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Comparison of the Antibacterial Activity of Cinnamon Bark Extract (Cinnamomum burmannii) Against the Growth of Staphylococcus aureus and Methicillin-Resistant Staphylococcus aureus

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ABSTRACT

This study aimed to compare the antibacterial activity of ethanol extract of cinnamon bark (Cinnamomum burmannii) against the growth of Staphylococcus aureus and Methicillin-Resistant Staphylococcus aureus (MRSA). This experimental study employed a post-test only design using the agar diffusion method (Kirby–Bauer) at extract concentrations of 25%, 50%, 75%, and 100%, with ciprofloxacin as the positive control and distilled water as the negative control. Inhibition zones were measured after 24 hours of incubation and analyzed using one-way ANOVA. The results showed that cinnamon bark extract produced strong inhibition zones for both bacteria, with diameters ranging from 11.53–12.97 mm for S. aureus and 12.00–13.47 mm for MRSA, although still lower than the positive control. The antibacterial activity of the extract was slightly higher against MRSA than S. aureus. In conclusion, ethanol extract of cinnamon bark exhibits antibacterial potential against both S. aureus and MRSA. Bioactive compounds such as alkaloids, flavonoids, tannins, and saponins are suspected to contribute to this effectiveness, warranting further research to clarify the mechanism of action and evaluate its potential application as a natural antibacterial agent.

Keywords: cinnamomum burmannii, cinnamon bark, staphylococcus aureus, antibacterial

INTRODUCTION

A significant global health challenge, particularly in developing countries, is infectious diseases. These diseases are caused by various microorganisms, including bacteria, viruses, fungi, and parasites [1]. Despite considerable advancements in the health sector, infectious diseases remain a leading cause of morbidity and mortality worldwide. According to the World Health Organization (WHO) report in 2015, infectious diseases ranked second after cardiovascular diseases as the leading cause of global mortality, accounting for approximately 25% of 53.9 million deaths annually, equivalent to more than 13 million lives lost [2]. These figures underscore the urgent need to develop more effective prevention and treatment strategies, including the discovery of new antibacterial agents capable of combating infections without causing excessive side effects.

Antibacterial agents have become a major focus because natural substances offer an environmentally friendly, affordable, and effective alternative to synthetic antibiotics. One plant that has garnered significant attention is cinnamon (Cinnamomum burmannii), which has long been used traditionally in herbal medicine, jamu, and as a spice. Cinnamon contains a key bioactive compound, cinnamaldehyde, which belongs to the aldehyde and alkene groups. This compound is known for its antibacterial and anti-inflammatory activities, making it a promising candidate for the development of modern herbal-based therapies [3]. Previous research has shown that from 150 grams of cinnamon crude material extracted with 96% ethanol, approximately 43.3 grams of a thick extract rich in active compounds can be obtained [4]. In addition to cinnamaldehyde, cinnamon contains various phenolic compounds such as tannins, flavonoids, triterpenoids, and saponins, all of which contribute to its antimicrobial activity. Proper extraction of cinnamon bark is crucial to obtain bioactive compounds that are effective against a range of pathogenic bacteria [5].

Among pathogenic bacteria of major concern, Staphylococcus aureus is a common component of the normal flora found on human skin and mucous membranes. The spread of pathogenic microbes can be harmful, both to healthy individuals and, more critically, to those who are already ill. Many infections are caused by Staphylococcus aureus [6]. Common skin infections caused by this bacterium includes acne. Infections are typically treated with antibiotics; however, such treatments can lead to bacterial resistance [7]. While usually harmless in healthy individuals, S. aureus can cause serious clinical infections if it enters the

bloodstream or internal tissues, including bacteremia, infective endocarditis, pneumonia, and various skin infections [8]. It is estimated that approximately 30% of the global population is colonized by Staphylococcus aureus, either symptomatically or asymptomatically. This coagulase-positive bacterium can cause a wide range of infections, from mild skin infections such as furuncles, acne, pyoderma, or impetigo, to severe and potentially fatal infections including pneumonia, meningitis, empyema, endocarditis, and sepsis [9]. In 2017, the World Health Organization (WHO) classified Staphylococcus aureus as a priority pathogen requiring the development of new antibiotics due to rising resistance to conventional antibiotics, known as Multi-Drug Resistance (MDR). This problem is further exacerbated by the emergence of more complex strains, such as Methicillin-Resistant Staphylococcus aureus (MRSA). MRSA is a form of S. aureus that shows resistance to standard antibiotics, including methicillin and several other commonly used clinical antibiotics [8], [10].

