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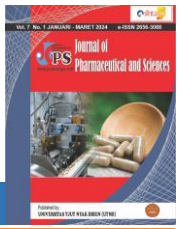

Potential Antioxidant and Antibacterial Activity of Curry Leaf Ethanol Extract (*Murraya koenigii*) against *Propionibacterium acnes*

Potensi Aktivitas Antioksidan dan Antibakteri Ekstrak Etanol Daun Kari (*Murraya koenigii*) terhadap *Propionibacterium acnes*

Nasri Nasri[a*], Vera Estefania Kaban[b], Zulmai Rani[c], Nurul Suci[d], Imelda Ferendina[b], Chyntia Glori Tania[e]

[a] *Department of Pharmaceutical Chemistry, Faculty of Pharmacy, Universitas Sumatera Utara, Sumatera Utara 20155, Indonesia*
[b] *Department of Clinical Pharmacy, Faculty of Medicine, Dentistry and Health Sciences, Universitas Prima Indonesia, Medan, Indonesia*
[c] *Department of Pharmacy, Universitas Muslim Nusantara Al Washliyah, Medan 20147, Indonesia*
[d] *Department of Pharmaceutical Technology, Faculty of Pharmacy, Universitas Sumatera Utara, Sumatera Utara 20155, Indonesia*
[e] *Murni Teguh Memorial Hospital, Sumatera Utara, Medan, 20231, Indonesia*

Corresponding Authors: nasri@usu.ac.id

Abstract

Indonesia is renowned for its rich natural resources, particularly medicinal plants with significant therapeutic potential. This study examined how the ethanolic extract of curry leaves (*Murraya koenigii*) can act as an antioxidant and antibacterial agent against Propionibacterium acnes, the primary cause of acne vulgaris. This study used phytochemical screening to identify secondary metabolites, such as alkaloids, flavonoids, tannins, saponins, and glycosides, which are associated with biological activities such as killing bacteria and protecting cells from damage. The DPPH method for testing antioxidants showed that the extract had an IC_{50} value of 45.88 mg/L, which is not significantly different from quercetin as a reference, at 23.7 mg/L. This result is still significant for the strong antioxidant category. We assessed antibacterial efficiency using a disc diffusion technique, which showed a zone of inhibition corresponding to the extract concentration. The widest zone of inhibition, measuring 17.77 ± 0.15 mm, was recorded at a concentration of 250 mg/mL, classifying its activity as strong by existing standards. These findings underscore the extract's promise as a natural acne therapy, addressing bacterial growth and oxidative stress. Furthermore, these results support the development of safe and efficacious pharmaceutical or cosmetic products derived from natural components. Future investigations should examine synergistic formulations and enhance bioavailability to optimize therapeutic outcomes.

Keywords*: *Murraya koenigii, Propionibacterium acnes, antioxidant activity, antibacterial activity, natural treatment.

Abstrak

Indonesia terkenal dengan kekayaan sumber daya alamnya, terutama tanaman obat yang memiliki potensi terapeutik yang signifikan. Penelitian ini melihat bagaimana ekstrak etanol daun kari (*Murraya koenigii*) dapat melawan *Propionibacterium acnes*, penyebab utama jerawat vulgaris, sebagai antioksidan dan antibakteri. Penelitian ini menggunakan skrining fitokimia untuk menemukan metabolit sekunder, seperti alkaloid, flavonoid, tanin, saponin, dan glikosida, yang terkait dengan aktivitas biologis seperti membunuh bakteri dan melindungi sel dari kerusakan. Metode DPPH untuk menguji antioksidan menunjukkan bahwa ekstrak tersebut memiliki nilai IC_{50} sebesar 45,88 mg/L yang tidak jauh berbeda dengan kuarsetin sebagai pembanding yaitu 23,7 mg/L hasil ini masih signifikan untuk kategori antioksidan kuat. Kami menilai efisiensi antibakteri menggunakan teknik difusi cakram, yang menunjukkan zona hambat yang sesuai dengan konsentrasi ekstrak. Zona penghambatan yang paling luas, berukuran 17,77 ± 0,15 mm, tercatat pada konsentrasi 250 mg / mL, mengklasifikasikan aktivitasnya sebagai kuat menurut standar yang ada. Temuan ini menggarisbawahi janji ekstrak sebagai terapi jerawat alami, mengatasi pertumbuhan bakteri dan stres oksidatif. Selain itu, hasil

