Comparison Of The Antibacterial Activity Of Palm Kernel Oil (PKO) & Virgin Coconut Oil (VCO) Against Pseudomonas Aeruginosa Bacteria

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Abstract.

Pseudomonas aeruginosa, a gram-negative bacterium, is a significant cause of nosocomial infections and exhibits high levels of multidrug resistance, necessitating the exploration of alternative antibacterial agents. This study investigates the antibacterial activity of Palm Kernel Oil (PKO) and Virgin Coconut Oil (VCO) against Pseudomonas aeruginosa, employing a true experimental post-test design with microdilution and agar dilution methods. Conducted at the Universitas Muslim Indonesia, the study determined the Minimum Inhibitory Concentration (MIC) and Minimum Bactericidal Concentration (MBC) of PKO, VCO, and gentamicin. Results revealed that PKO had an MIC of 4096 µg/mL and an MBC of 8192 µg/mL, while VCO exhibited an MIC of 2048 µg/mL and an MBC of 4096 µg/mL. Gentamicin, used as a control, demonstrated superior antibacterial effectiveness with an MIC of 2 µg/mL and an MBC of 4 µg/mL. Statistical analysis indicated that VCO, with its higher lauric and myristic acid content, was more effective than PKO in inhibiting bacterial growth, although both oils were less effective than gentamicin. The study highlights the potential of VCO as a natural antibacterial agent, suggesting further research to optimize its efficacy through formulation modifications and combinations with other antimicrobial agents. Additionally, evaluating the effectiveness of VCO and gentamicin against other bacterial strains is recommended to expand the understanding of VCO's antibacterial capabilities. These findings contribute to the growing body of evidence supporting the use of natural products in combating antibiotic-resistant infections.

Keywords: *Pseudomonas Aeruginosa; Palm Kernel Oil; Virgin Coconut Oil; Antibacterial Activity and Multidrug Resistance.*

I. INTRODUCTION

Pseudomonas aeruginosa, an opportunistic pathogenic gram-negative bacterium, is a prevalent cause of nosocomial infections, particularly in immunocompromised patients, including those with cystic fibrosis, burns, and chronic obstructive pulmonary disease. The World Health Organization (WHO) classifies Pseudomonas aeruginosa as one of the ESKAPE pathogens, characterized by a high level of multidrug resistance (MDR) alongside other notorious pathogens such as Enterococcus faecium and Staphylococcus aureus [1]. The urgent need for new antibiotics or alternative therapeutic strategies to combat infections caused by this bacterium is underscored by the increasing prevalence of antibiotic-resistant strains [2]. In this context, natural products, particularly those derived from medicinal plants, have emerged as promising alternatives to conventional antibiotics. Recent studies have highlighted the antimicrobial potential of various bioactive compounds, including phenolic compounds, alkaloids, saponins, flavonoids, terpenoids, and fatty acids [3].Among the natural oils gaining attention for their antimicrobial properties are palm kernel oil (PKO) and virgin coconut oil (VCO). PKO, derived from the kernel of the oil palm fruit (*Elaeis guineensis*), is rich in medium-chain fatty acids (MCFAs), particularly lauric acid, which constitutes approximately 52.465% of its total fatty acid content [4], [5]. VCO, extracted from fresh coconut meat (*Cocos nucifera*),

also boasts a high lauric acid content, ranging from 45-55% [6]. The antibacterial activity of these oils can be attributed to their distinct fatty acid profiles and the presence of bioactive compounds that disrupt bacterial cell membranes, leading to cell lysis and death [7]. Furthermore, the antioxidant properties of these oils, particularly PKO, enhance their antimicrobial effects by reducing oxidative stress in bacterial cells, thereby impairing their growth and survival [8], [9].

