*; Ethyl acetate; Lupeol; Molecular docking; Rhizome

Citation: Salsabilu, K., Galambi, A.Y., & Lawal, A.S. (2025). Antimicrobial Activity Studies of Lupeol Isolated from *Crinum jagus* Rhizome. *Sahel Journal of Life Sciences FUDMA (SAJOLS)*, 3(4), 497–508. DOI: <https://doi.org/10.33003/sajols-2025-0304-57>

INTRODUCTION

Crinum jagus, a botanical specimen known by the vernacular name poison bulb, is recognized as a blossoming flora. In accordance with longstanding customs, the extraction derived from the bulb is applied for medicinal purposes, particularly in the management of numerous afflictions (Salawu *et al.*, 2020). *Crinum* species have a high reputation as therapeutic plants in ethno pharmacology. They have been used for centuries and are still widely used today, especially in South America, tropical Asia, and Africa. Traditional uses for a number of *Crinums*

include emetic, laxative, expectorant, tonic antipyretic, diuretic, diaphoretic, anti-asthmatic, anti-malarial, anti-aging, antitumor, and Blactagogue properties. Other painful and inflammatory conditions such as rheumatism, lumbago, edema, headache, swelling, backache, wounds, and hemorrhoids are frequently subjected to treatment using these medicinal remedies. The bulbs of various *Crinum* species hold immense interest due to their global utilization in the management of afflictions such as urinary tract infections, cough and cold, ulcers, renal and hepatic disorders, sexually

transmitted diseases, backaches, and promotion of lactation in both humans and animals. Moreover, these bulbs possess analgesic, immune-stimulating, antiviral, antibacterial, and antimalarial attributes (Akinrinade *et al.*, 2012). They also exhibit insecticidal effects and demonstrate anticonvulsant capabilities. *Crinum jagus*, is a botanical species more commonly known as Harmattan or St. Christopher's lily. This particular plant belongs to the Amaryllis family and is indigenous to tropical regions of Africa. It possesses the characteristic of being a tender perennial bulb. During the summer season, it showcases the emergence of tulip-shaped white flowers, which are clustered together and situated atop stem-like structures devoid of leaves. These stems typically attain a height ranging from 2 to 3 feet, originating from a cluster of elongated, strap-shaped green leaves. An interesting aspect of this plant is that certain flowers emit a fragrant aroma, reminiscent of vanilla that permeates the surrounding garden during the nocturnal hours. In recent years, there has been growing interest in the isolation and characterization of plants' secondary metabolites of various therapeutic properties paving way for drug development of natural origin (Wang *et al.*, 2021) There is limited information on the chemical composition and biological activities of *Crinum jagus* Therefore, further research is needed to fully understand the potential therapeutic applications of *Crinum* and to possibly isolate and characterize those principles responsible for the plant's biological activities as prelude for new drugs discovery.

MATERIALS AND METHODS

Collection and Identification of Plant Material

Rhizomes of *Crinum jagus*, were collected and air-dried in June 2023, from Dabawa in Dutsin- Ma Katsina, Nigeria. The plant was authenticated by botanists in the Department of Biological Science, Faculty of life sciences, Federal University Dutsin-Ma, Nigeria.

Extraction and Isolation of the Compound

The bulb roots of *Crinum jagus* were collected, air-dried, ground (500g) and macerated with n-hexane, DCM and ETAC sequentially in this order and concentrated using rotary evaporator to give 3.5g, 5.0g and 7.0g, respectively. About 2g of the ethyl acetate extract were loaded on chromatographic column (2cm in diameter, 200cm. long over the bed

of silica gel (230-400 mesh size, ASTM). The column was eluted successively with absolute n- hexane (200ml) followed by solvent combination of n- hexane/AtOAc (5:95, 10:90, 15:85, 200ml,400ml, 300ml respectively). One hundred and fifty fractions were collected from the column. Lupeol (C₃₀H₅₀O): was obtained from the middle fractions (70-76), purified on burette by using solvent mixture of n- hexane/AtOAc (15:85), to give (80mg, with R_f =0.50), it is white crystal solid, with 212-213mp.

Preliminary Phytochemical Screening

The crude extracts of n-hexane, DCM, ethyl acetate and methanol were subjected to preliminary qualitative screening of secondary metabolites using standard methods as described by (Shwe *et al.* 2019).

Determination of the Antimicrobial activity

The test organisms used for this analysis were clinical isolates of bacteria and fungi obtained from the Department of Microbiology, Umar Musa Yar'adua University Katsina. Three of gram-positive bacteria, gram negative bacteria and three fungi were used as test isolate. The isolates were *Staphylococcus aureus*, *Staphylococcus epidermidis*, *Bacillus magisterium*, *Escherichia coli*, *Salmonella typhi*, *Pseudomonas aeruginosa*, *Candida albicans*, *Trichophyton rebrum* and *Aspergillus niger*. The Antimicrobial activity was measured according to agar well diffusion method in line with National committee for clinical laboratory Standard.

Molecular Docking Studies

Molecular docking was performed using computational software (Auto Dock, PyRx, Chimera and PyMOL) (Ahmad *et al.*, 2023).The 3D structure of the target protein was retrieved from the Protein Data Bank (PDB ID: 7RJC) is often used in such studies (Sabui and Kumar, 2023).The ligand (lupeol) structure was sourced from the PubChem database (CID: 259846) (Sousa *et al.*, 2023).

RESULTS

The extraction of *Crinum jagus* rhizome using solvents of increasing polarity produced varying yields (Table 1). Ethyl acetate extract gave the highest yield (7.00 g, 1.40%), followed by dichloromethane (5.00 g, 1.00%), and while n-hexane recorded the least yield (3.50 g, 0.70%). The higher yield obtained from ethyl acetate suggests that moderately polar solvents are more effective in extracting bioactive constituents from *C. jagus*.