Antibiotic resistance has become a serious global challenge in controlling infectious diseases. Bacterial resistance can arise from intrinsic bacterial mechanisms or from environmental and human behavioral factors. One major contributing factor is the easy public access to antibiotics without adequate medical supervision. Additionally, inappropriate antibiotic selection, incorrect dosing, and use of antibiotics for conditions that are not indicated can accelerate the development of resistance. As a result, the effectiveness of antibiotics against pathogens diminishes, making bacterial infections increasingly difficult to treat. The impact is not only higher morbidity and mortality, but antibiotic resistance also places a substantial burden on healthcare systems due to the need for more complex and expensive patient management [11]. This situation underscores the urgent need for effective and safe alternative antibacterial agents, particularly those derived from natural sources with minimal side effects. The use of cinnamon as an antibacterial agent is highly relevant, as its bioactive compounds have been shown to inhibit the growth of various pathogenic microorganisms. The antibacterial activity of cinnamon is believed to work through mechanisms affecting bacterial cell membranes and internal metabolism, thereby disrupting bacterial proliferation without rapidly inducing resistance. With this potential, cinnamon represents a promising candidate as an alternative to synthetic antibiotics, especially against resistant bacteria such as MRSA [3], [5]. Extracts from Cinnamomum burmannii have been demonstrated to inhibit the growth of Methicillin-Resistant Staphylococcus aureus [12].

The novelty of this study lies in its direct comparison of the antibacterial activity of ethanol extracts from cinnamon bark (Cinnamomum burmannii) against two bacterial groups with different sensitivity profiles: Staphylococcus aureus and Methicillin-Resistant Staphylococcus aureus (MRSA). Although several previous studies have reported the antibacterial potential of various herbal plants, including cinnamon, most have focused on a single type of bacteria or did not systematically compare sensitive and resistant strains. Therefore, this study contributes new insights by providing a clearer mapping of the effectiveness of cinnamon bark extract against both bacterial types, while addressing the scientific need for natural antibacterial alternatives capable of countering the increasing incidence of antibiotic resistance.

Based on the above, this study aims to compare the antibacterial activity of cinnamon bark extract (Cinnamomum burmannii) in inhibiting the growth of Staphylococcus aureus and Methicillin-Resistant Staphylococcus aureus (MRSA). The research is expected to provide more comprehensive scientific information regarding the potential of cinnamon extract as a natural antibacterial agent and to open opportunities for developing safer and more effective alternative therapies in response to the growing challenge of antibiotic resistance.

RESEARCH METHODS

This study employed an experimental research design with a post-test only approach. The first step involved sterilizing all equipment prior to use to eliminate any existing microorganisms. Glassware required for the procedures was sterilized in an oven at 160 °C for 1 hour. Inoculation loops were sterilized by flaming over a spirit lamp. Nutrient Agar (NA) media and distilled water were sterilized using an autoclave at 121 °C for 15 minutes under a pressure of 1.5 atmospheres [13].

The NA media was prepared by weighing 5 grams of Nutrient Agar and dissolving it in distilled water in a 250 mL Erlenmeyer flask. The mixture was then heated on a hot plate while continuously stirring until it reached boiling and completely dissolved, resulting in a clear yellow solution. The Erlenmeyer flask was then covered with gauze and cotton, and subsequently sterilized using an autoclave at 121 °C for 15 minutes under a pressure of 1.5 atmospheres. [14].

The sterilized Nutrient Agar was allowed to cool for several minutes until reaching a temperature of 40–50 °C. The medium was then poured into slanted test tubes and left to solidify. To culture the bacteria, one or two loops of bacterial inoculum were taken from the stock culture using an inoculation loop and streaked onto the medium in separate test tubes. The tubes were incubated for 24 hours at 37 °C, and after incubation, they were stored in a refrigerator at 4 °C to be used as bacterial stock [15].

The rejuvenated test bacteria were collected using 3–4 streaks and transferred into a test tube containing 6 mL of 0.9% w/v physiological NaCl solution, then homogenized using a vortex mixer. The resulting suspension was measured using a UV-Vis spectrophotometer at a wavelength of 580 nm to achieve a transmittance of 25%. If the bacterial suspension showed transmittance below 25%, additional NaCl solution was added; conversely, if the transmittance exceeded 25%, more bacterial inoculum

was added. Once a bacterial suspension with 25% transmittance was obtained, further dilution of the suspension was carried out [14].