Research has demonstrated significant antimicrobial activity for both PKO and VCO against a range of pathogens, including Pseudomonas aeruginosa, making them promising candidates for further investigation [7], [8], [10]. Studies have shown that PKO is effective in inhibiting the growth of Pseudomonas aeruginosa, particularly at concentrations of 25% and 30% [8], while VCO has also exhibited antibacterial effectiveness against this bacterium, with inhibition zones reported in various studies [11]. However, the extraction methods and processing conditions of these oils can significantly influence their antibacterial efficacy. Variations in extraction techniques can alter the quality and composition of PKO, which in turn affects its antimicrobial properties [12]. Similarly, the processing conditions of VCO, such as temperature and duration, can impact its fatty acid profile and, consequently, its antibacterial activity [13].Based on the background of the problem, this study formulates a question regarding the comparison of the antibacterial activity of Palm Kernel Oil (PKO) and Virgin Coconut Oil (VCO) against the bacterium Pseudomonas aeruginosa. The general objective of this study is to determine the comparative antibacterial activity of the two oils, while the specific objectives include the identification of the Minimum Inhibitory Concentration (MIC) and Minimum Lethal Concentration (MLC) of PKO and VCO against Pseudomonas aeruginosa bacteria, as well as the identification of the MIC and MLC of gentamicin as a conventional antibiotic against the same bacteria. In addition, this study aims to compare the effectiveness of PKO, VCO, and gentamicin in inhibiting the growth of these bacteria.

The benefits of this research are expected to contribute to educational institutions by adding to the literature on the antibacterial activity of PKO and VCO, as well as opening up the potential for further research development related to antibiotics. For researchers, this research is an opportunity to apply the knowledge gained in lectures and meet the requirements for graduation as a Doctor of Medicine, as well as to increase knowledge about the comparative antibacterial activity of the two oils. For the community, this research is expected to add to the knowledge about the antibacterial activity of PKO and VCO against Pseudomonas aeruginosa. The results of this research are expected to be published in an accredited journal, so that it can be accessed by the general public as information and reference for research on the same topic or its future development.In conclusion, the exploration of palm kernel oil and virgin coconut oil as potential antibacterial agents against Pseudomonas aeruginosa is both timely and relevant, given the global health challenge posed by antibiotic resistance. The unique chemical compositions of these oils, coupled with their demonstrated antimicrobial properties, warrant further investigation into their mechanisms of action and potential applications in healthcare. This study aims to provide a comprehensive comparison of the antibacterial activity of PKO and VCO, contributing to the growing body of evidence supporting the use of natural products in combating bacterial infections and addressing the pressing issue of antibiotic resistance.

II. METHODS

This research is a true experimental post-test study with a comparative design [14]–[16] that aims to assess the comparison of antibacterial activity between Palm Kernel Oil (PKO) and Virgin Coconut Oil (VCO) in inhibiting the growth of Pseudomonas aeruginosa bacteria. The research will be carried out at the Laboratory of the Research, Publication, and Community Service Unit (UP3M) of the Faculty of Medicine, Universitas Muslim Indonesia Makassar from January to February 2025. The dependent variable in this study is the minimum inhibitory activity (MIA) and minimum lethal concentration (MLC) against Pseudomonas aeruginosa, while the independent variables are various concentrations of PKO and VCO. Inclusion criteria include pure PKO and VCO without the addition of chemicals, as well as media overgrown with Pseudomonas aeruginosa, while exclusion criteria include oil that is contaminated or has undergone oxidative degradation.

The research procedure includes a series of steps starting from sterilization of tools and media, preparation of Mueller Hinton Agar (MHA) and Cation-Adjusted Mueller–Hinton Broth (CAMHB) media, to identification of Pseudomonas aeruginosa bacteria through culture, Gram staining, and biochemical tests. After identification, a bacterial suspension is made for use in antibacterial testing. The microdilution method is used to determine the MIC and MBC, where the sample concentration is tested in a microplate and incubated for 16-20 hours. The MIC observation results are determined based on the clarity of the wells, while the MBC is determined by the solid dilution method on MHA media. The data obtained will be analyzed descriptively using the SPSS program, and significant differences between treatment groups will be tested using One Way ANOVA followed by the LSD (Least Significant Difference) test [17], [18]. This study also complies with research ethics by including permission letters from the Faculty of Medicine, Universitas Muslim Indonesia and the UP3M Laboratory.

