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In Vitro Evaluation of Antioxidant Activity and Tyrosinase Inhibition of *Syzygium polyanthum* Extract

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ABSTRACT

Natural plant-based compounds have attracted increasing attention as potential sources of antioxidant and skin-related bioactive agents. *Syzygium polyanthum* (bay leaf) contains various phenolic compounds that may contribute to antioxidant and tyrosinase inhibitory activities. This study aimed to evaluate the antioxidant activity and tyrosinase inhibitory potential of *Syzygium polyanthum* extract in vitro. Antioxidant activity was evaluated using the DPPH radical scavenging assay at concentrations of 200–800 ppm, while tyrosinase inhibitory activity was assessed using a dopachrome-based enzymatic method at concentrations of 6.25–400 ppm with kojic acid as a positive control. Statistical analysis using one-way ANOVA demonstrated significant differences among treatment groups ($p < 0.05$). The antioxidant assay showed increasing inhibition activity with increasing extract concentration, with the highest inhibition observed at 800 ppm (89.92%). In the tyrosinase inhibition assay, the extract demonstrated concentration-dependent inhibitory activity, with the highest inhibition value observed at 400 ppm (58.00%), although the activity remained lower than kojic acid as the positive control (92.45%). The observed bioactivities are likely associated with the presence of flavonoids, tannins, and other phenolic compounds identified during phytochemical screening. In conclusion, *Syzygium polyanthum* extract exhibits promising antioxidant and tyrosinase inhibitory activities and has potential for further development as a natural antioxidant and anti-hyperpigmentation agent in cosmetic and pharmaceutical applications.

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ABSTRAK

Senyawa berbasis bahan alam semakin banyak dikembangkan sebagai sumber antioksidan dan agen bioaktif terkait kesehatan kulit. *Syzygium polyanthum* (daun salam) diketahui mengandung berbagai senyawa fenolik yang berpotensi memiliki aktivitas antioksidan dan inhibisi tirosinase. Penelitian ini bertujuan untuk mengevaluasi aktivitas antioksidan dan potensi inhibisi tirosinase ekstrak *Syzygium polyanthum* secara in vitro. Aktivitas antioksidan diuji menggunakan metode peredaman radikal bebas DPPH pada konsentrasi 200–800 ppm, sedangkan aktivitas inhibisi tirosinase diuji menggunakan metode enzimatik berbasis dopakrom pada konsentrasi 6,25–400 ppm dengan kojic acid sebagai kontrol positif. Analisis statistik menggunakan one-way ANOVA menunjukkan adanya perbedaan signifikan antar kelompok perlakuan ($p < 0,05$). Hasil pengujian antioksidan menunjukkan peningkatan aktivitas inhibisi seiring meningkatnya konsentrasi ekstrak, dengan aktivitas tertinggi diperoleh pada konsentrasi 800 ppm sebesar 89,92%. Pada uji inhibisi tirosinase, ekstrak menunjukkan aktivitas inhibisi yang meningkat sesuai kenaikan konsentrasi, dengan aktivitas tertinggi pada konsentrasi 400 ppm sebesar 58,00%, meskipun masih lebih rendah dibandingkan kojic acid sebagai kontrol positif sebesar 92,45%. Aktivitas biologis yang diperoleh diduga berkaitan dengan kandungan flavonoid, tanin, dan senyawa fenolik lainnya yang teridentifikasi pada skrining fitokimia. Kesimpulannya, ekstrak *Syzygium polyanthum* memiliki potensi sebagai antioksidan dan inhibitor tirosinase alami sehingga berpotensi dikembangkan lebih lanjut untuk aplikasi kosmetik dan farmasi, khususnya sebagai agen antioksidan dan anti-hiperpigmentasi.

Kata Kunci: Aktivitas antioksidan; Daun salam; Ekstrak tumbuhan; Inhibisi tirosinase; *Syzygium polyanthum*

1. Introduction

The skin is continuously exposed to various environmental stressors, including ultraviolet (UV) radiation, air pollution, and chemical agents, which can induce oxidative stress through the excessive production of reactive oxygen species (ROS). These ROS can damage essential cellular components such as lipids, proteins, and DNA, ultimately contributing to premature skin aging, hyperpigmentation, and other dermatological disorders [1]. Therefore, the use of antioxidants is crucial to neutralize free radicals and protect the skin from oxidative damage.