penelitian ini mendukung terciptanya produk farmasi atau kosmetik yang aman dan berkhasiat yang berasal dari komponen alami. Investigasi selanjutnya harus memeriksa formulasi sinergis dan meningkatkan ketersediaan hayati untuk mengoptimalkan hasil terapi.

Kata Kunci: Murraya koenigii, Propionibacterium acnes, aktivitas antioksidan, aktivitas antibakteri, pengobatan alami.

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Introduction

Indonesia is known as a country rich in natural resources, including tropical medicinal plants with great potential in treating various diseases [1]. Using plants as traditional medicine has been going on for thousands of years and has proven effective in various cases. However, scientific research has not documented the use of many medicinal plants well [2]. Plants with medicinal properties consist of various types that can be utilised in certain parts, such as roots, stems, leaves, flowers, and skin, which are believed to cure or reduce pain [3]. One of the skin diseases that many teenagers and young adults suffer from is acne or acne vulgaris [4]. Acne is a chronic, obstructive and inflammatory skin condition in the pilosebaceous, caused by increased sebum production, keratinocyte decay, and bacterial infection in the pilosebaceous ducts. One of the dominant acne-causing bacteria is *Propionibacterium acnes* (*P. acnes*). This Gram-positive bacterium is part of the normal flora of the skin, but can cause opportunistic infections by producing lipases that contribute to acne formation [5], [6], [7].

Using natural ingredients as traditional medicine is an alternative to overcome this problem because it is believed to have lower side effects than chemical drugs [8]. One of the natural ingredients that has potential as a traditional medicine for acne is curry leaf (*Murraya koenigii*), which contains active compounds that can provide antibacterial effects [9]. Several studies have shown that the activity of akri leaves is effective as an antifungal against the growth of Candida albicans fungus with an inhibition zone value of 12.3 mm [10]. Active compounds found in plants are often secondary metabolites such as alkaloids, flavonoids, saponins, tannins, steroids, and triterpenoids, which have various biological activities. Tannins and flavonoids, in particular, have antibacterial activity that can inhibit peptidoglycan synthesis in bacterial cell walls and disrupt organic components and nutrient transport, which can have a toxic effect on bacteria [11]. Curry leaves are known to contain alkaloids, terpenoids, saponins, flavonoids, and tannin compounds, which can potentially provide antibacterial activity. Traditionally, curry leaves have been used to treat various diseases, such as rheumatism, wounds, dysentery, diarrhoea, and snake bites [12]. In addition, in India, curry leaves are also used in cosmetics, as an acne remedy, as well as hair care, which is beneficial for reducing thinning and grey hair, and as a perfume and soap that has a distinctive aroma due to its essential oil content [13], [14].

However, to date, no study has tested the antibacterial activity of curry leaf extract against the growth of Propionibacterium acnes. Therefore, this study is important to explore the potential of curry leaves as an alternative acne treatment through the antibacterial test of ethanol extract of curry leaves against *P. acnes*. In addition, in the midst of the rapid development of science, it is also important to examine the potential of natural compounds in providing antioxidant effects. Antioxidants are very important in fighting free radicals that can cause cell damage, accelerate skin aging, and worsen acne conditions [15]. Therefore, the antioxidant activity test is also an integral part of this study, as it can increase the understanding of the additional benefits of curry leaves, both in treating acne and as a protective agent against skin damage. Research on antioxidant

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activity is urgent, given the importance of holistic treatment of skin problems that focuses on eradicating bacteria and protecting the skin from oxidative damage that can worsen acne conditions. Thus, this study is expected to contribute significantly to the development of safe and effective natural ingredient-based acne medications.