The bacterial suspension was then prepared at various dilution levels: 10^{-1}, 10^{-2}, 10^{-3}, 10^{-4}, and 10^{-5}. To prepare the 10^{-1} dilution, 0.5 mL of the stock solution was transferred into a test tube containing 4.5 mL of 0.9% NaCl. For the 10^{-2} dilution, 0.5 mL of the 10^{-1} dilution was mixed with 4.5 mL of 0.9% NaCl. Similarly, the 10^{-3} dilution was prepared by transferring 0.5 mL of the 10^{-2} dilution into 4.5 mL of 0.9% NaCl. The 10^{-4} dilution was made by mixing 0.5 mL of the 10^{-3} dilution with 4.5 mL of 0.9% NaCl. Finally, the 10^{-5} dilution was prepared by adding 0.5 mL of the 10^{-4} dilution into 4.5 mL of 0.9% NaCl [16].

The preparation of cinnamon bark (Cinnamomum burmannii) simplicia began with wet sorting, followed by thoroughly washing the bark under running water. The cleaned cinnamon bark was then sliced and dried under direct sunlight until completely dry. After drying, a dry sorting process was carried out, and the bark was finely ground using a blender. Extraction was performed using the maceration method with 96% ethanol as the solvent, at a ratio of 1:3 (simplicia to solvent). The maceration process was conducted for 24 hours at room temperature and repeated three times. The resulting extract solution was concentrated using a rotary evaporator at 60 °C and 70 RPM, followed by oven drying at 60 °C until a thick extract was obtained [4].

The antibacterial testing method used in this study was the agar diffusion technique, commonly known as the Kirby–Bauer disk diffusion method, using paper disks. The procedure involved inoculating bacteria onto Nutrient Agar (NA) media, where bacterial suspensions were collected using sterile cotton swabs and evenly spread across the agar surface. Paper disks were soaked in the positive control (Ciprofloxacin), negative control (distilled water), and various concentrations of cinnamon bark extract (Cinnamomum burmannii), and then placed on Petri dishes containing agar inoculated with Staphylococcus aureus and Methicillin-Resistant Staphylococcus aureus (MRSA). The disks were subsequently incubated for 24 hours.

Observations were carried out after a 24-hour incubation period. The area surrounding each disk indicated the bacterial response to the tested antibiotic or antibacterial agent, determined by measuring the diameter of the inhibition zone or bacterial killing zone. The diameter of the inhibition zone was recorded in millimeters (mm) using a caliper, measuring the total diameter of the clear or turbid zone formed around the disk [17].

The data obtained from this study were analyzed using SPSS (Statistical Package for the Social Sciences) Version 26.0. The statistical analysis began with a normality test to determine whether the data were normally distributed. Variance homogeneity was assessed using Levene's test to evaluate whether the data variances were homogeneous. If the data met the assumptions of normality and homogeneity, a One-Way ANOVA was applied to compare the means among different groups. Conversely, if the data did not meet the normality assumption, the Kruskal–Wallis test was used as a non-parametric alternative [18]. The hypothesis was considered significant if $p < 0.05$. In such cases, a t-test was subsequently performed to determine the effect of the antibacterial activity of cinnamon bark extract on the inhibition zone diameters formed against Staphylococcus aureus and Methicillin-Resistant Staphylococcus aureus (MRSA).

RESULT AND DISCUSSION

Phytochemical screening is a qualitative analytical method used to identify the presence of secondary metabolites or active compounds in plants. The results of the phytochemical screening of cinnamon bark extract are presented in Table 1.

Table 1. Phytochemical Screening Results of Cinnamon Bark Extract (Cinnamomum burmannii)

Secondary Metabolites	Reagents	Hasil
Alkaloid	Dragendorff	+
	Wagner	-
	Bouchardat	+
	Mayer	+
Flavonoid	Mg powder + Amyl Alcohol + HCl	+
Glycosides	Molisch + H_2SO_4	-
Saponins	Shaken Hot Water	+
Tannins	$FeCl_3$ 1%	+
Triterpenoids	Liebermann–Burchard	-