III. RESULT AND DISCUSSION

Result

Results of Antibacterial Activity Test of Palm Kernel Oil (PKO) and Virgin Coconut Oil (VCO) against Pseudomonas aeruginosa using the Dilution Method

The antibacterial activity test of Palm Kernel Oil (PKO) and Virgin Coconut Oil (VCO) against Pseudomonas aerugonisa bacteria was conducted from January to February 2025 at the UP3M Laboratory, Faculty of Medicine, Universitas Muslim Indonesia, using the microdilution and agar dilution methods. In this study, the researchers tested the types of PKO and VCO consumer oils. The results of this antibacterial activity test experiment will produce the Minimum Inhibitory Concentration (MIC) and the Minimum Lethal Concentration (MLC). The antibacterial activity test begins with the microdilution method to determine the MIC value. This method uses a 96-well microplate with visual interpretation based on the level of turbidity in each well. There are 8 rows with the following details: rows A - C are filled with PKO test samples, rows D - F are filled with VCO test samples, and rows G - H are filled with a gentamicin quality control (QC) solution. The initial concentration of each test sample is 8192 g/ml, which is then subjected to serial dilution. Readings are taken after incubation for 16-24 hours with three repetitions (triplicate).

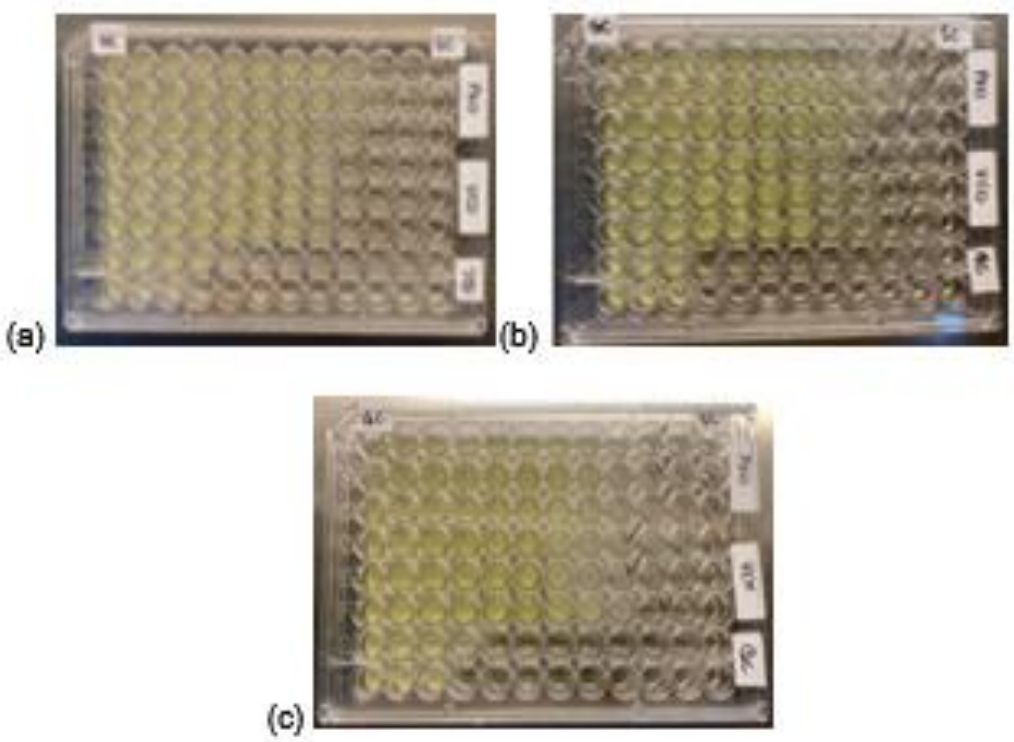


Fig 1. Test results for the determination of MIC by the microdilution method (a) Microplate Repetition 1; (b) Microplate Repetition 2; and (c) Microplate Repetition 3.

Table 1. Results of KHM-PKO Measurement Of Pseudomonas Aeruginosa Using The Microdilution Method

Concentration	Replication 1 PKO			Replication 2 PKO			Replication 3 PKO		
(µg/ml)	1-A	1-B	1-C	2-A	2-B	2-C	3-A	3-B	3-C
8192	+	+	+	+	+	+	+	+	+
4096	+	+	+	+	-	+	+	+	+
2048	-	-	-	-	-	-	-	-	-
1024	-	-	-	-	-	-	-	-	-
512	-	-	-	-	-	-	-	-	-
256	-	-	-	-	-	-	-	-	-
128	-	-	-	-	-	-	-	-	-
64	-	-	-	-	-	-	-	-	-
32	-	-	-	-	-	-	-	-	-
16	-	-	-	-	-	-	-	-	-
GC	-	-	-	-	-	-	-	-	-
SC	+	+	+	+	+	+	+	+	+

Description: "+" = Clear; "-" = Turbid; GC = Growth Control; and SC = Sterile Control.