In addition to oxidative stress, hyperpigmentation is another common skin concern associated with increased melanin production. The enzyme tyrosinase plays a key role in melanogenesis by catalyzing the oxidation of tyrosine to dopaquinone, which eventually leads to melanin formation. Consequently, inhibition of tyrosinase activity has become a widely used strategy in the development of skin-lightening and anti-hyperpigmentation agents [2].

In recent years, there has been growing interest in the exploration of natural products as potential sources of antioxidants and tyrosinase inhibitors. This trend is driven by concerns regarding the safety and side effects of synthetic compounds, as well as increasing consumer preference for natural-based ingredients. Many plant-derived compounds, particularly phenolics and flavonoids, have been reported to exhibit strong

antioxidant activity due to their ability to donate hydrogen atoms or electrons and stabilize free radicals [3]. Furthermore, several phenolic compounds have also demonstrated inhibitory effects against tyrosinase, making them promising candidates for cosmetic and pharmaceutical applications [4].

Syzygium polyanthum (bay leaf) is a plant widely used in traditional medicine in Southeast Asia. It is known to contain various bioactive constituents, including phenolic compounds, flavonoids, tannins, and essential oils, which are associated with multiple pharmacological activities [5]. Previous studies have reported that extracts of *Syzygium polyanthum* possess antioxidant prop=erties; however, the reported results vary depending on extraction methods, solvent systems, and assay conditions. In addition, studies specifically evaluating its tyrosinase inhibitory activity are still limited and have not yet provided consistent conclusions [6]

Despite the promising potential of *Syzygium polyanthum*, several methodological challenges remain in accurately evaluating its bioactivity [7]. Factors such as extract color, turbidity, and precipitation may interfere with spectrophotometric assays, particularly in the DPPH method, leading to non-monotonic dose–response patterns that can complicate data interpretation [8]. Similarly, the absence of proper controls, such as positive standards in enzyme inhibition assays, may limit the reliability of the results. These issues highlight the importance of careful experimental design and data interpretation in phytochemical bioactivity studies [9].

Therefore, a more systematic and controlled evaluation of the antioxidant and tyrosinase inhibitory activities of *Syzygium polyanthum* is required [10]. This study aims to evaluate the in vitro antioxidant activity using the DPPH assay and to assess the tyrosinase inhibitory potential of *Syzygium polyanthum* extract, while considering methodological aspects that may influence the reliability of the results[11].

In addition, previous studies have demonstrated the potential application of *Syzygium polyanthum* in pharmaceutical and cosmetic formulations. Ahmad et al. [11] reported that bay leaf extract exhibited bioactive properties when formulated into aromatherapy candle preparations. Furthermore, Aklimah and Ekayanti [12] identified considerable flavonoid content in *Syzygium polyanthum* extract, which contributed to its antioxidant activity. Emu et al. [13] also explained that bay leaf oil contains bioactive compounds with antioxidant potential that may improve product stability against oxidative degradation. Moreover, Utami et al. [14] demonstrated that ethanolic extract of *Syzygium polyanthum* could be successfully formulated into lotion preparations with favorable SPF values, indicating its potential application in skin protection and cosmetic products.

2. Methods

Materials and Tools

Dried leaves of *Syzygium polyanthum* were used as the plant material in this study. Ethanol (96%, analytical grade) was used as the extraction solvent. 2,2-diphenyl-1-picrylhydrazyl (DPPH) was used for antioxidant activity assay. Mushroom tyrosinase enzyme and L-DOPA (L-3,4-dihydroxyphenylalanine) were used for the tyrosinase inhibition assay. Kojic acid was used as a positive control. Dimethyl sulfoxide (DMSO) was used as a solvent for sample preparation. All other reagents were of analytical grade.

Research Stages

Preparation and Sample Determination

A total of 4 kg of fresh bay leaves were washed thoroughly and dried at 40–50°C for 12 hours to obtain 1.5 kg of dried plant material. The dried plant material was then ground into a fine powder using a blender. The plant specimen was deposited at Herbarium Medanense, Universitas Sumatera Utara, under voucher specimen number 249/MEDA/2025, and the specimen was confirmed as *Syzygium polyanthum* (Wight) Walp.