Experimental Section

Research Sample

The samples used in this study were fresh curry leaves obtained from Cot Ara Village, Kuta Blang District, Bireuen Regency. The sample collection was conducted using a purposive sampling technique, which is the selection of samples based on specific criteria without comparison with samples from other regions. The curry leaves taken were fresh and not too old, with optimal green colour.

Apparatus and materials

The apparatus used in this study include petri dish, autoclave, tweezers, 250 mL erlenmeyer, round ose, test tube, bunsen, porcelain cup, spatel, micropipette, analytical balance, stirring rod, laminar air flow, oven, glass jar, incubator, vernier caliper, blender (Philips), cotton swab, filter paper, parchment paper, rotary vacuum evaporator, disc paper, measuring cup, and drop pipette. The materials used in this study were curry leaf extract, Propionibacterium acnes bacterial culture, 70% ethanol, sterile distilled water, Nutrient Agar (NA), H_2SO_4, $BaCl_2$, DMSO, Chloramphenicol antibiotic disc, 70% alcohol, aluminium foil, filter paper, cotton swab, gauze, NaCl 0.9%, cotton buds, and paper discs.

Sample Preparation

After sampling, the curry leaves were cleaned of dirt and impurities with clean water. After washing, the curry leaves were drained, weighed, and then dried in a cabinet until completely dry. After drying, the curry leaves were weighed and then crushed using a blender until they became a fine powder. The curry leaf powder was then filtered to obtain a uniform particle size. The criteria for curry leaves used are fresh and not too old leaves with a light green colour [6], [16].

Extract Preparation

Extraction was carried out using the maceration method. 500 g of curry leaf powder was macerated with 3500 mL of 96% ethanol in a closed container for five days, stirring occasionally. After filtering, the first filtrate was obtained, and the first residue was then remacerated with 1250 mL of 96% ethanol for two days. The resulting second filtrate was combined with the first filtrate, then solidified using a rotary evaporator at 40°C and a rotation speed of 50 rpm. The thick extract obtained was then weighed and stored in a closed container before being used for testing [16], [17].

Phytochemical Screening

Phytochemical screening was conducted to detect alkaloid, flavonoid, tannin, saponin, terpenoid/steroid, and glycoside compounds in curry leaf extract. An alkaloid test was conducted by adding ammonia, chloroform, and HCl 2N to the extract. Mayer and Dragendorf reagents were added to produce yellowish white and orange precipitates, indicating alkaloids [18]. The flavonoid test was performed by adding hot water and magnesium to the extract, and red, yellow, or orange colour indicated the presence of flavonoids [19]. The tannin test uses 5% $FeCl_3$, which produces a black solution if positive. The saponin test is performed by adding distilled water and 2N HCl, where a stable foam indicates saponins [20]. The terpenoid/steroid test is carried out by adding anhydrous acetic acid and concentrated sulfuric acid, producing a purple or green colour if detected [21]. The glycoside test is carried out by refluxing the extract with a mixture of 95% ethanol and distilled water, and the purple ring formed after adding Molisch's reagent indicates the presence of glycosides [22].

Antioxidant Activity Test

Testing the antioxidant effectiveness of curry leaf extract was carried out using the DPPH (2,2-diphenyl-1-picrylhydrazyl) method. Samples with several concentrations were pipetted as much as 0.2 mL using a micro pipette. In the vial, 3.8 mL of 50 μM DPPH solution was added, homogenised, and allowed to stand for 30

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minutes in a dark place [2]. Measure the absorbance at the DPPH wavelength. The antioxidant activity was calculated using the formula:

$$\% \text{ inhibition } = \frac{\text{Abs Blank} - \text{Abs Sample}}{\text{Abs Blank}} \text{ x } 100\%$$

As a positive control, a quercetin solution was prepared at various concentrations (10, 20, 30, 40, and 50 mg/L) and treated under the same conditions as the test samples. The absorbance was measured at the same wavelength (517 nm), and a calibration curve was constructed to describe the relationship between quercetin concentration and the percentage of DPPH radical inhibition. From this curve, the regression equation was obtained and subsequently used to calculate the IC_{50} value of quercetin, which served as a reference standard for comparison with the test extract.

