



Effect of Cinnamon Leaf Extract (*Cinnamomum Burmannii*) on Inhibiting Biofilm Formation in *Klebsiella Pneumoniae* in Vitro**Christine Ayu Maharani^{1*}, Noorhamdani AS², Nadia Artha Dewi³**Universitas Brawijaya, Indonesia^{1,2,3}

Email: christinemhrni@gmail.com, noorhamdanas@yahoo.com, nadophthalmic@yahoo.com

KEYWORDS	ABSTRACT
biofilm, cinnamon leaves extract, <i>cinnamomum burmannii</i> , klebsiella pneumoniae	<p><i>Klebsiella pneumoniae</i> is an opportunistic pathogenic bacterium that can cause various nosocomial infections such as pneumonia, bacteremia, and urinary tract infections. These bacteria can form biofilms, which facilitate resistance to antibiotics. Cinnamon (<i>Cinnamomum burmannii</i>) is a native Indonesian spice that contains antibiofilm compounds such as flavonoids, tannins, and saponins. This study aimed to prove the effectiveness of Cinnamon leaves ethanol extract in inhibiting biofilm formation in <i>Klebsiella pneumoniae</i> in vitro. The method used was the tube method. The results from this method were documented and quantified as Mean Gray Value (MGV) using Adobe Photoshop CS6. The results showed that MGV increased with higher concentrations of Cinnamon leaves extract, indicating inhibition of biofilm formation in <i>Klebsiella pneumoniae</i>. The Minimum Biofilm Inhibitory Concentration (MBIC) was determined to be 37.5%. A one-way ANOVA test revealed a significant difference between the mean values of each group ($p=0.000$), and the Pearson correlation test showed a very strong and significant correlation ($r=0.841$; $p=0.000$). This study concludes that Cinnamon leaves ethanol extract can inhibit biofilm formation in <i>Klebsiella pneumoniae</i> in vitro. The implications of this research suggest that Cinnamon leaves ethanol extract could be explored as a potential natural alternative to conventional antibiotics in managing biofilm-related infections, particularly those caused by multidrug-resistant <i>Klebsiella pneumoniae</i>. Further studies are needed to evaluate the efficacy of this extract in vivo and its potential for clinical application.</p>

DOI: 10.58860/ijsh.v4i2.286

Corresponding Author: Christine Ayu Maharani***Email:** christinemhrni@gmail.com**INTRODUCTION**

Biofilm formation is a critical survival strategy for microorganisms, creating a matrix of Extracellular Polymeric Substances (EPS) that protect them from physical, chemical, and biological threats (Paterson, 2017). This phenomenon enhances microbial resistance against the immune system and antibiotics, allowing pathogenic bacteria to persist and cause chronic infections (Sharma et al., 2023). *Klebsiella pneumoniae*, an opportunistic pathogen, is one of the major bacteria known to form biofilms on both medical devices and human tissue, leading to severe nosocomial infections such as pneumonia, bacteremia, and urinary tract infections, especially in immunocompromised patients (Al-Abeadi et al., 2023). The increasing resistance of *Klebsiella pneumoniae* to antibiotics is particularly concerning, as it contributes significantly to higher mortality rates (Holban et al., 2016). Therefore, it is crucial to explore new, effective ways to prevent biofilm formation and combat the growing antibiotic resistance crisis.

While much research has focused on the antibiofilm potential of essential oils, particularly cinnamon bark, the bioactive properties of cinnamon leaves have not been widely explored (Liu et al., 2021). This gap presents a unique opportunity for novel research. Some studies have suggested that cinnamon leaf extracts contain bioactive compounds such as eugenol, flavonoids, and saponins, which have antibacterial and potential antibiofilm properties. For instance, has demonstrated the antibacterial

and anti-quorum sensing properties of cinnamon leaf extracts against various pathogens, including *Escherichia coli* and *Pseudomonas aeruginosa*. However, the inhibitory effects of cinnamon leaf extract on biofilm formation in *Klebsiella pneumoniae* remain underexplored.

This research is timely and critical as it aims to fill this gap by investigating the effect of cinnamon leaf extract (*Cinnamomum burmannii*) on inhibiting biofilm formation in *Klebsiella pneumoniae*. The novelty of this study lies in its focus on cinnamon leaf extract, an underutilized natural resource, which could provide a new, alternative strategy for managing *Klebsiella pneumoniae* infections. With the increasing challenges posed by antibiotic resistance, finding non-antibiotic solutions is more urgent than ever. Moreover, the active compounds in cinnamon leaves, such as flavonoids, tannins, and saponins, have shown potential antibiofilm activity, making them a promising source for future therapeutic agents (Shariati et al., 2022).