Table 2. Results of KHM-VCO Measurement Against Pseudomonas Aeruginosa Using The Microdilution Method

Concentration	Replication 1 VCO			Replication 2 VCO			Replication 3 VCO		
(µg/ml)	1-D	1-E	1-F	2-D	2-E	2-F	3-D	3-E	3-F
8192	+	+	+	+	+	+	+	+	+
4096	+	+	+	+	+	+	+	+	+
2048	+	+	+	+	-	-	+	+	-
1024	-	-	-	-	-	-	-	-	-
512	-	-	-	-	-	-	-	-	-
256	-	-	-	-	-	-	-	-	-
128	-	-	-	-	-	-	-	-	-
64	-	-	-	-	-	-	-	-	-
32	-	-	-	-	-	-	-	-	-
16	-	-	-	-	-	-	-	-	-
GC	-	-	-	-	-	-	-	-	-
SC	+	+	+	+	+	+	+	+	+

Description: "+" = Clear; "-" = Turbid; GC = Growth Control;
SC = Sterile Control; and QC = Quality Control

Table 3. Measurement results of KHM Quality Control (Gentamicin Sulfate) Against Pseudomonas Aeruginosa Using The Microdilution Method

Concentration	Replication 1 QC		Replication 2 QC		Replication 3 QC	
(µg/ml)	1-G	1-H	2-G	2-H	3-G	3-H
256	+	+	+	+	+	+
128	+	+	+	+	+	+
64	+	+	+	+	+	+
32	+	+	+	+	+	+
16	+	+	+	+	+	+
8	+	+	+	+	+	+
4	+	+	+	+	+	+
2	-	+	+	+	-	+
1	-	-	-	-	-	-
0,5	-	-	-	-	-	-
GC	-	-	-	-	-	-
SC	+	+	+	+	+	+

Description: "+" = Clear; '-' = Turbid; GC = *Growth Control*;
SC = *Sterile Control; and QC = Quality* Control

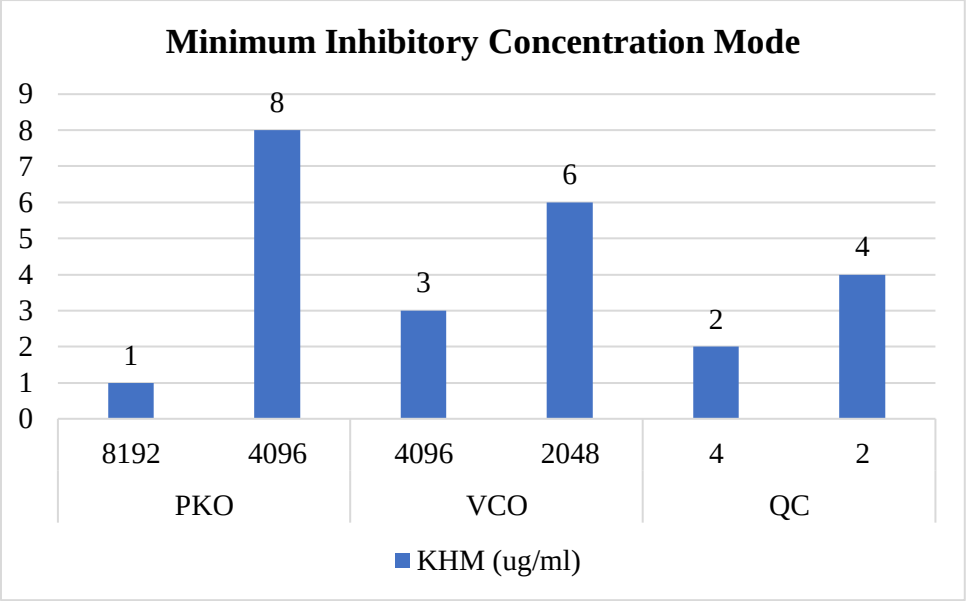


Fig 2. Mode Graph of KHM PKO, VCO, and QC (Gentamicin)