Based on Table 1, the phytochemical screening results of cinnamon bark extract (Cinnamomum burmannii) identified the presence of several important secondary metabolites. The compounds detected as positive include alkaloids, flavonoids, saponins, and tannins, whereas glycosides and triterpenoids tested with specific reagents yielded negative results. Consistently, cinnamon extract is known to contain chemical compounds such as alkaloids, saponins, tannins, polyphenols, flavonoids, quinones, and triterpenoids [19]. These findings provide a strong scientific basis for explaining the antibacterial activity of the extract, as each metabolite has mechanisms that can disrupt bacterial cell structure and function. Alkaloids are known to interfere with bacterial cell membrane integrity, flavonoids can inhibit nucleic acid synthesis and inactivate essential enzymes, while tannins act through protein precipitation and cell wall damage. Additionally, lipophilic triterpenoids facilitate penetration into bacterial membranes, causing leakage of intracellular components. The combination of these mechanisms provides a logical explanation for the

strong antibacterial activity exhibited by cinnamon bark extract against both Staphylococcus aureus and MRSA in the agar diffusion tests.

The main finding from this table is that cinnamon bark extract contains several active metabolites that may act synergistically to inhibit bacterial growth. Several factors contribute to these results, including the use of ethanol as a solvent, which effectively extracts polar and semi-polar compounds such as flavonoids, tannins, and glycosides, as well as the specific characteristics of Cinnamomum burmannii, which is known for its high phenolic content. In addition, using multiple reagents for alkaloid detection, such as Dragendorff, Mayer, and Wagner, enhances the validity of the identification results.

However, this study has limitations, as it did not quantify the metabolites, so the relative contribution of each compound to the antibacterial activity cannot be determined, and it did not employ advanced analyses such as GC-MS or LC-MS that could identify active compounds more specifically. These findings are in line with [20] which reported that cinnamon extract contains flavonoids and tannins that play an important role in inhibiting the growth of S. aureus. They are also consistent with [21] which indicated that cinnamon exhibits significant antibacterial activity against MRSA, reinforcing the relevance of this study's results to antibiotic-resistant bacteria. Furthermore, [22] explained that flavonoids and terpenoids in spices can work synergistically to disrupt the membranes of Gram-positive bacteria, supporting the mechanistic explanation observed in this study.

The measurements of antibacterial activity of cinnamon bark extract (Cinnamomum burmannii) against Staphylococcus aureus and Methicillin-Resistant Staphylococcus aureus (MRSA), observed over a 24-hour period with three repetitions, are presented in Table 2.

Table 2. Measurement Results of Inhibition Zone Diameter on Staphylococcus aureus

Extract Concentration (%)	Inhibition Zone Diameter (mm)				
	P1	P2	P3	Average	Standard Deviation
25	11.5	11.4	11.7	11.53	0.15
50	11.8	11.9	12.0	11.90	0.10
75	12.6	12.4	12.7	12.57	0.15
100	12.8	13.0	13.1	12.97	0.15

Table 2 shows that increasing the concentration of cinnamon bark extract (Cinnamomum burmannii) correlates positively with an increase in the inhibition zone diameter against Staphylococcus aureus. At a 25% concentration, three repetitions produced an average inhibition zone of 11.53 mm, indicating strong antibacterial activity. When the concentration was increased to 50%, the average inhibition zone diameter rose to 11.90 mm, demonstrating enhanced effectiveness as more active metabolites were available to interact with bacterial cells. A more significant increase was observed at a 75% concentration, where the inhibition zone reached 12.57 mm. At the highest concentration, 100%, the average inhibition zone reached 12.97 mm, the largest value across all treatments, confirming that higher extract concentrations result in greater inhibition of S. aureus growth.

The consistent increase in the inhibition zones across all repetitions indicates that the antibacterial activity of the extract is dose-dependent. This effect can be attributed to the higher amounts of active compounds, including flavonoids, tannins, alkaloids, and triterpenoids, which act by damaging the cell wall, inhibiting bacterial enzymes, and increasing membrane permeability. The low standard deviation values for each concentration (0.10–0.15) also demonstrate stable measurements and high consistency across experiment replications. The measured results for positive and negative controls observed over the 24-hour period are presented in Table 3.