The comparison of IC_{50} values between the curry leaf extract and quercetin was used to determine the category of antioxidant activity strength, classified as follows: Very strong: IC_{50} < 50 mg/L, Strong: 50–100 mg/L, Moderate: 100–150 mg/L and Weak: >150 mg/L.

Sterilisation of Apparatus and Materials

All microbiological testing glassware was sterilised in an oven at 170°C for 1 hour. Test media such as Nutrient Agar (NA) were sterilised using an autoclave at 121°C for 15 minutes. Ose and tweezers were sterilised by direct exposure [23].

Test Media Preparation

Nutrient Agar (NA) media was prepared by dissolving 7 g of NA in 250 mL of distilled water, then heated on a water bath until dissolved. After that, the media were sterilised in an autoclave at 121°C for 15 minutes. After cooling to an ambient temperature of 45-50°C, the media were ready for antibacterial testing [24].

Preparation of test bacterial suspensions

Propionibacterium acnes bacteria were taken from cultures on Nutrient Agar media and inoculated into test tubes containing 10 mL of Nutrient Broth. The bacterial suspension was then adjusted to the McFarland standard turbidity to ensure that the bacterial concentration was in accordance with the test standard [25].

Preparation of Various Concentration Test Solutions

The ethanol extract of curry leaves was weighed as much as 2.5 g and dissolved with dimethyl sulfoxide (DMSO) until the volume reached 10 mL, thus obtaining an extract concentration of 250 mg/ml. Furthermore, extract solutions with concentrations of 200 mg/ml, 150 mg/ml, 100 mg/ml, and 50 mg/ml were made to be used in antibacterial testing [26].

Antibacterial Activity Test

The antibacterial activity test was conducted using the agar diffusion method. A total of 0.1 mL of bacterial inoculum was put into a Petri dish, then 15 mL of Nutrient Agar media was thawed and heated to 45°C. After homogeneous, the media was left until solid. Paper discs dabbed with extract solutions at several concentrations were placed on top of the solid media and incubated at 36-37°C for 24 hours. The diameter of the inhibition zone was measured using a digital calliper, and this test was carried out three times [18], [27].

Results and Discussion

Extract Yield

Yield is the ratio between the weight of the obtained extract and the raw material used in the extraction process, usually expressed as a percentage. The yield illustrates the efficiency of the extraction process in producing active compounds from raw materials [28], [29].

In this study, the curry leaf sample used had an initial weight of 5000 grams. After drying, the weight of the curry leaves obtained was 750 grams. From 750 grams of dried curry leaves, the mashed simplisia weighed 582.4 grams, which was used for extraction. Extraction was carried out using 96% ethanol solvent,

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and after being extracted by the maceration method, the extract obtained was then solidified using a rotary vacuum evaporator. The resulting thick extract weighed 19.6019 grams.

Thus, the extraction yield in this study is 3.37%, which shows the efficiency of the extraction process in producing thick extracts from curry leaves. This yield is quite important in evaluating how much active compound can be obtained from the raw material and gives an idea of the success of the extraction method used [30], [31].

Phytochemical Screening

Phytochemical screening on ethanol extract of curry leaves was conducted to detect the class of secondary metabolite compounds contained in the extract, namely alkaloids, flavonoids, saponins, tannins, steroids/triterpenoids, and glycosides. The results of the phytochemical screening test can be seen in Table 1 below.