Minimum Inhibitory Concentration (MIC) or MIC is defined as the lowest concentration of an antimicrobial agent capable of inhibiting the growth of microorganisms. 62 In the experiment, two types of repetition or replication were carried out. Technical replication on PKO and VCO samples was carried out 3 times, while on QC it was carried out 2 times. Biological replication was carried out 3 times on each test sample. Based on the MHL Mode graph, it can be concluded that the PKO sample has an MHL in the range of 4096 µg/mL - 8192 µg/mL, with an MHL-PKO mode of 4096 µg/mL. Meanwhile, the VCO sample had an MIC range of 2048 µg/mL - 4096 µg/mL, with an MIC-VCO mode of 2048 µg/mL. For comparison, in the gentamicin sulfate sample used as quality control (QC), the MIC was in the range of 2 µg/mL - 4 µg/mL, with a QC-MIC mode of 2 µg/mL. After the MIC has been determined, the MPC will be determined using the agar dilution method. A total of 5 µL of MIC from each test sample is taken and streaked on MHA medium. The petri dish containing the MHA medium is divided into 9 sections and labeled according to the test sample taken. Next, the medium is incubated at 37°C for 16-20 hours.

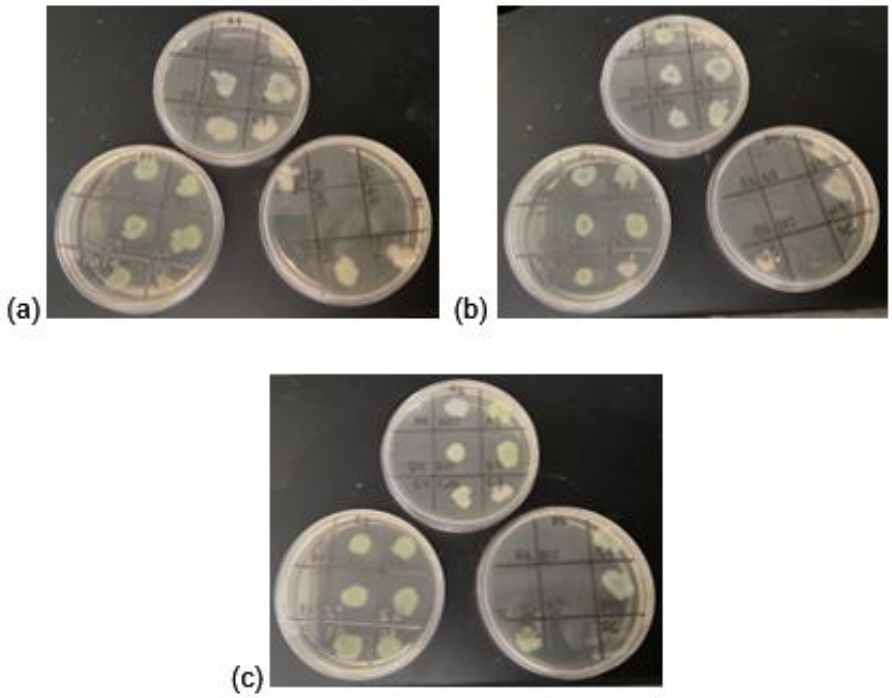


Fig 3. Microdilution Method MIC Determination Test Results (a) Microplate Repeat 1; (b) Microplate Repeat 2; and (c) Microplate Repeat 3

Table 4. KBM-PKO Measurement Results Against Pseudomonas Aeruginosa Using The Agar Dilution Method

Concentration	Replication 1 PKO			Replication 2 PKO			Replication 3 PKO		
(µg/ml)	1-A	1-B	1-C	2-A	2-B	2-C	3-A	3-B	3-C
8192	+	+	+	+	+	+	+	+	+
4096	+	-	-	-	-	-	-	-	-
2048	-	-	-	-	-	-	-	-	-
GC	-	-	-	-	-	-	-	-	-
SC	+	+	+	+	+	+	+	+	+

Description: "+" = Not growing; "-" = Growing; GC = *Growth Control*; and SC = *Sterile Control;*

Table 5. KBM-VCO Measurement Results Against Pseudomonas Aeruginosa Using The Agar Dilution Method