By advancing our understanding of the bioactive compounds in cinnamon leaves, this study could contribute valuable insights into alternative treatments for preventing *Klebsiella pneumoniae* infections, reducing reliance on antibiotics, and addressing the global health crisis of antimicrobial resistance. The formulation of the problem in this study is whether cinnamon leaf extract (*Cinnamomum burmannii*) has the effect of inhibiting biofilm formation in *Klebsiella pneumoniae* in vitro. The primary goal is to provide experimental evidence supporting the use of cinnamon leaf extract as an effective biofilm inhibitor. This research not only adds theoretical knowledge about the therapeutic potential of cinnamon leaf extract but also contributes to the development of alternative, sustainable treatments for combating biofilm-related infections (Ali et al., 2023).

METHOD

In this study, the research design used was a true experimental design. This study aimed to determine the effect of cinnamon leaf extract (*Cinnamomum burmannii*) on inhibiting biofilm formation in *Klebsiella pneumoniae* bacteria. The data collection technique employed was the tube method to assess biofilm formation. The research was conducted from July to August 2020 at the Microbiology Laboratory of the Faculty of Medicine, Brawijaya University Malang. The preparation of cinnamon (*Cinnamomum burmannii*) leaf extract was carried out at the Chemical Engineering Laboratory of Malang State Polytechnic. The population in this study consisted of *Klebsiella pneumoniae* bacteria, and the samples used were biofilm-forming *Klebsiella pneumoniae* bacteria obtained from the Microbiology Laboratory of the Faculty of Medicine, Brawijaya University Malang.

RESULT AND DISCUSSION

Cinnamon Leaf Extraction Results

The extract used in this study was made from 100 grams of cinnamon leaves (*Cinnamomum burmannii*). Cinnamon leaves were washed first until clean then dried. The drying process uses an oven at 80°C for 2 days. After the drying process, the process continued by blending the cinnamon leaves to make a powder preparation. After that, enter the extraction process, namely by soaking the cinnamon leaf powder with 96% ethanol. After the extraction process is complete, the remaining solvent in the cinnamon leaf extract is removed by oven at a temperature of 70°-80°C until a constant weight of the extract is obtained.

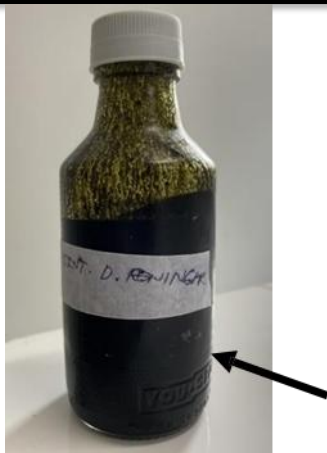


Figure 1: Cinnamon Leaf Ethanol Extract Results

Description: The arrow indicates the 96% ethanol extract of cinnamon leaves is blackish green in color.

Bacterial Identification Results

The *Klebsiella pneumoniae* bacterial identification test uses Gram staining, planting on MacConkey agar media, and VITEK test. In Gram staining, a red rod-shaped bacterial colony was obtained, indicating that *Klebsiella pneumoniae* is a Gram-negative bacterium as shown in Figure 2.

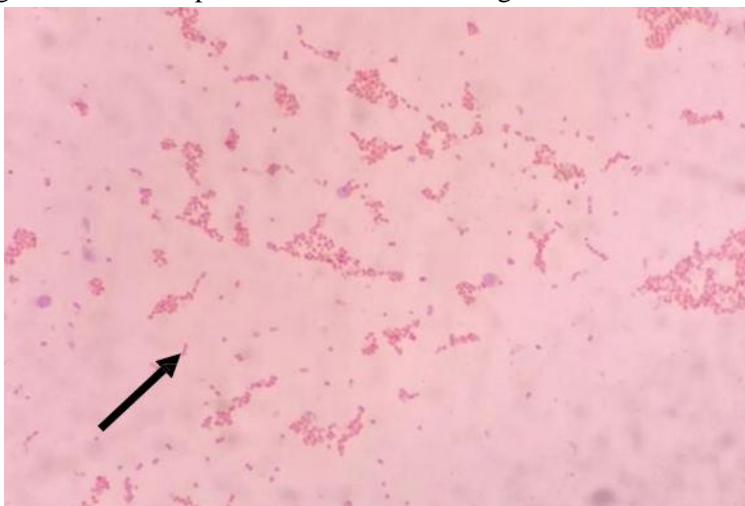


Figure 2. Gram Staining Results of *Klebsiella pneumoniae* Bacteria

Description: The arrow shows that Gram staining with a total magnification of 1000x obtained red rod-shaped bacteria which indicates that *Klebsiella pneumoniae* is a Gram negative bacteria.