Table 1. Phytochemical screening test results of the ethanol extract of curry leaves

No	Secondary Metabolite	Reagent	Color Change	Result
1	Alkaloid	Dragendorff	Brown precipitate	+
		Mayer	White to yellowish precipitate	+
2	Flavonoid	HCl (conc) + heated	Red	+
3	Saponin	Destilled water (Heating)	Stable foam formed (2cm high for 10 minutes)	+
4	Tanin	$FeCl_3$ 1%	Dark green/blue	+
5	Steroid / Triterpenoid	Lieberman Buchard + $CH_3COOH + H_2SO_4$ (conc) HCl (conc) + H_2SO_4 (conc)	Red-purple (steroid) / Green (Triterpenoid)	- +
6	Glikoside	$CH_3COOH + H_2SO_4$ (conc)	Blue / Green	+

Phytochemical screening conducted on the ethanol extract of curry leaves showed that the extract contained several secondary metabolite compounds with potential therapeutic effects [32]. Alkaloid compounds were detected through two reagents, Dragendorff and Mayer, each producing brown and yellowish-white precipitates. Alkaloids are bioactive compounds widely found in plants and have a variety of significant biological activities, including antibacterial and anticancer effects. The presence of alkaloids in curry leaf extract indicates the potential of these compounds to be used in the development of herbal medicines, particularly to treat bacterial infections and cancer [33].

In addition to alkaloids, flavonoids were also detected in curry leaf extract through the red colour change after heating with HCl (conc) reagent. Flavonoids are polyphenolic compounds known for their strong antioxidant abilities, which protect the body from oxidative damage caused by free radicals [34]. In addition, flavonoids also possess anti-inflammatory and antibacterial activities, making them important in the treatment of various inflammatory and infectious diseases [35]. Another compound detected was saponins, which was evident by the formation of stable foam when tested with distilled water and heating. Saponins are known to have antibacterial, antifungal, and hypocholesterolemic properties. They can lower the surface tension of bacterial cells, which increases cell membrane permeability and causes leakage of cellular components, contributing to their antibacterial effects [36], [37].

In addition to these compounds, curry leaf extract also contains tannins, triterpenoids, and glycosides, which were detected by $FeCl_3$, Liebermann-Buchard, and Molisch tests, respectively. Tannins, which produce a dark green/blue colour in the $FeCl_3$ assay, are known to have the ability to bind to proteins and inhibit certain enzyme activities, making them effective as antibacterial agents. Triterpenoids, which were detected with a green colour change, have potential as anti-inflammatory and antimicrobial agents, and play a role in strengthening cell membranes and enhancing the immune response to infection [38]. Glycosides, which were detected with a blue/green colour change in the Molisch test, increase heart contractions and have potential as antimicrobial agents. The presence of these various compounds in curry leaf extract supports its use in traditional medicine and as a potential source for developing effective herbal medicines in treating different health conditions, especially infection and inflammation [39], [40].

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Antioxidant Activity Test

Testing the antioxidant activity of the DPPH method with the mechanism of donating hydrogen atoms from phenolic compounds to reduce free radicals. The comparator used in this test is quinine. The results of antioxidant activity testing can be seen in Table 1. The curve of antioxidant test results of curry leaf ethanol extract using the DPPH method can be seen in Figure 1.

Table 3. Regression equation and IC_{50} values of test samples

No	Sample	Linear Equation	IC_{50} (mg/L)
1.	Quercetin	y = y=0.6273x+ 36.626 (R^2=0.978)	22.7
2.	Ethanol extract of curry leaves	y= 21.429x + 33.333 (R^2= 0.9041)	45.88