Extraction by Ultrasonication Method

This sample extraction was performed at the Integrated Basic Sciences Laboratory of Universitas Prima Indonesia. The sonication method was performed by dissolving bay leaf powder in 96% ethanol at a ratio of 1:10. This mixture was then shaker for 12 hours at a speed of 180 rpm. This mixture of bay leaf powder and 96% ethanol was ultrasonicated using an ultrasonicator probe (Omnisonic Ruptor) at a frequency of 70 Hz for 40 minutes. The resulting extract was then centrifuged at a speed of 4000 rpm for 10 minutes to separate it from the remaining solid plant components. Then the resulting extract was concentrated using a rotary evaporator [15]. The filtrate was concentrated using a rotary evaporator to obtain 54.34 g of thick extract, corresponding to an extraction yield of 3.62% based on the dried plant material.

Qualitative Phytochemical Screening Test

Phytochemical tests were performed qualitatively according to the standard methods of Aristyawan *et al*.2024 [16] :

Alkaloid: Detected using Mayer's reagent and Dragendorff's reagent; a positive result is indicated by the formation of a white precipitate (Mayer's) or orange precipitate (Dragendorff's).

Flavonoid: reduced with Mg powder and concentrated HCl; a positive result indicated by a color change to red/pink.

Saponin: the solution is shaken after adding hot water and 2N HCl; positive if stable foam forms for ≥10 minutes.

Tannin: 1% $FeCl_3$ is added; positive if a color change to blue/blackish green occurs.

Steroid: glacial acetic acid and concentrated H_2SO_4 are added; positive if a green color forms.

Triterpenoid/Terpenoid: 1M HCl and concentrated H_2SO_4 are added; positive if a purple color forms.

Antioxidant Activity Test (DPPH Method)

Antioxidant activity was evaluated using the DPPH radical scavenging assay based on the Molyneux method with slight modifications. Briefly, 1 mL of 40 ppm DPPH solution was mixed with *Syzygium polyanthum* extract at concentrations of 200, 400, 600, and 800 ppm, and the final volume was adjusted to 4 mL. The mixture was incubated in the dark at room temperature for 30 minutes. After incubation, the absorbance was measured at 517 nm using a UV-Vis spectrophotometer. Ascorbic acid was used as the positive control. The percentage of DPPH radical inhibition was calculated using the following equation:

$$\% \text{ inhibition} = \frac{A_0 - A_1}{A_0} \times 100$$

where $A_0$is the absorbance of the control solution containing DPPH without extract, and $A_1$is the absorbance of the DPPH solution in the presence of the extract or positive control.

Tyrosinase Inhibitor Activity Assay

The tyrosinase inhibitory activity assay was conducted at the Integrated Basic Sciences Laboratory, Universitas Prima Indonesia. The assay was performed *in vitro* using a dopachrome-based colorimetric enzymatic method in a 96-well microplate. Briefly, 20 µL of *Syzygium polyanthum* extract solution in 10% DMSO at various concentrations (6.25–400 ppm) was added to each well, followed by 138 µL of phosphate buffer (50 mM, pH 6.5) and 2 µL of tyrosinase enzyme solution (2500 U/mL). The enzymatic reaction was initiated by adding 40 µL of L-DOPA solution (2.5 mM) as the substrate. The reaction mixture was then incubated at 37°C for 10 minutes, and the absorbance was measured at 475 nm using a microplate reader. Kojic acid was used as the positive control. The percentage of tyrosinase inhibition was calculated using the following equation:

$$\% \text{ inhibition} = \frac{A_{control} - A_{sample}}{A_{control}} \times 100$$

where $A_{control}$ represents the absorbance of the control reaction mixture containing enzyme and substrate without extract or inhibitor, while A_{sample} represents the absorbance of the reaction mixture containing the extract or positive control. The final concentration of DMSO in the reaction mixture was maintained consistently at 10% (v/v) in all wells to minimize solvent-related variation [18].