Further bacterial identification test using MacConkey agar media. On MacConkey agar media, *Klebsiella pneumoniae* produces pink bacterial colonies indicating that *Klebsiella pneumoniae* can ferment lactose as shown in Figure 3.



Identification Results on MacConkey Agar Media

Description: The arrow shows that on MacConkey agar media, pink bacterial colonies were obtained, indicating that *Klebsiella pneumoniae* can ferment lactose.

Bacterial identification tests were also carried out using the VITEK method. The VITEK method was carried out for further confirmation and obtained a probability result of 99% *Klebsiella pneumoniae* as shown in Figure 4. These results indicate that the culture bacteria used in this study are *Klebsiella pneumoniae* bacteria.

Source: SPT Collected:

Comments: ESBL phenotype detected

Identification Information		Analysis Time: 3.92 hours	Status: Final
Selected Organism		99% Probability	<i>Klebsiella pneumoniae</i> ssp <i>pneumoniae</i>
ID Analysis Messages		Bionumber:	6607734653564010

Susceptibility Information		Analysis Time: 9.05 hours		Status: Final	
Antimicrobial	MIC	Interpretation	Antimicrobial	MIC	Interpretation
ESBL	POS	+	Aztreonam	<= 1	S
Ampicillin	>= 32	R	Ertapenem	<= 0.5	S
Ampicillin/Subactam	>= 32	R	Meropenem	<= 0.25	S
Piperacilin/Tazobactam	<= 4	S	Amikacin	<= 2	S
Cefazolin			Gentamicin	>= 16	R
Urine	>= 64	R	Ciprofloxacin	1	R
Other	>= 64*	R	Tigecycline	1	S
Ceftazidime	<= 1	S	Nitrofurantoin	64	I
Ceftriaxone	8	R	Trimethoprim/Sulfamethoxazole	<= 20	S
Cefepime	<= 1	S			

+= Deduced drug * = AES modified ** = User modified

AES Findings	
Confidence:	Consistent

Figure 4. VITEK results on *Klebsiella pneumoniae* bacteria

Description: The arrow indicates a 99% probability of the bacteria being *Klebsiella pneumoniae*.

Biofilm Formation Inhibition Test Results

Before the core research is carried out, preliminary research needs to be carried out with the aim of getting the right concentration to be studied. The concentrations used in preliminary research include 0%; 3.125%; 6.25%; 12.5%; 25%; 50%; and 100%. Based on the results of the preliminary research, it was determined that the concentrations to be used in the core research included 0%; 7.5%; 15%; 22.5%; 30%; 37.5%; and 100%. The treatment with 0% extract concentration is a negative control group without the administration of cinnamon leaf extract, while the treatment with 100% extract concentration is a positive control group. In the core research, there will be a repetition of 4 times at each concentration.