The TLC profile of the crude ethyl acetate extract and the isolated compound revealed several distinct spots (Fig. 1), indicating the presence of multiple phytoconstituents. Eight components were resolved with retention factor (Rf) values ranging from 0.10 to 0.63 (Table 2). The isolated compound showed a single prominent spot, suggesting its purity and successful isolation from the crude extract.

Qualitative phytochemical analysis of the ethyl acetate extract revealed the presence of flavonoids, alkaloids, terpenes, steroids, and saponins, while phenolics, tannins, and anthraquinones were absent (Table 3). The presence of these secondary metabolites is consistent with the reported medicinal relevance of *C. jagus*, particularly its antimicrobial potential.

The antimicrobial assay showed that the ethyl acetate extract exhibited appreciable inhibitory activity against *Staphylococcus epidermidis*, *Bacillus magisterium*, *Salmonella typhi*, *Pseudomonas aeruginosa*, *Candida albicans*, and *Trichophyton rubrum* (Table 4). The isolated compound also demonstrated activity, though generally lower than the crude extract, indicating possible synergistic effects among constituents in the extract. No activity was observed against *Staphylococcus aureus*, *Escherichia coli*, and *Aspergillus niger*. The standard drugs showed superior activity, validating the assay.

The MIC values revealed that the ethyl acetate extract was most active against *S. epidermidis* (25 mg/ml) and *C. albicans* (50 mg/ml), while higher concentrations were required for other organisms (Table 5). The isolated compound showed comparatively higher MIC values, further supporting the enhanced antimicrobial efficacy of the crude extract due to combined phytochemicals.

Molecular docking of lupeol against *Staphylococcus epidermidis* protein (PDB ID: 7RJC) revealed strong binding interactions, with the best binding affinity of -9.0 kcal/mol (Table 6). The low RMSD values indicate stable ligand–protein interactions. The two- and three-dimensional docking poses (Fig. 3) further confirmed favorable binding orientations within the active site of the protein.

The mass spectrum of the isolated compound (Fig. 4) showed a molecular ion peak consistent with lupeol. FTIR analysis (Fig. 5) revealed characteristic functional groups such as hydroxyl and aliphatic C–H stretches. The ^1H NMR, ^{13}C NMR, and DEPT spectra (Figs. 6–9) confirmed the triterpenoid skeleton. The ^{13}C NMR data of the isolated compound closely matched reported literature values for lupeol (Table 7), confirming its identity. The chemical structure of the isolated compound is shown in Fig. 10.

Table 1: Yields and Percentage Yields of the Extract

S/No	Extract	Yield(g)	%Yield (%)
1	n-hexane	3.50	0.70
2	DCM	5.00	1.00
3	Ethyl acetate	7.00	1.40



Fig1: TLC Profile of the crude extract and isolated compound

Table 2: Retention factors of the phytoconstituents of ethyl acetate crude extract

Component	Distance traveled by component (cm)	Distance traveled by solvent system (cm)	Retention Factor (Rf)
E1	0.45	4.5	0.10
E2	0.90	4.5	0.20
E3	1.25	4.5	0.28
E4	1.50	4.5	0.33
E5	1.80	4.5	0.40
E6	2.00	4.5	0.44
E7	2.50	4.5	4.56
E8	2.85	4.5	0.63

Table 3: Qualitative Phytochemical Constituents of ethyl acetate

Test Compounds	Inference
Flavonoids	+
Alkaloids	+
Phenolics	-
Tannins	-
Anthraquinones	-
Terpenes	+
Steroids	+
Saponins	+

Key: +=Present, -=Absent

Table 4: Zone of inhibition of the Ethyl acetate Extract and Isolate on the Test Organisms

Test Organisms	Ethyl acetate Extract	Isolated Compound	Ciprofloxacin/Fluconazole
<i>S. aureus</i>	0.0	0.0	22
<i>S. epidermidis</i>	19	07	22
<i>B. Magisterium</i>	16	10	21
<i>E. coli</i>	0.0	0.0	22
<i>S. typhi</i>	13	11	22
<i>P. aeruginosa</i>	15	12	22
<i>C. albicans</i>	18	16	22
<i>T. rebrum</i>	14	11	0.0
<i>A. niger</i>	0.0	0.0	22

Key: 0.0 = o zone of inhibition

Table 5: Minimum Inhibitory Concentration (MIC) of *Crinum jagus* Extract on Test Organisms

Extract/Isolate	Organisms	MIC (mg/ml)
Ethyl acetate	<i>S. aureus</i>	ND
	<i>S. epidermidis</i>	25
	<i>B. magisterium</i>	100
	<i>E. coli</i>	ND
	<i>S. typhi</i>	100
	<i>P. aeruginosa</i>	100
	<i>C. albicans</i>	50
	<i>T. rebrum</i>	200
	<i>A. niger</i>	ND
Isolate	<i>S. aureus</i>	ND
	<i>S. epidermidis</i>	100
	<i>B. magisterium</i>	200
	<i>E. coli</i>	ND
	<i>S. typhi</i>	100
	<i>P. aeruginosa</i>	200
	<i>C. albicans</i>	100
	<i>T. rebrum</i>	100
	<i>A. niger</i>	ND

Key: ND= Not detected

Table 6: Molecular Docking Studies of Lupeol against *Staphylococcus epidermidis*

Ligand	Binding Affinity	rmsd/ub	rmsd/lb
7RJC_prep_259846_uff_E=928.19	-9	0	0
7RJC_prep_259846_uff_E=928.19	-8.6	7.653	2.43
7RJC_prep_259846_uff_E=928.19	-7.6	2.947	2.103
7RJC_prep_259846_uff_E=928.19	-7.4	31.097	27.829
7RJC_prep_259846_uff_E=928.19	-7.3	19.333	17.38
7RJC_prep_259846_uff_E=928.19	-7.2	28.472	25.703
7RJC_prep_259846_uff_E=928.19	-7.2	26.341	23.697
7RJC_prep_259846_uff_E=928.19	-7.1	33.464	29.7
7RJC_prep_259846_uff_E=928.19	-7.1	18.323	15.415