Table 3. Measurement Results of Inhibition Zone Diameters Controls against Staphylococcus aureus

Control	Inhibition Zone Diameter (mm)
Ciprofloxacin (+)	20.7
Distilled Water (-)	0.00

Table 3 presents the measurement results of the inhibition zone diameters for the positive and negative controls against Staphylococcus aureus. The positive control, using the antibiotic ciprofloxacin, produced an inhibition zone of 20.7 mm, indicating that S. aureus is highly sensitive to this antibiotic. The strong inhibitory effect aligns with the mechanism of ciprofloxacin, a fluoroquinolone, which inhibits the bacterial enzymes DNA gyrase and topoisomerase IV, thereby blocking DNA replication. This potent antibacterial activity of ciprofloxacin is consistent with previous studies showing that S. aureus typically exhibits large inhibition zones when tested with ciprofloxacin. [23].

In contrast, the negative control, consisting of distilled water, showed no antibacterial activity, with an inhibition zone of 0.00 mm. The absence of an inhibition zone confirms that distilled water has no effect on bacterial growth, ensuring that the inhibition zones observed in the test samples are attributable to the active compounds being tested rather than the solvent.

Table 4. Measurement Results of Inhibition Zone Diameter on Methicillin-Resistant Staphylococcus aureus

Extract Concentration (%)	Inhibition Zone Diameter (mm)				
	P1	P2	P3	Average	Standard Deviation
25	12.2	11.8	12.0	12.00	0.20
50	12.6	12.2	12.5	12.43	0.21
75	13.1	12.6	13.2	12.97	0.32
100	13.5	13.3	13.6	13.47	0.15

Table 4 shows that increasing the concentration of cinnamon bark extract (Cinnamomum burmannii) correlates directly with an increase in the inhibition zone diameter against Methicillin-Resistant Staphylococcus aureus (MRSA). At a concentration of 25%, three repetitions produced inhibition zones of 12.2 mm, 11.8 mm, and 12.0 mm, with an average of 12.00 mm and a standard deviation of 0.20, indicating relatively stable antibacterial activity at a low concentration.

Antibacterial activity increased at a 50% concentration, with inhibition zones of 12.6 mm, 12.2 mm, and 12.5 mm, resulting in an average of 12.43 mm. This indicates enhanced effectiveness corresponding to the higher number of active compounds such as cinnamaldehyde and eugenol in the extract. At a 75% concentration, the inhibition zones further increased to 13.1 mm, 12.6 mm, and 13.2 mm, with an average of 12.97 mm and a slightly higher standard deviation of 0.32. This small increase in variation is still within an acceptable range and reflects the bacterial response to the higher levels of antibacterial compounds.

At 100% concentration, the extract exhibited the strongest antibacterial activity, with inhibition zones of 13.5 mm, 13.3 mm, and 13.6 mm, giving an average of 13.47 mm. These results confirm that higher extract concentrations correspond to greater antibacterial efficacy in inhibiting MRSA growth. The observed trend of increasing inhibition zone diameter with higher concentrations aligns with recent studies indicating that the antibacterial effectiveness of plant extracts generally follows a positive dose-response pattern [24].

Table 5. Measurement Results of Inhibition Zone Diameters for Methicillin-Resistant Staphylococcus aureus (MRSA)

Control	Inhibition Zone Diameter (mm)
Ciprofloxacin (+)	19.2
Distilled Water (-)	0.00

Table 5 illustrates a clear distinction between the positive and negative controls in producing inhibition zones against Methicillin-Resistant Staphylococcus aureus (MRSA). The positive control, using the antibiotic ciprofloxacin, produced an inhibition zone with a diameter of 19.2 mm, indicating that this antibiotic remains highly effective in suppressing the growth of S. aureus. The relatively large inhibition zone reflects the mechanism of ciprofloxacin as a broad-spectrum antibiotic, which inhibits bacterial DNA gyrase and thereby disrupts DNA replication.

In contrast, the negative control, using distilled water, resulted in a 0.00 mm inhibition zone, indicating no antibacterial activity. This outcome confirms that no inhibitory factors were present other than the test treatment, ensuring that the observed inhibition zones in the extract treatments are solely attributable to the antibacterial activity of the cinnamon bark extract. The marked difference between the positive and negative controls further validates the reliability of the testing method, as the negative control exhibited no inhibitory effects that could interfere with result interpretation.