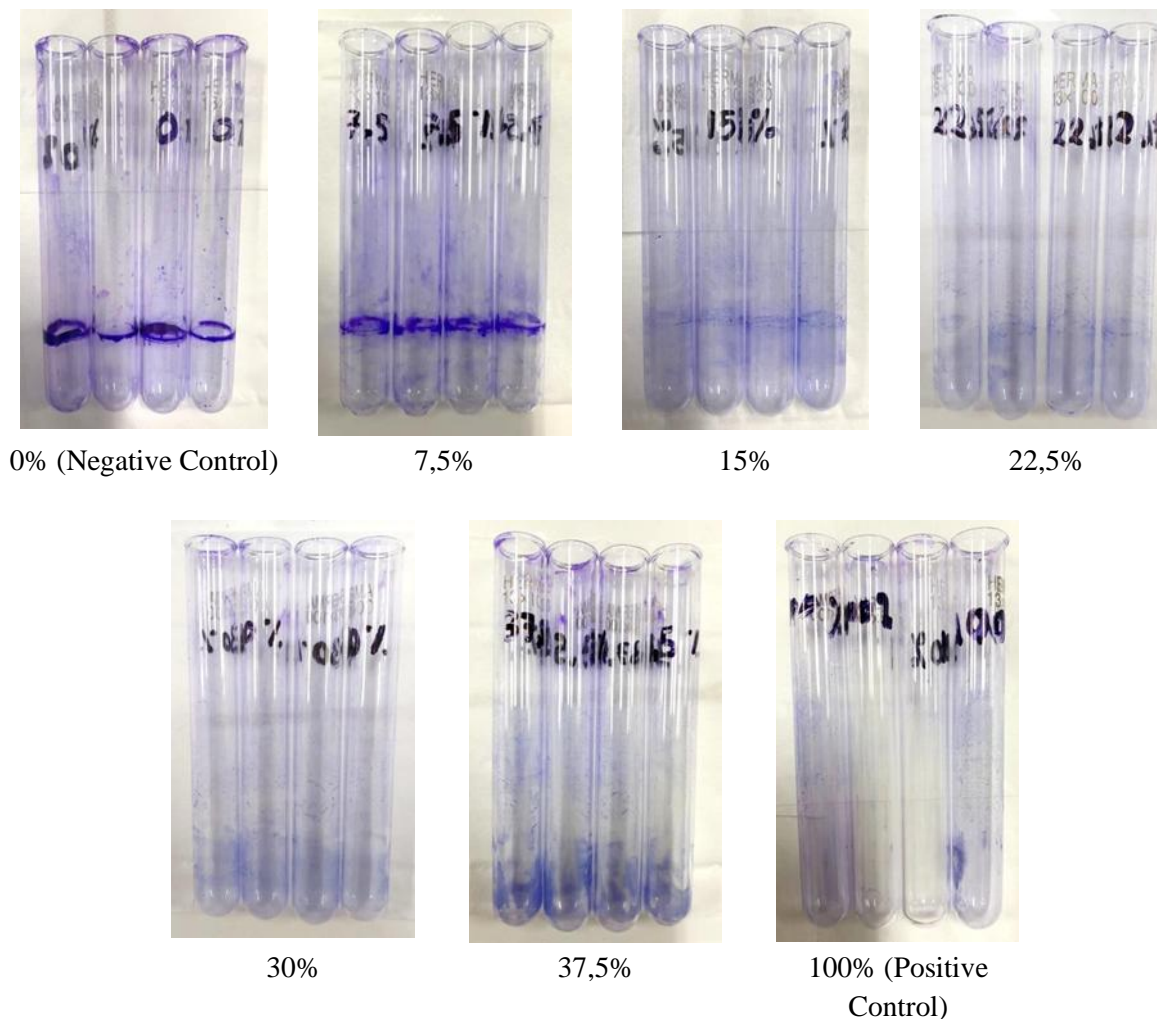


Figure 5: Core Research Results

Description: At each increase in the concentration of cinnamon leaf extract, the biofilm ring was found to be thinner, which means that bacterial growth and biofilm formation by *Klebsiella pneumoniae* were inhibited.

In this study, the extraction process of cinnamon leaves produces a crude extract which can cause extract particles to stick to the tube wall so that when staining with 0.1% crystal violet will leave residual purplish spots on the tube wall. Observation of the core research results was carried out on the intensity of the ring-shaped bluish purple color on the tube wall which indicated the formation of biofilm. The Mean Gray Value was then compared with the Mean Gray Value of the treated tubes as shown in Table 1. and converted into a graph in Figure 6.

Table 1. Mean Gray Value Measurement Results

Cinnamon Leaf Extract Concentration	Repetition				Mean ± SD
	I	II	III	IV	
0%	89,01	86,23	82,95	90,46	87,16 ± 3,31
7,5%	92,59	92,97	95,82	99,4	95,2 ± 3,15
15%	115,57	110,17	102,03	104,58	108,09 ± 6,04
22,5%	129,45	125,22	122,11	121,56	124,59 ± 3,62
30%	131,75	137,39	130,05	133,11	133,08 ± 3,14
37,5%	148,26	147,38	145,37	145,21	146,56 ± 1,51
100%	153,71	159,26	158,02	150,48	155,37 ± 4,03
<i>Mean Gray Value</i> Empty Tube	160,12				

Description: The Mean Gray Value measurement is used to quantitatively measure the intensity of the color density of the biofilm ring formed. The higher the Mean Gray Value value, the thinner the biofilm ring formed. Minimum Biofilm Inhibition Level (KHBM) can be known by the Mean Gray Value value which is 10% different from the Mean Gray Value value of the empty tube which is above 144.108. KHBM was obtained at a concentration of 37.5%.