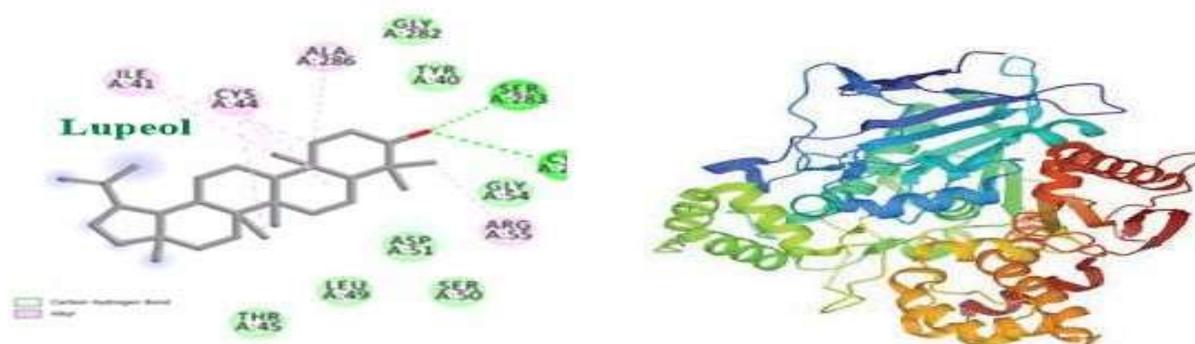


Fig.3: Two dimensional and three-dimensional images of lupeol docked against 7RJC protein