Table 6. Normality Test Results

Sample	Shapiro-Wilk		
	Concentration (%)	Replication	p-*value*
Staphylococcus aureus	25	3	0.637
	50	3	1.000
	75	3	0.637
	100	3	0.637
Methicillin Resistant Staphylococcus aureus	25	3	1.000
	50	3	0.463
	75	3	0.298
	100	3	0.637

Based on the results of the normality test using the Shapiro–Wilk method, the data distribution for the Staphylococcus aureus treatment groups at concentrations of 25%, 50%, 75%, and 100% showed significance values of p = 0.637, p = 1.000, p = 0.637, and p = 0.637, respectively. All significance values are greater than 0.05, indicating that the data for each S. aureus concentration group are normally distributed (p > 0.05). Therefore, the measurement data for the S. aureus groups meet the normality assumption and are suitable for parametric analysis.

Meanwhile, for the Methicillin-Resistant Staphylococcus aureus (MRSA) groups at concentrations of 25%, 50%, 75%, and 100%, the Shapiro–Wilk test yielded significance values of p = 1.000, p = 0.463, p = 0.298, and p = 0.637, respectively. All significance values are also greater than 0.05, indicating that the data for each MRSA concentration group are normally distributed. Thus, the datasets for both Staphylococcus aureus and MRSA meet the normality assumption and are suitable for further statistical analysis using parametric methods.

Table 7. Homogeneity Test Results

Sample	Inhibitory Power	Shapiro-Wilk	
		Levene Statistic	p- *value*
Staphylococcus aureus	Average Inhibitory Power	3.000	0.055
Methicillin Resistant Staphylococcus aureus		2.733	0.071

Based on Table 7, the results of the homogeneity of variance test using Levene's Test show that the Staphylococcus aureus group obtained a significance value of p = 0.055, while the Methicillin-Resistant Staphylococcus aureus (MRSA) group obtained a significance value of p = 0.071. Both significance values are greater than 0.05, which indicates that the data variance in each group is homogeneous. By fulfilling the assumption of homogeneity of variance for the Staphylococcus aureus and MRSA groups, the data are worthy of further analysis using the parametric ANOVA test to determine whether there are significant differences between treatment groups.

Table 8. Results of One-Way ANOVA Test

Sample	p-*value*
Staphylococcus aureus	0.000
Methicillin Resistant Staphylococcus aureus	0.000

Based on Table 8, the results of the one-way ANOVA analysis obtained a p-value < 0.001 for the Staphylococcus aureus group. A significance value less than 0.05 indicates a statistically significant difference between treatment groups in terms of Staphylococcus aureus growth. Therefore, it can be concluded that variations in treatment concentration significantly affected Staphylococcus aureus growth.

In the methicillin-resistant Staphylococcus aureus group, the p-value is less than 0.001, which is also less than 0.05. These results indicate a significant difference in the growth of methicillin-resistant Staphylococcus aureus. It can be concluded that variations in treatment concentration significantly affected the inhibitory activity of methicillin-resistant Staphylococcus aureus. Overall, these results indicate that the treatments for Staphylococcus aureus and methicillin-resistant Staphylococcus aureus produced significant differences between groups. Therefore, the analysis continued with a post hoc test (Duncan) to determine which group had the most significant difference.

Table 9. Posthoc Test Results

Sample	*Posthoc* (Duncan)		
	Concentration (%)	Replication	Mean
Staphylococcus aureus	Negative	3	0.00
	25	3	11.53
	50	3	11.90
	75	3	12.57
	100	3	12.97
	Positive	3	20.70
Methicillin Resistant Staphylococcus aureus	Negative	3	0.00
	25	3	12.00
	50	3	12.43
	75	3	12.97
	100	3	13.47
	Positive	3	19.22

Based on Table 9, the results of the posthoc (Duncan) test on the Staphylococcus aureus group, it was found that each concentration group showed different average values and formed different subsets. The average inhibitory effect value increased with increasing treatment concentration, namely from 25% to 100%. These results indicate a significant increase in the inhibitory effect on Staphylococcus aureus at higher concentrations. Thus, it can be concluded that the treatment concentration significantly affected the growth of Staphylococcus aureus, with the 100% concentration and the positive control providing the strongest effect compared to lower concentrations.

In the methicillin-resistant Staphylococcus aureus group, the post hoc (Duncan) test results showed a similar pattern. These results indicate that the higher the treatment concentration, the greater the inhibitory effect on the growth of methicillin-resistant Staphylococcus aureus. Overall, the post hoc (Duncan) test supports the findings of the previous ANOVA test, namely that there were significant differences between treatment groups and that increasing treatment concentration was directly proportional to increasing inhibitory effects against Staphylococcus aureus and methicillin-resistant Staphylococcus aureus.