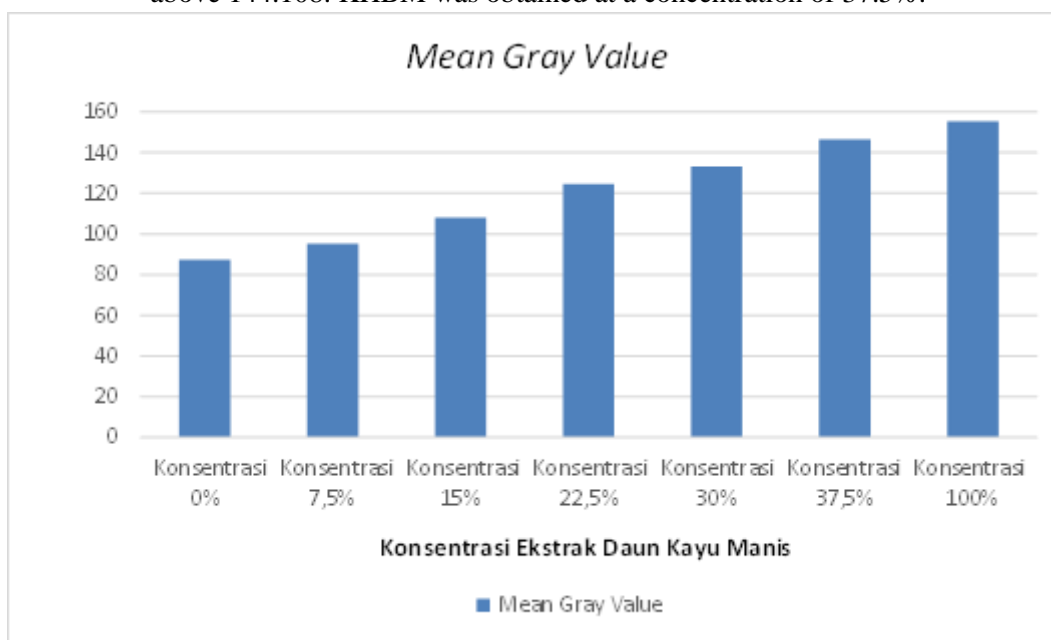


Figure 6. Graph of Mean Gray Value Measurement

Description: The Mean Gray Value measurement graph shows that the greater the concentration of the extract, the greater the Mean Gray Value obtained. This indicates that the greater the extract concentration, the thinner the biofilm ring formed and the more biofilm formation is inhibited.

This study is an experimental study to determine the effect of cinnamon leaf extract (*Cinnamomum burmannii*) in inhibiting biofilm formation in *Klebsiella pneumoniae* bacteria in vitro. In this study the independent variable is the concentration of cinnamon leaf extract and the dependent variable is biofilm formation by *Klebsiella pneumoniae* which is carried out by the tube method (Abu El-Wafa et al., 2020). The bacteria used in this study were *Klebsiella pneumoniae* bacteria obtained from the Microbiology Laboratory of the Faculty of Medicine, Universitas Brawijaya and grown on

Nutrient Agar Plate media. Cinnamon leaves (*Cinnamomum burmannii*) used were obtained from Materia Medica Batu in the form of dry powder. Cinnamon leaf powder was then extracted using 96% ethanol solvent at the Chemical Engineering Laboratory of Malang State Polytechnic. The method used for making cinnamon leaf extract is the maceration method. The advantages of this method are simpler procedures and equipment and more economical to obtain cinnamon leaf extract.

Based on research by Slobodnikova et al. (2016), flavonoid content can inhibit biofilm formation. Phytochemical test results of cinnamon leaf extract showed flavonoid content of 8.64% (Susanti et al., 2021). The antibiofilm ability played by flavonoids works by reducing bacterial attachment and inhibiting bacterial protein synthesis (Shariati et al., 2024; Tocci et al., 2018). Another mechanism is by inhibiting intercellular adhesion. If intercellular adhesion is inhibited, biofilm formation will be disrupted (Cui et al., 2020). Other research conducted by Trentin et al. (2024), regarding tannin content which has a role as an antibiofilm. The results of the phytochemical test of cinnamon leaf extract showed a tannin content of 4.69% (Susanti et al., 2021). The antibiofilm mechanism by tannins is by inhibiting bacterial attachment and EPS matrix formation (Silva et al., 2024), inhibiting biofilm formation by reducing the hydrophobic nature of bacteria which is an important factor in the attachment of bacterial cells to the medium (Shariati et al., 2024; Shineh et al., 2023) and inhibiting the quorum sensing mechanism so that fewer colonies form on biofilms (Asfour, 2018). Another study conducted by Santiago et al. (2015), regarding the role of saponins as antibiofilms by preventing the attachment of bacteria to the surface of the object. The results of the phytochemical test of cinnamon leaf extract showed a saponin content of 2.19% (Susanti et al., 2021). Based on this theoretical basis, the content in cinnamon leaf extract can inhibit the formation of bacterial biofilms.