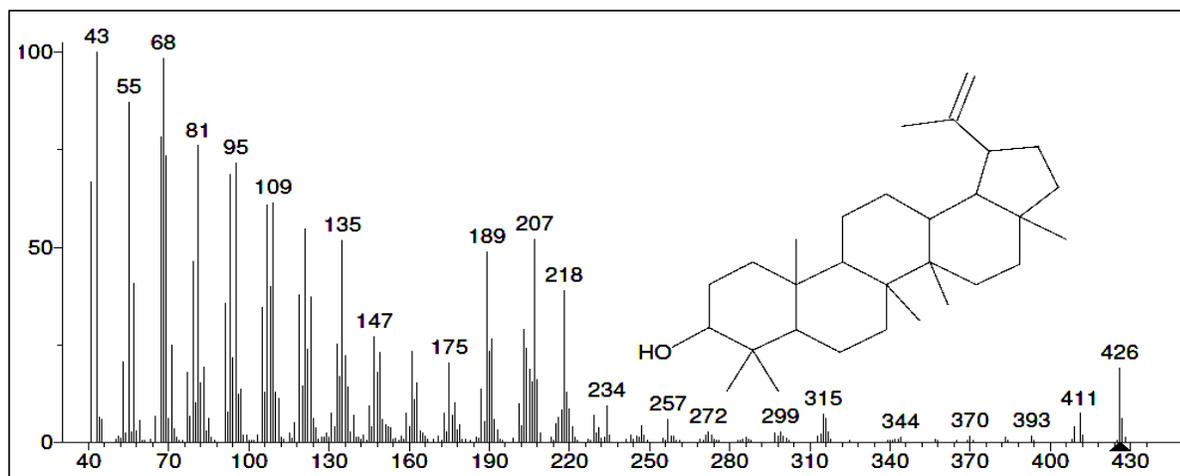


Fig.4: Mass spectrum of lupeol

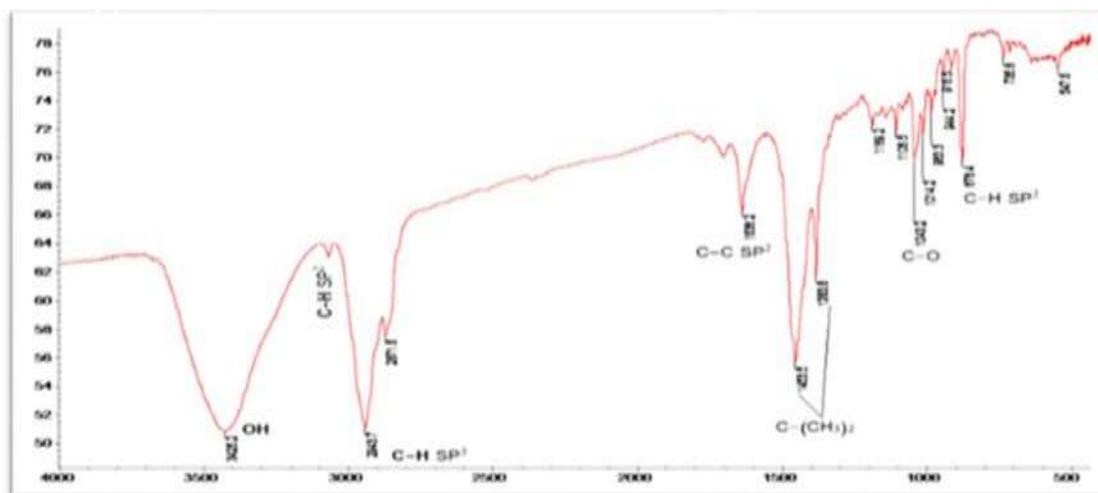


Fig 5:IR Spectrum of the isolated compound

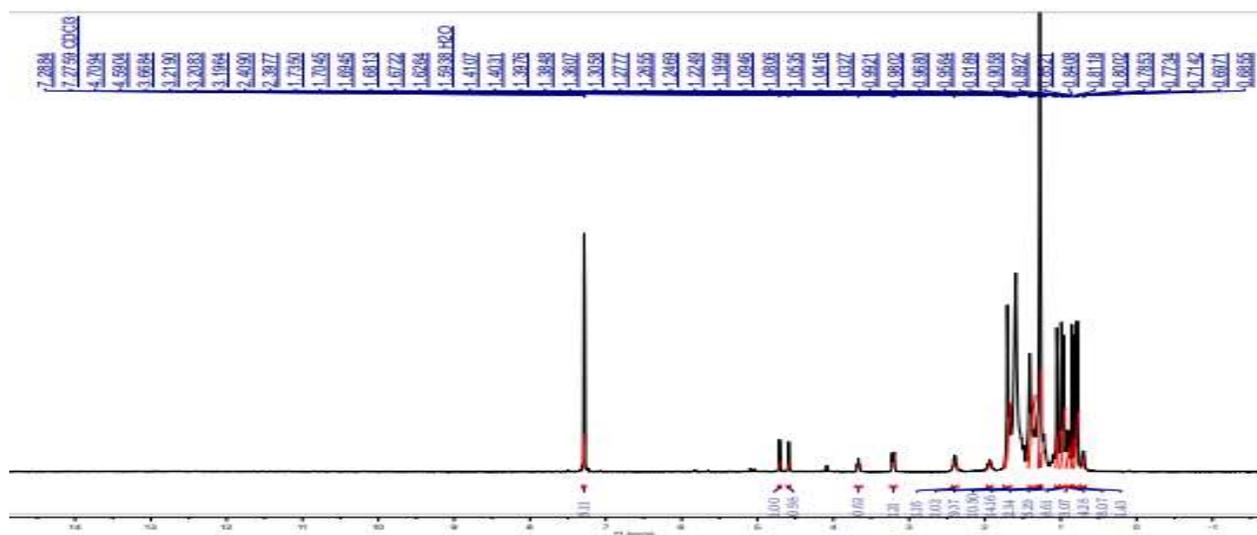


Fig.6: ^1H NMR of the isolated compound

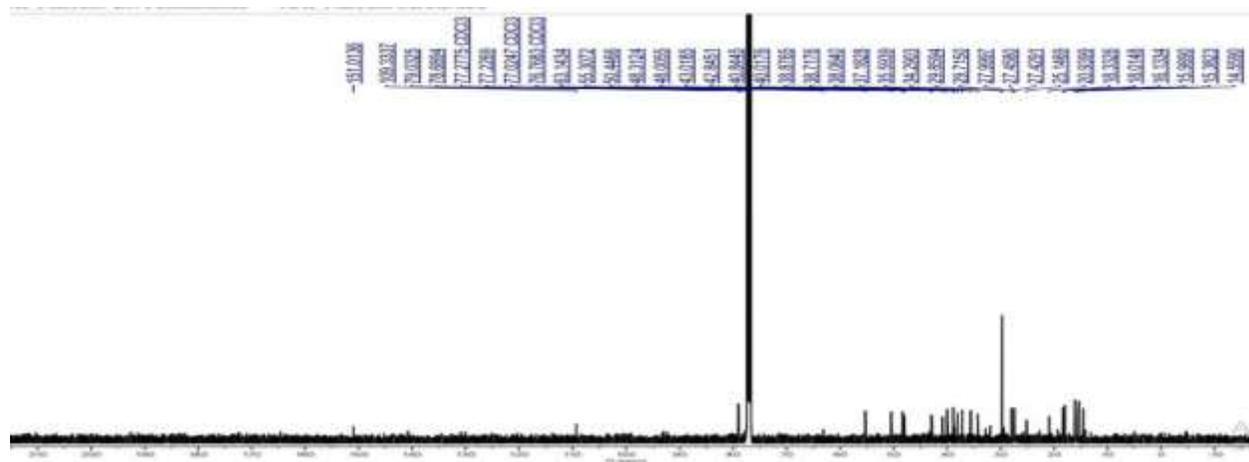


Fig 7: ^{13}C NMR Spectrum of the isolated compound

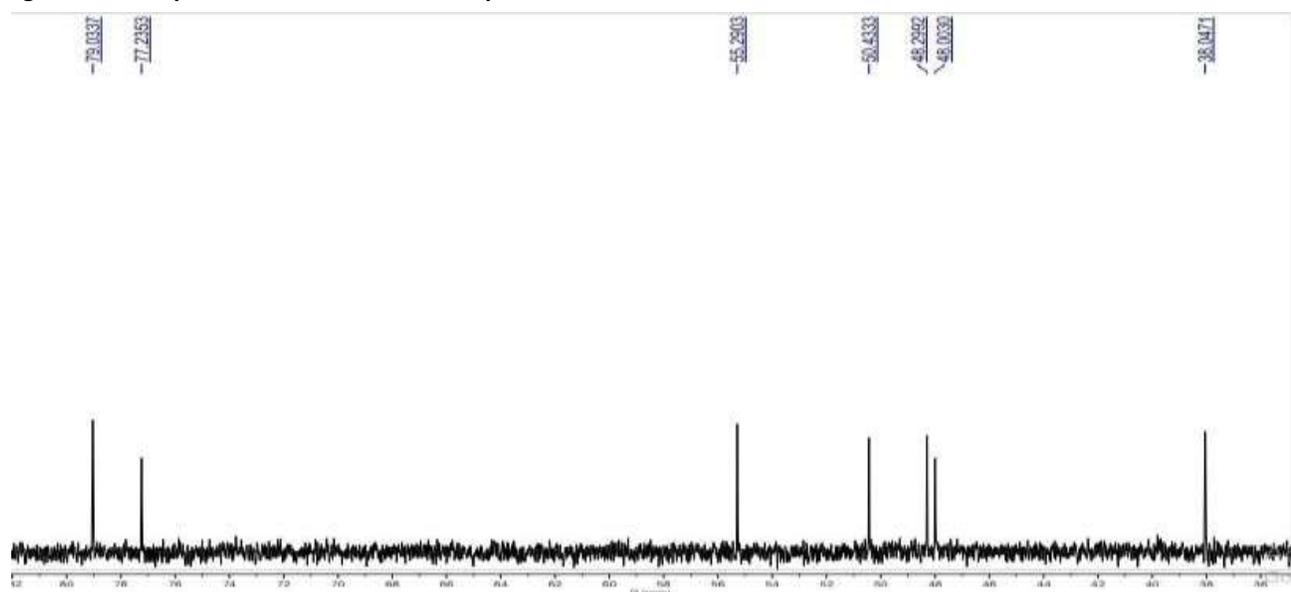


Fig 8: DEPT.90 Spectrum of the isolated compound

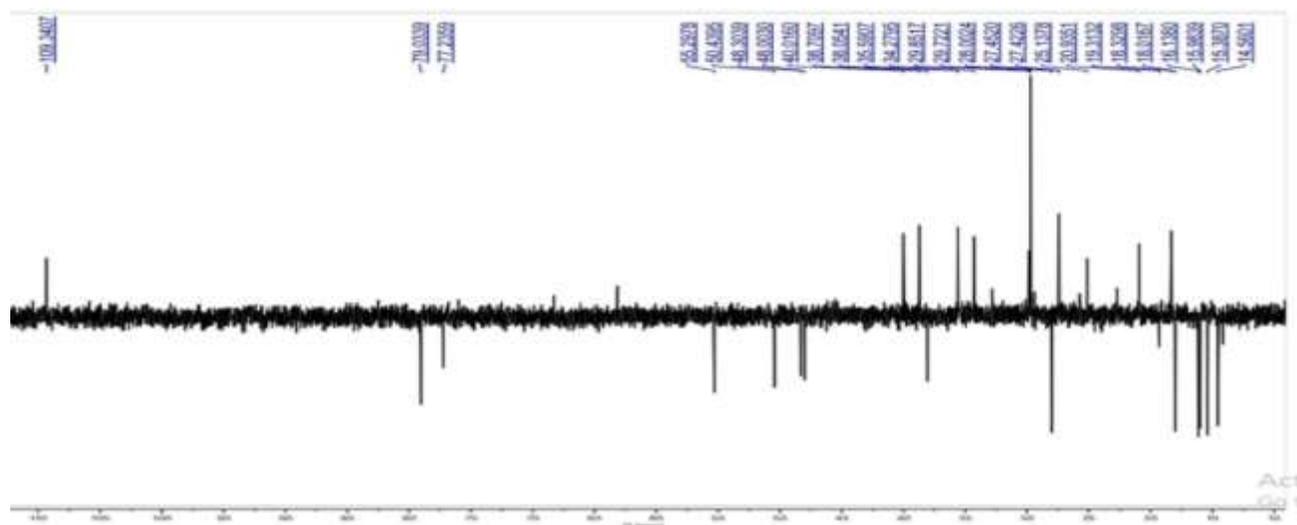


Fig 9: DEPT135.Spectrum of the isolated compound

Table7: ¹³C Spectroscopic data of the isolated compound compared with literature

No of carbon	¹³ CNMR δppm of the isolated compound, Experimental	¹³ CNMR δppm Lupeol, Literature (Musa <i>et al.</i> , 2023)	DEPT (135-90)
1.	38.4	38.5	CH2
2.	27.4	29.2	CH2
3.	78.6	78.2	CH
4.	38.8	38.6	C
5.	55.2	55.4	CH
6.	17.4	18.1	CH2