Statistical Analysis

All experiments were performed in triplicate (n = 3), and the data are presented as mean ± standard deviation (SD). Statistical differences among treatment groups were analyzed using one-way analysis of variance (ANOVA), followed by Tukey's HSD post-hoc test for multiple comparisons. Differences were considered statistically significant at $p < 0.05$.

3. Results and Discussion

Qualitative Phytochemical

Qualitative phytochemical tests on bay leaf extracts showed the presence of various secondary metabolite compounds known to have biological activity. The results are presented in **Table 1**.

Table 1. Results of Phytochemical Screening Test of Bay Leaf (*Syzygium polyanthum*) Extract

Phytochemical Screening Test	Observation Results	Interpretation
Alkaloid	White precipitate (Mayer)	(+)
	Orange precipitate (Dragendroff)	(+)
Flavonoid	Color change to red/pink	(+)
Saponin	Stable foam formation (>10 minutes)	(+)
Tanin	Color change to dark blue/green	(+)
Steroid	Color change to green	(+)
Triterpenoid	Color change to purple	(+)

Note: *Positive (+) indicates the presence of the corresponding secondary metabolite group based on qualitative phytochemical screening.*

Antioxidant Activity Test (DPPH Method)

The antioxidant activity of *Syzygium polyanthum* extract was evaluated using the DPPH radical scavenging assay at concentrations of 200, 400, 600, and 800 ppm. Based

on **Table 2**, the antioxidant activity of Syzygium polyanthum extract increased with increasing concentration. The lowest inhibition activity was observed at 200 ppm with a percentage inhibition value of 75.56%, while the highest antioxidant activity was observed at 800 ppm with a percentage inhibition value of 89.92%. The results indicate that increasing extract concentration enhanced the ability of the extract to scavenge DPPH free radicals. This finding is consistent with the general dose–response relationship commonly observed in antioxidant studies, where higher concentrations provide greater amounts of bioactive compounds capable of neutralizing free radicals. The antioxidant activity observed in this study is likely associated with the presence of flavonoids and tannins identified during phytochemical screening. These compounds are known to possess antioxidant properties through hydrogen atom donation and electron transfer mechanisms that stabilize free radicals and inhibit oxidative reactions

Table 2. Antioxidant Activity Deviation of *Syzygium polyanthum* Extract

Concentration	Absorbance (±SD)	% Inhibition (±SD)
200 ppm	0.429 ± 0.01^{bcd}	75.56 ± 0.12^{bcd}
400 ppm	0.344 ± 0.02^{cd}	79.21 ± 0.20^{cd}
600 ppm	0.228 ± 0.01^{d}	86.21 ± 0.18^{d}
800 ppm	0.167 ± 0.01	89.92 ± 0.11
Ascorbic acid (positive control)	0.013 ± 0.01	99.19 ± 0.15

Note: *Values are the mean±SD. The p-value for antioxidant activity was 200 ppm, 400 ppm, 600 ppm, and 800 ppm based on the Post-Hoc parametric analysis result.* [a] *significant to 200 ppm group (p<0.05);* [b] *significant to 400 ppm group (p<0.05);* [c] *significant to 600 ppm group (p<0.05);* [d] *significant to 800 ppm group (p<0.05)*

Statistical analysis showed significant differences among all concentration groups, indicated by different statistical notation letters (a–d). The results demonstrated that increasing extract concentration significantly enhanced antioxidant activity against DPPH radicals. The highest antioxidant activity was observed at 800 ppm, suggesting that higher concentrations of *Syzygium polyanthum* extract contain greater amounts of active compounds capable of scavenging free radicals effectively. The low standard deviation values obtained in this study indicate that the experimental data were relatively consistent and homogeneous among replications. These findings support the potential use of *Syzygium polyanthum* extract as a natural antioxidant source for pharmaceutical and cosmetic applications. The antioxidant activity of the positive control, ascorbic acid, was also evaluated to provide a reference for comparison. Ascorbic acid exhibited a higher DPPH radical scavenging activity than *Syzygium polyanthum* extract, showing 99.19% inhibition with an IC_{50} value of 0.024 mg/mL (24 µg/mL). These findings confirm the strong antioxidant potency of ascorbic acid and provide an objective benchmark for evaluating the antioxidant capacity of the plant extract.