The preliminary study was conducted to determine a tighter concentration that would be used in the core study. In preliminary research, it was found that at a concentration of 12.5% the biofilm ring had begun to be inhibited. The core research was then carried out using 7 extract concentrations, namely 0% (negative control); 7.5%; 15%; 22.5%; 30%; 37.5%; and 100% (positive control). The core study used the tube method with four repetitions according to Federer's formula.

The core research results were then documented using a cellphone camera with a resolution of 12 megapixels and processed into quantitative data. Quantitative data observation by looking at the intensity of the bluish purple ring color in each tube with Mean Gray Value in Adobe Photoshop CS6 application. The results showed an increase in the average Mean Gray Value which was directly proportional to the increase in the concentration of cinnamon leaf extract. Minimum Biofilm Inhibition Level (MWI) was obtained at a concentration of 37.5%. The results of this study prove that cinnamon leaf extract (*Cinnamomum burmannii*) can inhibit the formation of *Klebsiella pneumoniae* bacterial biofilm in vitro.

There are several other studies that support the results of this study. Which examines the effect of green tea extract (*Camellia sinensis* var. *assamica*) on the formation of *Klebsiella pneumoniae* biofilm with the tube method, it was found that green tea leaf extract has the effect of inhibiting the formation of *Klebsiella pneumoniae* biofilm at a Mean Gray Value of 144.61 which is at 20% KHBM. Another study conducted by Henry (2025), which examined the ethanol extract of basil leaves (*Ocimum sanctum*) can inhibit the growth of *Klebsiella pneumoniae* with the agar dilution method at a Minimum Inhibitory Level of 14%. In this study, cinnamon leaf extract (*Cinnamomum burmannii*) can inhibit the formation of *Klebsiella pneumoniae* biofilm at a Mean Gray Value of 146.56 which is at 37.5% KHBM. The difference in Minimum Inhibitory Levels in each plant extract can be caused by the antibiofilm content such as flavonoids, tannins, and saponins contained more than in cinnamon leaves. In addition, the difference in Minimum Inhibitory Level can also be caused by differences in the research methods

used. In this study using the tube method, while research conducted by Henry (2025) used the agar dilution method.

Regarding anti-quorum sensing activity in cinnamon leaf extract (*Cinnamomum burmannii*) against *Pseudomonas aeruginosa* by KLT (Thin Layer Chromatography) method - bioautography. In the study, the Minimum Inhibitory Level (KHM) of 8 micrograms/milliliter was obtained. The differences in this study can be caused by the methods and bacteria used. Another study conducted by Keerthana (2025), regarding the potential of ethanol extract of cinnamon (*Cinnamomum verum*) as an antibiofilm on *Burkholderia pseudomallei* with tube method. In this study, the Mean Gray Value was obtained at 131.40 at 50% KHBM. In this study, cinnamon leaf extract (*Cinnamomum burmannii*) can inhibit the formation of *Klebsiella pneumoniae* biofilm at a Mean Gray Value of 146.56 which is at 37.5% KHBM. This can be caused by differences in bacteria and types of cinnamon used in research. In this study using the type of *Cinnamomum burmannii*, while used *Cinnamomum verum*. Showed that cinnamon extract also has an effect in inhibiting biofilm formation on Gram-negative bacteria other than *Klebsiella pneumoniae* bacteria.

According to research conducted by Mubarak et al. (2022), regarding the antibacterial activity of cinnamon extract (*Cinnamomum burmannii*) against the growth of *Enterococcus faecalis* by dilution method. In this study, it was found that the Minimum Inhibitory Level (KHM) was at a concentration of 1.5%. The difference in the minimum concentration in the study compared to the minimum concentration in this study can be due to differences in bacteria, methods, and parts of cinnamon used. In this study using cinnamon leaf extract, while the study used cinnamon bark extract. Research conducted by Mubarak et al. (2022), showed that cinnamon extract also has an effect in inhibiting the growth of Gram-positive bacteria.