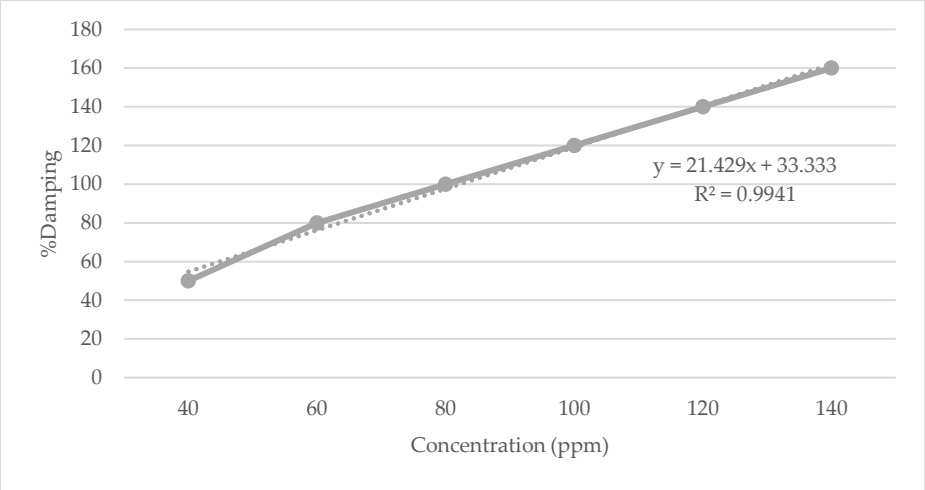

Figure 1. Regression equation graph

Although the findings indicate a positive correlation between the concentration of curry leaf extract and its antioxidant activity, high concentrations present certain limitations. At elevated levels, increasing the extract concentration does not always lead to a proportional enhancement in activity, possibly due to radical saturation effects in the DPPH system or optical interference caused by sample turbidity. Moreover, excessively high concentrations may pose potential toxicity risks in biological applications. Therefore, further studies are required to establish the optimal concentration that ensures effective antioxidant activity and safety, which can be confirmed through extended *in vitro* assays or *in vivo* evaluations[41], [42].

Testing the antioxidant effect of ethanol extract of curry leaves was carried out using the DPPH (2,2-diphenyl-1-picrylhydrazyl) method, which evaluates the ability of phenolic compounds in neutralising free radicals through hydrogen atom donation [43]. Antioxidant activity was assessed based on the IC_{50} value, the sample concentration that can reduce 50% of DPPH free radicals. The smaller the IC_{50} value, the better the antioxidant capacity of the extract [44].

The flavonoids, tannins and alkaloids in curry leaf extract play a significant role in its antioxidant activity. Flavonoids work by donating hydrogen atoms to neutralise free radicals, while tannins can inhibit oxidation reactions through complex formation with transition metals that trigger free radical formation. This combination of bioactive compounds contributes to the antioxidant capacity of the ethanol extract of curry leaves [45]. This antioxidant activity is relevant in treating acne (acne vulgaris) and skin protection [46]. Free radicals can aggravate inflammatory conditions in acne-prone skin, so compounds with antioxidant activity, such as curry leaf extract, can help reduce oxidative stress and improve skin regeneration [47]. Thus, these extracts can provide a holistic approach in treating acne, both from the antibacterial aspect and protection against oxidative damage [3].

The results of this study support the potential development of curry leaf extract as an active ingredient in the formulation of pharmaceutical or cosmetic antioxidant products. The significant antioxidant activity indicates its potential application in improving skin health and preventing premature aging due to free radical exposure [48], [49]. Further research is needed to explore the optimal formulation and potential synergism with other active ingredients.

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Antibacterial Activity Test

The antibacterial activity of curry leaf ethanol extract against Propionibacterium acnes was tested using the disc diffusion method. The test results at various concentrations of curry leaf ethanol extract (50, 100, 150, 200, and 250 mg/ml) showed the formation of varying inhibition zones. Table 2 shows the diameter of the inhibition zone at each tested extract concentration.