7.	35.2	34.2	CH2
8.	40.9	40.5	C
9.	50.3	50.6	CH
10.	37.4	37.0	C
11.	21.7	22.7	CH2
12.	25.2	25.5	CH2
13.	37.9	38.1	CH
14.	42.9	42.1	C
15.	26.4	27.1	CH2
16.	35.6	36.0	CH2
17.	43.0	43.0	C
18.	48.4	49.1	CH
19.	48.0	47.9	CH
20.	150.3	150.9	C
21.	29.8	30.4	CH2
22.	40.0	40.0	CH2
23.	23,4	23,4	CH3
24.	23.4	29.5	CH3
25.	16.1	15.9	CH3
26.	18.5	15.3	CH3
27.	15.0	13.6	CH3
28.	18.5	18.0	CH3
29.	110.6	108.5	CH2
30.	21.7	20.7	CH3

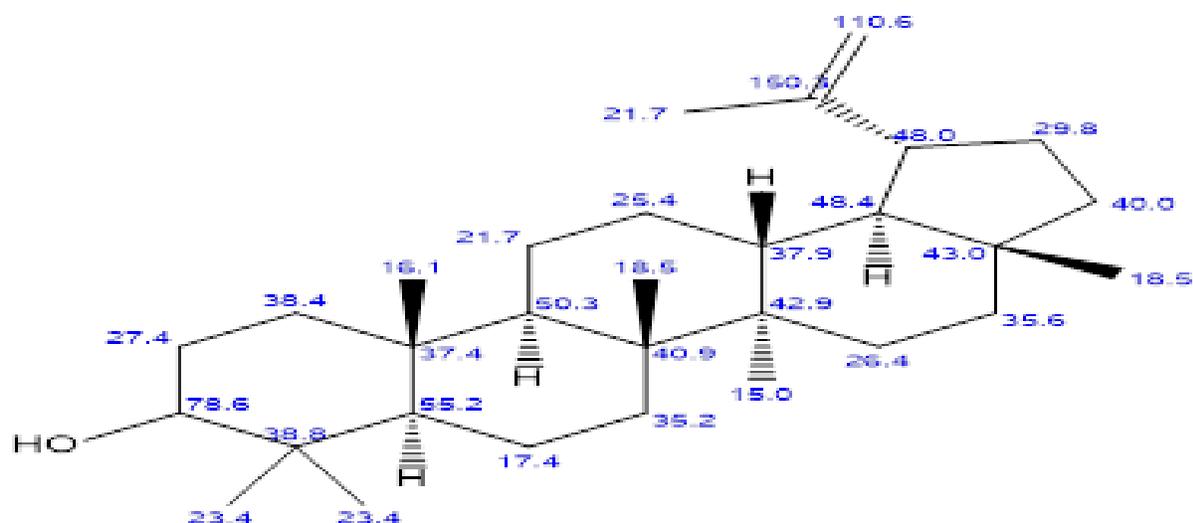


Fig 10: Structure of the isolated compound

DISCUSSION

Among the solvents employed, ethyl acetate produced the highest yield, indicating its superior efficiency in extracting bioactive constituents from the rhizome. This observation suggests that the major phytochemicals present in *C. jagus* rhizome possess moderate polarity and are better solubilized in ethyl acetate.