Further research conducted by Harmoko (2025), regarding the antifungal potential of cinnamon extract (*Cinnamomum burmannii*) against the growth of *Candida albicans* with the pitting method. In the study, it was found that cinnamon extract showed a zone of inhibition against the growth of *Candida albicans* starting at a concentration of 10%. The study shows that cinnamon extract also has an effect in inhibiting fungal growth. The difference in minimum concentration from that obtained in this study can be caused by differences in microorganisms and methods used. The advantages of this study are that there have not been many previous studies that utilize cinnamon as a bacterial antibiofilm and in this study utilizing the antibiofilm content only in the leaves of cinnamon. The limitation of this study is that observations were only made after the incubation period was complete, not all the time. Therefore, researchers could not observe the biofilm formation process directly in detail. Another limitation is the extraction process that produces crude extract so that it does not specifically produce one type of active substance. This leads to not knowing which antibiofilm content is most influential in inhibiting biofilms. In addition, the crude extract can cause extract particles to stick to the tube wall so that during the staining process with 0.1% crystal violet will make the attached extract particles colored and produce purplish spots on the tube wall. Another limitation is the unknown effect of the length of storage of the extract on the content and effectiveness of active substances in cinnamon leaf extract in inhibiting biofilm (Vlčko et al., 2022).

CONCLUSION

Based on the research objectives, it can be concluded that cinnamon leaf extract (*Cinnamomum burmannii*) effectively inhibits the formation of *Klebsiella pneumoniae* bacterial biofilm in vitro, with inhibition increasing as the concentration of the extract rises. The Minimum Biofilm Inhibition Level (KHBM) observed in this study was at a concentration of 37.5%. Future research could further explore

the underlying mechanisms of biofilm inhibition by cinnamon leaf extract and assess its potential in clinical applications.

REFERENCES

- Abu El-Wafa, W. M., Ahmed, R. H., & Ramadan, M. A.-H. (2020). Synergistic effects of pomegranate and rosemary extracts in combination with antibiotics against antibiotic resistance and biofilm formation of *Pseudomonas aeruginosa*. *Brazilian Journal of Microbiology*, *51*(3), 1079–1092.
- Al-Abjadi, R. S., Suhail, A. A., & Almousawi, A. E. (2023). An overview of *Klebsiella pneumoniae*: History, taxonomy, epidemiology, pathogenicity, virulence factors and treatment. *AIP Conference Proceedings*, *2977*(1).
- Ali, A., Zahra, A., Kamthan, M., Husain, F. M., Albalawi, T., Zubair, M., Alatawy, R., Abid, M., & Noorani, M. S. (2023). Microbial biofilms: applications, clinical consequences, and alternative therapies. *Microorganisms*, *11*(8), 1934.
- Asfour, H. Z. (2018). Anti-quorum sensing natural compounds. *Journal of Microscopy and Ultrastructure*, *6*(1), 1–10.
- Aslan, S., Hasanuddin, N. R., Mallombasang, A. T. B., & AR, N. A. (2022). Effectiveness of Mixed Clove Flower Extract (*Syzygium Aromaticum*) And Sweet Wood (*Cinnamon Burmannii*) on the Growth of *Enterococcus Faecalis*. *Indian Journal of Forensic Medicine & Toxicology*, *16*(1), 1089–1094.
- Cui, H., Zhang, C., Li, C., & Lin, L. (2020). Inhibition mechanism of cardamom essential oil on methicillin-resistant *Staphylococcus aureus* biofilm. *LWT*, *122*, 109057. <https://doi.org/10.1016/j.lwt.2020.109057>
- Holban, A. M., Gestal, M. C., & Grumezescu, A. M. (2016). Control of biofilm-associated infections by signaling molecules and nanoparticles. *International Journal of Pharmaceutics*, *510*(2), 409–418. <https://doi.org/10.1016/j.ijpharm.2016.02.044>
- Liu, S., Yang, L., Zheng, S., Hou, A., Man, W., Zhang, J., Wang, S., Wang, X., Yu, H., & Jiang, H. (2021). A review: the botany, ethnopharmacology, phytochemistry, pharmacology of *Cinnamomi cortex*. *RSC Advances*, *11*(44), 27461–27497.
- Paterson, S. (2017). Biofilms: their importance in veterinary medicine. *Companion Animal*, *22*(11), 659–668.
- Sakulsathaporn, A., Chantasit, P., Kwantrairat, S., Jirukkakul, N., & Sripan, S. (2025). Red-Blue LED lights promoting on biomass production and MRSA inhibition properties in callus cultures of the endemic Thai plant *Platostoma hemratanum* Suddee, Puudjaa & Kiewbang (Lamiaceae). *Plant Cell, Tissue and Organ Culture (PCTOC)*, *160*(1), 13.
- Santiago, C., Lim, K.-H., Loh, H.-S., & Ting, K. N. (2015). Inhibitory effect of *Duabanga grandiflora* on MRSA biofilm formation via prevention of cell-surface attachment and PBP2a production. *Molecules*, *20*(3), 4473–4482.
- Shariati, A., Didehdar, M., Razavi, S., Heidary, M., Soroush, F., & Chegini, Z. (2022). Natural compounds: a hopeful promise as an antibiofilm agent against *Candida* species. *Frontiers in Pharmacology*, *13*, 917787.
- Shariati, A., Noei, M., Askarina, M., Khoshbayan, A., Farahani, A., & Chegini, Z. (2024). Inhibitory effect of natural compounds on quorum sensing system in *Pseudomonas aeruginosa*: a helpful promise for managing biofilm community. *Frontiers in Pharmacology*, *15*, 1350391.
- Sharma, S., Mohler, J., Mahajan, S. D., Schwartz, S. A., Bruggemann, L., & Aalinkeel, R. (2023). Microbial biofilm: a review on formation, infection, antibiotic resistance, control measures, and innovative treatment. *Microorganisms*, *11*(6), 1614.
-