Table 2. Antibacterial activity test results of curry leaf ethanol extract against Propionibacterium acnes

Concentration (mg/ml)	Inhibition Zone Diameter (mm)			
	Rep-1	Rep-2	Rep-3	Average
C-	0.0	0.0	0.0	0.00 ± 0.00
50	15.3	15.1	15.1	15.17 ± 0.12
100	15.9	15.9	16.2	16.00 ± 0.17
150	16.6	16.4	16.4	16.47 ± 0.12
200	17.0	16.4	17.0	16.80 ± 0.35
250	17.6	17.8	17.9	17.77 ± 0.15
C+	27.5	27.3	28.6	27.80 ± 0.70

Description: C- (DMSO)
C+ (*dics antibiotics chloramphenicol 30 mcg*)

At a concentration of 250 mg/ml, the ethanol extract of curry leaves showed the largest inhibition zone, which was 17.77 ± 0.15 mm, followed by a concentration of 200 mg/ml which produced an inhibition zone of 16.80 ± 0.35 mm, a concentration of 150 mg/ml with an inhibition zone of 16.47 ± 0.12 mm, a concentration of 10 mg/ml with an inhibition zone of 16.00 ± 0.17 mm, and a concentration of 50 mg/ml with an inhibition zone of 15.17 ± 0.12 mm. In the negative control (DMSO), no inhibition zone was formed, indicating that DMSO has no antibacterial activity. Whereas in the positive control, which was 30 mcg chloramphenicol, the zone of inhibition formed was 27.80 ± 0.70 mm, indicating very strong antibacterial activity. These results can be seen more clearly in the graph presented in Figure 3.

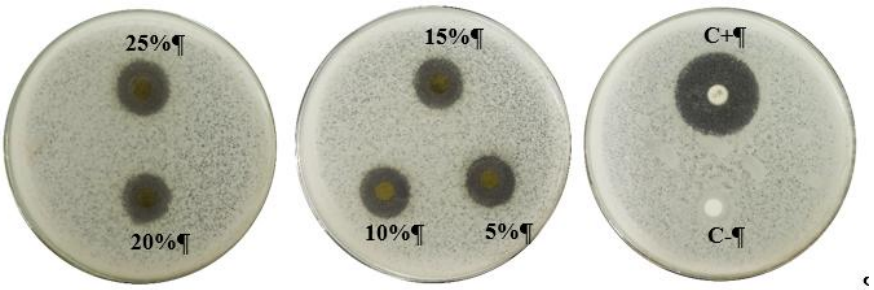

Figure 2. Results of antibacterial activity test against Propionibacterium acnes bacteria

The test results showed that the ethanol extract of curry leaves had significant antibacterial activity against Propionibacterium acnes. The zone of inhibition formed showed that the higher the extract concentration used, the larger the diameter of the inhibition zone formed. At a concentration of 250 mg/ml, the inhibition zone reached 17.77 ± 0.15 mm, indicating that the curry leaf extract has strong antibacterial ability. Lower concentrations, such as 50 mg/ml, also showed effectiveness, although the inhibition zone formed was smaller (15.17 ± 0.12 mm). Thus, it can be concluded that the ethanol extract of curry leaves has antibacterial potential that is directly proportional to the concentration of the extract used.

This test uses the Kirby-Bauer or disc diffusion method, which assesses the sensitivity of bacteria to antibacterial compounds based on forming a zone of inhibition around discs containing extract solutions [50]. The larger the zone of inhibition formed, the stronger the antibacterial activity of the compound. Based on Davis & Stout's (1971) criteria, inhibition zones with diameters above 20 mm are classified as very strong antibacterial activity, between 10-20 mm as strong activity, and between 5-10 mm as moderate activity. For the ethanol extract of curry leaves, all test concentrations showed inhibition zones in the strong category (10-20 mm), which proves that this extract has quite effective antibacterial potential against *P. acnes* [51].