Thin-layer chromatography (TLC) analysis of the ethyl acetate extract revealed a complex phytochemical profile, with eight prominent spots observed under ultraviolet light at 366 nm. Each spot represents a distinct compound, and the retention factor (R_f) values reflect the relative polarity of the constituents within the solvent system. The presence of eight major spots indicates that the extract contains at least eight chemically distinct compounds. One spot exhibited a distinct fluorescent appearance with an R_f value of 0.44, suggesting it is a major component of the extract. An R_f value of 0.44 indicates moderate polarity, implying that the compound is neither highly polar nor nonpolar. The fluorescence observed under UV light further suggests the presence of a conjugated system, characteristic of triterpenoids with chromophoric groups (Huang *et al.*, 2024).

Qualitative phytochemical screening of the ethyl acetate extract revealed the presence of steroids, terpenes, saponins, flavonoids, and alkaloids, while tannins and phenolic compounds were absent. Alkaloids constitute a major class of secondary metabolites in *Crinum jagus*. Previous studies have reported the presence of alkaloids such as crinine and lycorine, which exhibit anti-inflammatory, analgesic, and antitumor activities (Verma *et al.*, 2021).

Lycorine, in particular, has gained attention for its anticancer potential due to its ability to inhibit protein synthesis in malignant cells (Chen *et al.*, 2020). Saponins identified in the extract are known for diverse pharmacological activities, including antioxidant and antidiabetic effects. Their ability to modulate glucose absorption and improve insulin sensitivity highlights their relevance in diabetes management (Ndiaye *et al.*, 2022; Gao *et al.*, 2023). Flavonoids, also detected in the extract, contribute significantly to antioxidant activity by neutralizing free radicals and reducing oxidative stress, thereby lowering the risk of chronic diseases (Kumar *et al.*, 2023). Compounds such as quercetin and kaempferol have previously been reported in *C. jagus* and are associated with its antioxidant potential (Jiang *et al.*, 2022). Terpenoids present in *C. jagus* have demonstrated notable antimicrobial and anti-inflammatory properties. These compounds, particularly those associated with essential oils, exhibit activity against a broad spectrum of pathogenic microorganisms (Singh *et al.*, 2023).

The dried ethyl acetate crude extract and the isolated compound were evaluated *in vitro* for antimicrobial activity against three Gram-positive bacteria (*Staphylococcus aureus*, *Staphylococcus epidermidis*, *Bacillus megaterium*), three Gram-negative bacteria (*Escherichia coli*, *Salmonella typhi*, *Pseudomonas aeruginosa*), and three fungi (*Candida albicans*, *Trichophyton rubrum*, and *Aspergillus niger*). The zones of inhibition for the ethyl acetate extract and the isolated compound ranged from 11–19 mm and 7–16 mm, respectively, while the standard drug ciprofloxacin produced inhibition zones of 20–29 mm.

The minimum inhibitory concentration (MIC) values ranged from 25 to 200 mg/mL, with variations observed among the extract, isolate, and test organisms (Table 5). The antimicrobial activity observed may be attributed to the presence of bioactive secondary metabolites identified during phytochemical screening. These findings are consistent with previous reports on the antimicrobial potential of *C. jagus* rhizomes (Alawode *et al.*, 2021). Additionally, the synergistic or antagonistic interactions among diverse phytochemicals within the crude extract may influence overall bioactivity (Salawu *et al.*, 2020). The sensitivity of the tested organisms suggests that these compounds may serve as potential therapeutic agents for the treatment of infections associated with diseases such as ulcers, typhoid, asthma, and inflammatory conditions (Wang *et al.*, 2021).

Molecular docking studies revealed favorable interactions between lupeol and the 7RJC protein of *Staphylococcus epidermidis*, as indicated by negative binding affinity values (Table 6). Higher negative binding energies correspond to stronger ligand–protein interactions (Smith *et al.*, 2021; Chatterjee *et al.*, 2022). The most favorable binding affinity observed was -9.0 kcal/mol, suggesting a strong and stable interaction between lupeol and the target protein. The second-best docking pose exhibited a binding energy of -8.6 kcal/mol, with RMSD values of 7.653 Å (upper bound) and 2.43 Å (lower bound), indicating ligand flexibility within the binding pocket and the possibility of multiple binding conformations (Kumar *et al.*, 2023). Moderate binding affinities ranging from -7.6 to -7.1 kcal/mol further support the ability of lupeol to form stable complexes with the protein (Chandrasekaran *et al.*, 2022). These interactions suggest that lupeol may inhibit the biological function of the 7RJC protein, contributing to the observed antimicrobial activity.

The mass spectrum of the isolated compound displayed a molecular ion peak at m/z 426, corresponding to the molecular ion (M^+), indicative of a triterpenoid structure containing 30 carbon atoms, 50 hydrogen atoms, and one oxygen atom. Fragmentation peaks observed at m/z 411 resulted from the loss of a methyl group ($-CH_3$), forming the $[M-15]^+$ ion. Prominent fragment ions at m/z 207 and 218 arose from cleavage within the triterpenoid skeleton, while peaks at m/z 189 resulted from ring

fragmentation. Infrared (IR) spectral analysis revealed absorption bands at 3451, 2945, 1638, 1455, and 1386 cm^{-1} , corresponding to hydroxyl, aliphatic C–H, olefinic C=C, and methyl bending vibrations, respectively (Figure 5). These values are consistent with reported data for lupeol (Sitrallah & Merza, 2020).