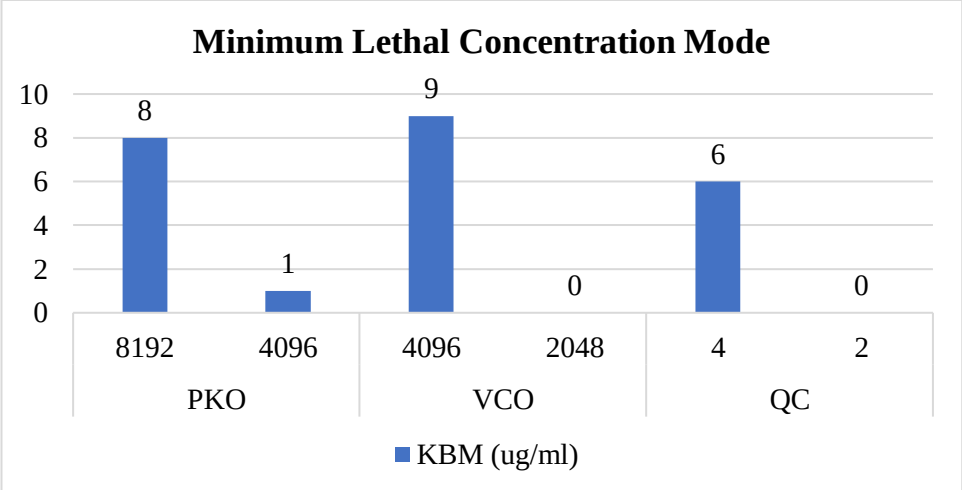
Concentration	**Replication** 1 VCO			**Replication** 2 VCO			**Replication** 3 VCO		
(µg/ml)	1-D	1-E	1-F	2-D	2-E	2-F	3-D	3-E	3-F
4096	+	+	+	+	+	+	+	+	+
2048	-	-	-	-	-	-	-	-	-
1024	-	-	-	-	-	-	-	-	-
GC	-	-	-	-	-	-	-	-	-
SC	+	+	+	+	+	+	+	+	+

Description: "+" = Not growing; "-" = Growing; GC = *Growth Control*; and SC = *Sterile Control;*

Table 6. Results of KBM Quality Control (Gentamicin Sulfate) Measurements Against Pseudomonas Aeruginosa Using The Agar Dilution Method

Concentration	**Replication** 1 QC		**Replication** 2 QC		**Replication** 3 QC	
(µg/ml)	1-G	1-H	2-G	2-H	3-G	3-H
8	+	+	+	+	+	+
4	+	+	+	+	+	+
2	-	-	-	-	-	-
GC	-	-	-	-	-	-
SC	+	+	+	+	+	+

Description: "+" = Not growing; "-" = Growing; GC = *Growth Control*; and SC = *Sterile Control;*



Description: PKO = Palm Kernel Oil; VCO = Virgin Coconut Oil; QC = Quality Control; and KBM = Minimum Killing Concentration

Minimum Bactericidal Concentration (MBC) or KBM is defined as the lowest concentration capable of killing bacteria. 60 In the experiment, two types of repetition or replication were carried out. Technical replication on PKO and VCO samples was carried out 3 times, while on QC it was carried out 2 times. Biological replication was carried out 3 times on each test sample. It can be concluded based on the mode graph in Figure 4.4 that the PKO sample has a MBC in the range of 4096 µg/mL - 8192 µg/mL, with a MBC-

PKO mode of 8192 µg/mL. Meanwhile, the VCO sample has only one MBC value of 4096 µg/mL. In comparison, the gentamicin sulfate sample used as quality control (QC) has a KBM value of 4 µg/mL. Based on the results of the study of PKO and VCO antibacterial activity against Pseudomonas aeruginosa bacteria, the following is a summary of the data presented above.

Table 7. KHM and KBM Mode Results from PKO, VCO, and Gentamicin

Sample	KHM	KBM
PKO	4096 µg/mL	8192 µg/mL
VCO	2048 µg/mL	4096 µg/mL
Gentamisin	2 µg/mL	4 µg/mL

Statistics Test

The Shapiro-Wilk normality test is carried out to determine whether the data is normally distributed or not, where if the p-value is > 0.05, the data is normally distributed, whereas if the p-value is < 0.05, it can be concluded that the data is not normally distributed. In addition, a homogeneity test is carried out to ensure that the data obtained has a uniform variance between sample groups, with the aim of verifying that the differences observed in the research results are not caused by the inhomogeneity of variance between groups, but rather by the treatment given, where if the p-value is > 0.05, the data is homogeneous, while if the p-value is < 0.05, it can be concluded that the data is not homogeneous. If the normality test is not fulfilled or the homogeneity test is not fulfilled, it will be continued with the Kruskal-Wallis test and the Mann-Whitney test, whereas if both tests are fulfilled (normality test and homogeneity test), it will be continued with the One-Way ANOVA test [19].