The content of secondary metabolite compounds, such as alkaloids, flavonoids, saponins, tannins, and triterpenoids, can explain the success of curry leaf extract in inhibiting bacterial growth. Flavonoids, for example, are known to inhibit nucleic acid synthesis, damage bacterial cytoplasmic membranes, and inhibit

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bacterial energy metabolism [52]. Saponins work by lowering the surface tension of bacterial cells, which increases cell membrane permeability and causes cellular leakage [53]. Tannins can bind to proteins and inhibit bacterial growth by interfering with bacterial cell metabolism, while triterpenoids damage bacterial cell membranes by increasing protein metabolism and affecting bacterial cell stability [54], [55]. Thus, combining these compounds contributes to the antibacterial ability of curry leaf extract.

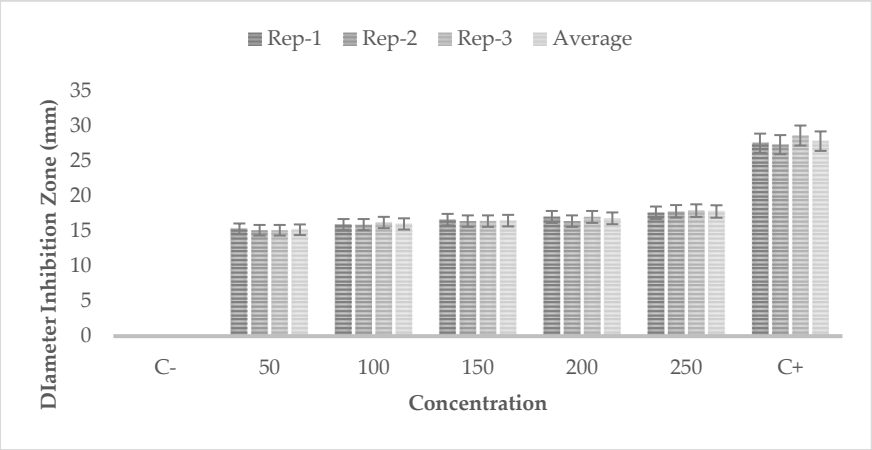

Figure 3. Graph of antibacterial activity test against *Propionibacterium acnes*

Phytochemical screening and previous reports indicate that curry leaves (*Murraya koenigii*) are rich in carbazole alkaloids such as mahanimbine, girinimbine, koenimbine, and murrayazoline, which are recognized as major contributors to the plant's biological activities. Among these, mahanimbine has been reported to exhibit potent antibacterial properties against Gram-positive bacteria, including Propionibacterium acnes, through mechanisms involving cell membrane disruption, inhibition of protein synthesis, and interference with enzymatic systems essential for cellular energy metabolism. Meanwhile, girinimbine and koenimbine possess conjugated phenolic structures capable of donating protons and stabilizing free radicals, suggesting their significant role in antioxidant activity via radical scavenging mechanisms. The aromatic carbazole ring system further enhances electron delocalization, allowing these compounds to effectively neutralize reactive oxygen species (ROS), thereby providing protective effects against oxidative stress and reducing secondary inflammation induced by P. acnes infection. These findings suggest that carbazole alkaloids are the key players responsible for curry leaf extract's dual antibacterial and antioxidant actions [56].

Conclusions

This study confirms that curry leaf extract possesses dual significant biological activities, acting as an antibacterial and antioxidant agent. Its antibacterial potential against several tested microorganisms indicates its efficacy in inhibiting pathogenic bacterial growth, while the DPPH assay results demonstrate strong antioxidant capacity through free radical scavenging mechanisms. These findings emphasize the potential of curry leaf extract as a promising natural source of active compounds for pharmaceutical and cosmetic development. However, further research is required to identify and characterize the main bioactive constituents that contribute to these effects, particularly from alkaloid and flavonoid fractions. Moreover, in vitro toxicity evaluation on human keratinocyte (HaCaT) cells should be conducted to ensure its safety for topical formulations. Future studies are also encouraged to assess the synergistic relationship between antibacterial and antioxidant activities using more complex biological models, thereby supporting the advancement of curry leaf extract toward effective, safe, and nature-based phytopharmaceutical or therapeutic cosmetic products.

Conflict of Interest

The authors declare that there is no conflict of interest regarding the publication of this paper.

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