- Shineh, G., Mobaraki, M., Perves Bappy, M. J., & Mills, D. K. (2023). Biofilm formation, and related impacts on healthcare, food processing and packaging, industrial manufacturing, marine industries, and sanitation—a review. *Applied Microbiology*, 3(3), 629–665.
- Silva, N. L. F., Vieira, P. de B., Silva, M. V. da, Macedo, A. J., & Tasca, T. (2024). The Enhanced Activity of a Plant Mixture from the Brazilian Caatinga Biome against Venereal Trichomonads Confirms the Traditional Use. *Venereology*, 3(1), 15–25.
- Slobodníková, L., Fialová, S., Rendeková, K., Kováč, J., & Mučaji, P. (2016). Antibiofilm activity of plant polyphenols. *Molecules*, 21(12), 1717.
- Susanti, E., Wahjuningrum, D., Nuryati, S., & Setiawati, M. (2021). The effectiveness of cinnamon powder and cinnamon leaf extract to prevent *Aeromonas hydrophila* infection on striped catfish *Pangasianodon hypophthalmus*. *Jurnal Akuakultur Indonesia*, 20(2), 163–173.
- Tocci, N., Weil, T., Perenzoni, D., Narduzzi, L., Madriñán, S., Crockett, S., Nürk, N. M., Cavaliere, D., & Mattivi, F. (2018). Phenolic profile, chemical relationship and antifungal activity of Andean *Hypericum* species. *Industrial Crops and Products*, 112, 32–37. <https://doi.org/10.1016/j.indcrop.2017.10.030>
- Varalakshmi, B., Firdous, J., Manikandan, R., Karpagam, T., Shanmugapriya, A., Abarna, V., & Jeyachristy, S. A. (2025). Antibiofilm Efficacy of Phenolic Rich Fraction from *Cinnamomum zeylanicum* Bark against *Pseudomonas aeruginosa*. *International Journal of Advancement in Life Sciences Research*, 8(1), 89–99.
- Vlčko, T., Rathod, N. B., Kulawik, P., Ozogul, Y., & Ozogul, F. (2022). *The impact of aromatic plant-derived bioactive compounds on seafood quality and safety* (pp. 275–339). <https://doi.org/10.1016/bs.afnr.2022.05.002>
- Yadav, N., Saini, N., Rath, N., Chauhan, S., Sharma, P. K., & Sangwan, N. S. (2025). Health-promoting effects of cinnamon. In *Cinnamon* (pp. 219–241). Elsevier. <https://doi.org/10.1016/B978-0-443-21820-0.00015-5>



© 2025 by the authors. It was submitted for possible open-access publication under the terms and conditions of the Creative Commons Attribution (CC BY SA) license (<https://creativecommons.org/licenses/by-sa/4.0/>).