Table 8. MIC and MBC Data Analysis Results

Sample		Statistics Test					
		N	Mean	SD	Normality Test	Homogeneity Test	Kruskal Wallis Test
MIC	PKO	9	1.89	0.333	<0.001	0.035	<0.001
	VCO	9	2.67	0.500	<0.001		
	QC	6	12.67	0.516	0.001		
MBC	PKO	9	1.11	0.333	<0.001	0.027	<0.001
	VCO	9	2.00	0.000	.		
	QC	6	12.00	0.000	.		

In this study, the Shapiro-Wilk test was used for normality testing due to the small sample size (less than 50), consisting of 3 samples tested 3 times for technical repetition and 3 times for biological repetition, resulting in a total of 24 samples. The Shapiro-Wilk test yielded p-values <0.05 for both Minimum Inhibition Concentration (MIC) and Minimum Bactericidal Concentration (MBC) across all three treatments, indicating that the data were not normally distributed. Additionally, the homogeneity test revealed non-homogeneous variances between groups, with p-values of 0.035 for MIC and 0.027 for MBC, signifying significant variability differences. Given that the data were neither normally distributed nor homogeneous, the Kruskal-Wallis nonparametric test was employed to compare the antibacterial effectiveness of Palm Kernel Oil (PKO), Virgin Coconut Oil (VCO), and Quality Control (QC) against Pseudomonas aeruginosa. The Kruskal-Wallis test results demonstrated significant differences in effectiveness, as evidenced by Asymp. Sig. values <0.001 for both MIC and MBC, confirming statistically distinct levels of effectiveness among the three groups. Consequently, further pairwise comparisons were conducted using the Mann-Whitney test to analyze the differences between each test sample.

Table 9. MIC Comparison Statistical Analysis Test between Samples

Comparison of MIC Between Samples	P-Value
PKO and VCO	0.003
PKO and Gentamisin	<.001
VCO and Gentamisin	<.001

Table 10. Statistical Analysis Test of Comparison of MBC between Samples

Comparison of MBC Between Samples	P-Value
PKO and VCO	<.001
PKO and Gentamisin	<.001
VCO and Gentamisin	<.001

Tables 9 and 10 present the results of the Mann-Whitney test comparing MIC (Minimum Inhibitory Concentration) and MBC (Minimum Bactericidal Concentration) between sample groups, with the p-values indicating the statistical significance of the differences observed. In Table 9, significant differences in MIC values were found between PKO & VCO ($p = 0.003$), PKO & Gentamicin ($p < 0.001$), and VCO & Gentamicin ($p < 0.001$), demonstrating distinct effectiveness in inhibiting bacterial growth across the groups. Similarly, Table 10 reveals significant differences in MBC values for all comparisons PKO & VCO, PKO & Gentamicin, and VCO & Gentamicin with p-values < 0.001, indicating notable variations in bacterial killing power. Overall, the statistical analysis confirms significant differences in antibacterial effectiveness between PKO, VCO, and Gentamicin, both in terms of inhibiting bacterial growth (MIC) and killing bacteria (MBC), as evidenced by the very small p-values (< 0.05), which strongly suggest that the observed differences are not due to chance. These findings highlight that VCO is more effective than PKO in inhibiting the growth of Pseudomonas aeruginosa, although its efficacy remains lower than that of Gentamicin as a quality control. The results underscore the potential of VCO as a natural antibacterial agent, particularly in medical or pharmaceutical applications seeking alternatives to conventional antibiotics.