1H NMR spectroscopy showed signals corresponding to seven methyl groups and two olefinic protons at δH 4.58 and 4.69 ppm (H-29a and H-29b), along with a hydroxyl-bearing proton at δH 3.20 ppm (Figure 6). These chemical shifts align with literature reports (Ipav *et al.*, 2022). The ^{13}C NMR spectrum displayed 30 carbon signals, confirming the triterpenoid framework. DEPT-90 and DEPT-135 spectra further revealed the presence of tertiary, primary, secondary, and quaternary carbons, consistent with a pentacyclic triterpenoid structure.

Based on combined spectroscopic evidence (MS, IR, 1H NMR, ^{13}C NMR, and DEPT), the isolated compound was identified as lupeol, a pentacyclic triterpenoid of the lupane type, characterized by a hydroxyl group at the 3β position. Lupeol is widely distributed in nature and occurs in various edible fruits and vegetables, including mangoes, grapes, olives, strawberries, and cabbage. It is known to exhibit preventive and therapeutic effects against several diseases, including inflammatory disorders, microbial infections, and cancer (Vázquez *et al.*, 2024).

CONCLUSION

Based on spectroscopic analyses including mass spectrometry (MS), infrared spectroscopy (IR), and one- and two-dimensional nuclear magnetic resonance (1D and 2D NMR) techniques, as well as comparison with reported literature, the isolated compound was identified as lupeol. *Staphylococcus epidermidis* was selected for molecular docking studies due to its exhibition of the highest zone of inhibition (19 mm) during antimicrobial evaluation. The molecular docking results demonstrated that lupeol has a strong binding affinity toward the 7RJC protein of *S. epidermidis*. The observed binding energies suggest that lupeol may inhibit the activity of this protein, potentially reducing bacterial resistance to antibiotics. Furthermore, the molecular docking results of lupeol, together with other secondary metabolites identified in the rhizome, correlate with the observed antimicrobial activity.

These findings indicate that *Crinum jagus* is a promising natural source of antimicrobial agents, particularly against *Staphylococcus epidermidis*.

ACKNOWLEDGMENT

The author gratefully acknowledges Dr. Syed Adnan Ali Shah of the Atta-ur-Rahman Institute for Natural Product Discovery (AuRIns), Universiti Teknologi MARA, Cawangan Selangor, Kampus Puncak Alam, Bandar Puncak Alam, 42300 Selangor Darul Ehsan, Malaysia, for his support and assistance during this study.

REFERENCES

Ahmad, S., Munir, A., Bashir, S., & Irshad, M. (2023). Molecular docking and molecular dynamics simulation studies of natural compounds as potential inhibitors of resistant bacterial strains. *Journal of Molecular Structure*, 1276, 134663. <https://doi.org/10.1016/j.molstruc.2023.134663>

Akinrinade, I. D., Ajayi, A. M., & Akinrinade, A. S. (2020). *Crinum jagus* extract attenuates cerebral ischemia/reperfusion injury via modulation of oxidative stress, inflammation, and apoptotic signaling pathways. *Biomedicine & Pharmacotherapy*, 129, 110460. <https://doi.org/10.1016/j.biopha.2020.110460>

Alawode, T. T., Lajide, L., Owolabi, B. J., & Olaleye, M. T. (2020). Evaluation of extracts of leaves of *Crinum jagus* for antimicrobial properties. *Journal of Applied Sciences and Environmental Management*, 24(7), 1197–1201. <https://doi.org/10.4314/jasem.v24i7.11>

Alawode, T. T., Lajide, L., Owolabi, B. J., & Olaleye, M. T. (2021). Investigation of bulb extracts of *Crinum jagus* for antibacterial and antifungal activities. *Journal of Applied Sciences and Environmental Management*, 25(1), 113–117. <https://doi.org/10.4314/jasem.v25i1.16>

Chandrasekaran, M., Sivasankar, P., & Somasundaram, S. (2022). Binding affinity of lupeol against key enzymes of drug-resistant *Staphylococcus* species: A molecular docking study. *Journal of Biomolecular Structure and Dynamics*, 40(11), 1–13. <https://doi.org/10.1080/07391102.2021.1994552>

Chatterjee, S., & Sarkar, P. (2022). Mechanisms of resistance in MRSA and MRSE: Focus on PBP2a structure and function. *Clinical Microbiology and Infection*, 28(3), 237–245. <https://doi.org/10.1016/j.cmi.2021.10.002>

Chen, L., Zhang, Y., & Wang, J. (2020). Lycorine as a potential anticancer agent: Mechanisms of action and therapeutic prospects. *Frontiers in Oncology*, 10, 523–536. <https://doi.org/10.3389/fonc.2020.00523>

Dhanani, T., Shah, S., & Kumar, S. (2017). Structural characterization and anti-inflammatory activity of lupeol isolated from *Strobilanthes callosus* Nees. *Journal of Analytical & Pharmaceutical Research*, 4(4), 00104.

Evans, W. C. (2002). *Trease and Evans pharmacognosy* (15th ed.). Bailliere Tindall.