This study used cinnamon bark extract (Cinnamomum burmannii) extracted using a maceration method with 96% ethanol as the solvent. The positive control was ciprofloxacin, and the negative control was distilled water. Antibacterial testing used the agar diffusion method, also known as the Kirby-Bauer disc diffusion method.

The results of this study indicate that cinnamon bark extract effectively inhibits the growth of Staphylococcus aureus and methicillin-resistant Staphylococcus aureus. At concentrations of 25% to

100%, there was an increase in the diameter of the inhibition zone that could be measured quantitatively, with the greatest inhibition at a concentration of 100% with an average value of 12.97 mm for Staphylococcus aureus and 13.47 mm for methicillin-resistant Staphylococcus aureus. In accordance with previous studies, cinnamon infusion has been shown to inhibit the growth of Staphylococcus aureus but is not strong enough to kill the bacteria [25], [26].

Measurement of the inhibition zone diameter showed a fairly strong antibacterial effect, but the diameter of the inhibition zone produced by cinnamon bark (Cinnamomum burmannii) was still smaller than the positive control (Ciprofloxacin), which had an average value of 20.7 mm in Staphylococcus aureus and 19.2 mm in Staphylococcus aureus resistant to methicillin. The negative control showed an inhibition zone diameter with an average value of 0.00 mm, which means that the antibacterial effect was present in cinnamon bark extract.

Phytochemical screening tests showed that the sample contained alkaloids, flavonoids, saponins, and tannins. Flavonoids can form bonds that inhibit bacterial metabolism by damaging bacterial proteins and DNA. This causes bacterial death by inhibiting the vital enzyme topoisomerase. Alkaloids have antimicrobial activity, demonstrating their ability to fight bacteria by disrupting the process of bacterial cell wall formation, ultimately killing the bacteria [27]. Tannins work against bacteria by binding to proteins in cells and inactivating them, disrupting vital enzymes and the bacteria's genetic material. Tannins also react with cell membranes, causing damage or leakage of cell contents, making the bacteria unable to survive. Saponins work as antibacterials by weakening the bacterial cell membrane, making it more permeable. This triggers the release of vital cell contents, such as proteins and nucleic acids, within the bacteria [28].

Staphylococcus aureus is a Gram-positive bacterium that is a common pathogen in medical practice due to its ability to cause a variety of infections, both hospital-acquired and community-acquired. In healthy individuals, this bacterium can be found on human skin and mucous membranes and can become pathogenic if the skin barrier is compromised. Inappropriate antibiotic use can lead to the rise of multidrug-resistant strains, such as methicillin-resistant Staphylococcus aureus [29].

Staphylococcus aureus strains that are resistant to methicillin are called methicillin-resistant Staphylococcus aureus (MRSA). Infections caused by this bacterium are transmitted through direct contact with infected areas, such as open wounds [30]. In this study, cinnamon bark extract was more effective against methicillin-resistant Staphylococcus aureus compared to Staphylococcus aureus, where the inhibition test produced on methicillin-resistant Staphylococcus aureus at a concentration of 100% had an average value of 13.47 mm, while on Staphylococcus aureus the average value produced at a concentration of 100% was 12.97 mm.

CONCLUSION

This study proves that cinnamon bark extract (Cinnamomum burmannii) has the ability to inhibit the growth of Staphylococcus aureus bacteria, where the diameter of the inhibition zone produced has an average value at each concentration of 25% (11.53 mm), 50% (11.90 mm), 75% (12.57 mm), and 100% (12.97 mm), while in methicillin-resistant Staphylococcus aureus, the diameter of the inhibition zone produced has an average value at each concentration of 25% (12.00 mm), 50% (12.43 mm), 75% (12.97 mm), and 100% (13.47 mm), so that the results of the measurement of the inhibition zone of these two bacteria are included in the strong category with an average value of >10 mm-20 mm. Based on the results of this study, it is recommended to isolate or purify the active compounds from cinnamon bark extract (Cinnamomum burmannii) considering that the resulting inhibition zone is still smaller than the positive control. Further research is also needed to examine the mechanism of action of these active compounds to clarify their antibacterial molecular targets. Furthermore, the use of different or more sensitive research methods is recommended to obtain a more detailed picture of the antibacterial effectiveness of Cinnamomum burmannii extract against Staphylococcus aureus and methicillin-resistant Staphylococcus aureus (MRSA).

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