Discussion

The investigation into the antibacterial activity of Palm Kernel Oil (PKO) and Virgin Coconut Oil (VCO) against Pseudomonas aeruginosa is particularly relevant in the context of increasing antibiotic resistance and the search for natural alternatives. This study employed a true experimental post-test method with a comparative design using the dilution method, conducted at the Laboratory of the Research, Publication, and Community Service Unit (UP3M) of the Faculty of Medicine, Universitas Muslim Indonesia Makassar, from January to February 2025. The study was structured in two stages: the determination of the Minimum Inhibitory Concentration (MIC) using the microdilution method, followed by the determination of the Minimum Bactericidal Concentration (MBC) using the agar dilution method. The initial concentration of the test samples began at 8192 µg/mL, with a two-fold dilution down to 16 µg/mL, adhering to CLSI (Clinical and Laboratory Standards Institute) standards. This method was chosen for its accuracy and sensitivity in testing the antibacterial activity of oil compounds like PKO and VCO.

The results indicated that PKO had an MIC of 4096 µg/mL and an MBC of 8192 µg/mL, while VCO exhibited an MIC of 2048 µg/mL and an MBC of 4096 µg/mL. In comparison, the control antibiotic, gentamicin sulfate, demonstrated an MIC of 2 µg/mL and an MBC of 4 µg/mL, highlighting its superior antibacterial effectiveness. Statistical analysis revealed that VCO had a lower concentration of inhibitory and bactericidal power than PKO, suggesting a higher antibacterial potential due to its more dominant medium-chain fatty acid (MCFA) content, particularly lauric and myristic acids, which are known for their strong antimicrobial activity [5], [6]. The higher MIC values compared to MBC for both oils suggest a bacteriostatic effect at certain concentrations, requiring higher doses for bactericidal action, indicating a mechanism more focused on inhibiting bacterial growth rather than direct killing.Virgin Coconut Oil (VCO) is recognized for its significant antibacterial properties, largely attributed to its high content of medium-chain fatty acids, particularly lauric acid. Studies have shown that VCO exhibits antibacterial activity against a range of pathogens, including Staphylococcus aureus and Pseudomonas aeruginosa [20], [21].

The composition of VCO, with a higher concentration of lauric acid (41%–54.5%), plays a crucial role in its efficacy, disrupting bacterial cell membranes and leading to cell lysis and death [22], [23]. In contrast, while PKO has been studied for its antibacterial properties, it is less extensively documented than VCO. PKO contains long-chain fatty acids, which contribute to its antimicrobial effects, but its specific effectiveness against Pseudomonas aeruginosa requires further investigation [4].The comparative analysis underscores that VCO is a more potent antibacterial agent against Pseudomonas aeruginosa, primarily due to its higher concentration of lauric acid and other bioactive compounds, enhancing its antimicrobial activity [24], [25]. The mechanism of action involves disrupting bacterial cell membranes, leading to leakage of cellular contents and cell death, supported by various studies linking VCO's efficacy to its fatty acid composition [24]. While PKO exhibits some antibacterial properties, its effectiveness is less documented, indicating a gap in the literature that warrants further exploration. These findings highlight the potential of natural oils as alternatives to conventional antibiotics, especially in an era of rising antibiotic resistance.

IV. CONCLUSION

Based on research on the comparison of the antibacterial activity of Palm Kernel Oil (PKO) and Virgin Coconut Oil (VCO) against Pseudomonas aeruginosa bacteria, several important conclusions were obtained. Palm Kernel Oil (PKO) showed a Minimum Inhibitory Concentration (MIC) value of 4096 µg/mL and a Minimum Lethal Concentration (MLC) of 8192 µg/mL, while Virgin Coconut Oil (VCO) had a MIC of 2048 µg/mL and an MLC of 4096 µg/mL. Gentamicin, as a conventional antibiotic, shows a minimum inhibitory concentration (MIC) of 2 µg/mL and a minimum bactericidal concentration (MBC) of 4 µg/mL against Pseudomonas aeruginosa. A comparison of the effectiveness between PKO and VCO shows that VCO is more effective in inhibiting and killing Pseudomonas aeruginosa than PKO, but the effectiveness of VCO as an antibacterial is still much lower than that of gentamicin. Therefore, suggestions for further research include the need for in vitro clinical trials to evaluate the effectiveness of PKO and VCO in the human body, as well as further research to optimize the effectiveness of both oils as natural antibacterial agents through formulation modification and combination with other antimicrobial ingredients. In addition, evaluation of the effectiveness of VCO and gentamicin against other bacteria is also needed to further assess the antibacterial ability of VCO.

V. ACKNOWLEDGMENTS

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