Gao, S., Zhang, W., & Li, X. (2023). The role of saponins in glucose metabolism and diabetes management: A review. *Journal of Diabetes Research*, 2023, 1–15. <https://doi.org/10.1155/2023/6587823>

Huang, X. F., et al. (2024). Chemical derivatization strategies for enhancing the HPLC analytical performance of natural active triterpenoids. *Journal of Pharmaceutical Analysis*, 14(3), 295–307. <https://doi.org/10.1016/j.jpha.2023.07.004>

Ipav, S. S., Igoli, J. O., Tor-Anyiin, T. A., & Anyam, A. J. V. (2022). Isolation and characterisation of lupeol and lupeol acetate from propolis obtained from Benue State. *Journal of the Chemical Society of Nigeria*, 47(1), 152–159. <https://doi.org/10.46602/jcsn.v47i1.708>

Jiang, Z., Zhang, H., & Xu, L. (2022). Identification and antioxidant activity of flavonoids in *Crinum jagus*. *Journal of Agricultural and Food Chemistry*, 70(14), 4324–4331. <https://doi.org/10.1021/acs.jafc.2c00985>

Kumar, A., & Sharma, N. (2023). Molecular docking studies of natural compounds as potential inhibitors of PBP2a in methicillin-resistant staphylococci. *Computational Biology and Chemistry*, 101, 107786. <https://doi.org/10.1016/j.compbiolchem.2022.107786>

Kumar, V., Sharma, S., & Choudhury, S. (2023). Flavonoids in *Crinum jagus*: Antioxidant properties and therapeutic potential. *Antioxidants*, 12(4), 764–780. <https://doi.org/10.3390/antiox12040764>

Musa, N. M., Sallau, M. S., Oyewale, A. O., Ali, T., & Kabir, S. (2023). Isolation, characterization and evaluation of anti-schistosomal activity of triterpenes from crude ethyl acetate extract of the rhizome of *Dolichos pachyrhizus*. *African Journal of Health, Safety and Environment*, 4(1), 117–131. <https://doi.org/10.52417/ajhse.v4i1.424>

- Ndiaye, M., Sall, A., & Sy, M. (2022). Saponins in *Crinum jagus* : Bioactivity and potential therapeutic applications. *Pharmacognosy Reviews*, 16(32), 58–67. https://doi.org/10.4103/phrev.phrev_78_22
- Olaniyi, O., Ajiboye, T., & Adebayo, M. (2024). Tannins from *Crinum jagus* : A review of their pharmacological properties and therapeutic uses. *Medicinal Plants Research*, 11(1), 42–55. <https://doi.org/10.1016/j.medres.2024.01.007>
- Rahman, M. M., & Ashraf, A. M. (2022). Computational analysis of triterpenoids as potential inhibitors of penicillin-binding proteins. *Journal of Pharmacology and Drug Design*, 8(3), 123–130.
- Rahman, P. K. S. M. (2018). Medicinal plants: Their use in anticancer treatment. *International Journal of Pharmaceutical Sciences and Research*, 6(10), 4103–4112. [https://doi.org/10.13040/IJPSR.0975-8232.6\(10\).4103-12](https://doi.org/10.13040/IJPSR.0975-8232.6(10).4103-12)
- Sabui, S., & Kumar, A. (2023). Molecular docking studies of plant-derived compounds against bacterial proteins involved in antibiotic resistance. *Journal of Natural Products and Drug Research*, 15(2), 45–52.
- Salawu, K. M., Atunwa, S. A., & Eniyewu, O. I. (2020). Cytotoxicity and anti-proliferative studies of *Crinum jagus* L. (Amaryllidaceae) bulb extract. *Journal of Medicinal Plants Research*, 14(10), 560–567.
- Shwe, H. H., Win, K. K., Moe, T. T., Myint, A. A., & Win, T. (2019). Isolation and structural characterization of lupeol from the stem bark of *Diospyros ehretioides* Wall. *IEEE-SEM*, 7(8), 140–144.
- Silva, G. L., Lee, I. S., & Kinghorn, A. D. (1998). Special problems with the extraction of plants. In S. D. Sarker, Z. Latif, & A. I. Gray (Eds.), *Natural products isolation* (pp. 343–363). Humana Press.
- Singh, R., Gupta, A., & Verma, S. (2023). Terpenoids in *Crinum jagus*: Pharmacological activities and therapeutic potentials. *Bioorganic & Medicinal Chemistry*, 31(9), 732–740. <https://doi.org/10.1016/j.bmc.2023.115446>
- Sitrallah, S., & Merza, J. (2020). Isolation and identification of lupeol from Syrian *Euphorbia helioscopia*. *Journal of Natural Products Chemistry*, 11(10), 779–782.
- Smith, C. A., & Toth, M. (2021). Structural basis for β -lactam resistance in penicillin-binding protein 2a from methicillin-resistant *Staphylococcus epidermidis*. *Journal of Biological Chemistry*, 296, 100657. <https://doi.org/10.1074/jbc.RA120.015527>
- Sofowora, A. (1996). Research on medicinal plants and traditional medicine in Africa. *Journal of Alternative and Complementary Medicine*, 2(3), 365–372.
- Sousa, A. M., Gomes, F., Faria, J., & Barbosa, M. (2023). Molecular docking studies of triterpenoids as antibacterial agents against *Staphylococcus epidermidis*. *Journal of Molecular Modeling*, 29(2), 1123–1130. <https://doi.org/10.1007/s00894-023-05312-8>
- Tamboura, H. H., Bayala, B., Lompo, M., Guissou, I. P., & Sawadogo, L. (2007). Ecology, morphological characteristics, and acute toxicity of aqueous extracts of some medicinal plants used in traditional medicine in Burkina Faso. *African Journal of Biotechnology*, 6(8), 894–896.
- Vázquez, L., et al. (2024). Supercritical fluid technology for lupin hulls valorization: Extraction and fractionation of lupeol. *Biomass Conversion and Biorefinery*. Advance online publication. <https://doi.org/10.1007/s13399-024-05511-7>
- Verma, P., Kumar, A., Singh, V., & Gupta, R. (2021). Alkaloids from *Crinum jagus*: A review of their pharmacological activities. *Journal of Phytochemistry Research*, 34(2), 119–135. <https://doi.org/10.1016/j.jphytochem.2021.04.002>
- Wang, J., & Lee, A. (2021). The structural basis of PBP2a-mediated methicillin resistance in staphylococci. *Journal of Antimicrobial Chemotherapy*, 76(5), 1102–1110. <https://doi.org/10.1093/jac/dkaa539>