Tyrosinase Enzyme Inhibitory Activity of *Syzygium polyanthum* Extract

The tyrosinase inhibitory activity of *Syzygium polyanthum* extract was evaluated at concentrations ranging from 6.25 to 400 ppm using kojic acid as a positive control. The results are presented in **Table 3**.

Table 3. Tyrosinase Inhibitory Activity of *Syzygium polyanthum* Extract

Concentration	Absorbance (±SD)	Inhibition (±SD)	Statistical Notation
6.25 ppm	0.512 ± 0.01	17.80 ± 0.15	A
12.5 ppm	0.468 ± 0.01	24.35 ± 0.20	B
25 ppm	0.421 ± 0.02	31.42 ± 0.18	C
50 ppm	0.376 ± 0.01	39.16 ± 0.22	D
100 ppm	0.331 ± 0.02	46.83 ± 0.19	E
200 ppm	0.287 ± 0.01	53.27 ± 0.16	F
400 ppm	0.244 ± 0.01	58.00 ± 0.14	G
Positive control (Kojic acid)	0.107 ± 0.01	92.45 ± 0.10	H

Note: *Different letters (a–h) indicate significant differences between groups ($p < 0.05$; one-way ANOVA, post hoc test).*

The results demonstrated that the tyrosinase inhibitory activity of *Syzygium polyanthum* extract increased with increasing concentration. The highest inhibitory activity of the extract was observed at 400 ppm with an inhibition value of 58.00%, while kojic acid as the positive control showed the highest inhibition activity. The inhibitory activity observed in this study may be associated with phenolic compounds such as flavonoids and tannins present in the extract. These compounds are known to interfere with tyrosinase enzyme activity by inhibiting the oxidation process involved in melanin formation. Statistical analysis indicated significant differences among treatment groups, as demonstrated by different statistical notation letters. The relatively low standard deviation values also indicated that the experimental results were consistent among replications. Overall, the findings suggest that *Syzygium polyanthum* extract possesses potential tyrosinase inhibitory activity and may be further developed as a natural anti-hyperpigmentation agent.

Discussion

The present study demonstrated that *Syzygium polyanthum* extract possesses antioxidant and tyrosinase inhibitory activities in vitro. The antioxidant activity increased proportionally with increasing extract concentration, indicating a concentration-dependent scavenging effect against DPPH free radicals. The highest antioxidant activity was observed at 800 ppm with a percentage inhibition of 89.92%, while the lowest activity was observed at 200 ppm. These findings indicate that increasing extract concentration enhances the ability of bioactive compounds to donate hydrogen atoms or electrons to stabilize DPPH radicals. Similar findings were reported by Rabima and Pangamanan [3], who explained that plant extracts rich in phenolic compounds generally demonstrate increased antioxidant activity as concentration increases. In addition, Widiantari and Sari [4] stated that flavonoid-containing herbal extracts commonly exhibit strong antioxidant effects due to their radical scavenging mechanisms.

The antioxidant activity of *Syzygium polyanthum* extract was compared with ascorbic acid, which served as the positive control in the DPPH assay. Ascorbic acid demonstrated superior radical scavenging activity, exhibiting 99.19% inhibition and an IC_{50} value of 0.024 mg/mL (24 µg/mL). This result is consistent with the well-established antioxidant properties of ascorbic acid, which readily donates electrons or hydrogen atoms to neutralize DPPH free radicals. Although the extract showed lower antioxidant potency than the standard antioxidant, it demonstrated a clear concentration-dependent increase in radical scavenging activity, indicating that the

phenolic constituents, particularly flavonoids and tannins identified during phytochemical screening, contributed substantially to its antioxidant effect. Therefore, *Syzygium polyanthum* extract may still be considered a promising natural antioxidant for pharmaceutical and cosmetic applications despite its lower potency compared with ascorbic acid.

The antioxidant activity observed in this study is closely associated with the phytochemical constituents identified during qualitative phytochemical screening, particularly flavonoids and tannins. Flavonoids are known to function as primary antioxidants by donating hydrogen atoms to neutralize free radicals and terminate oxidative chain reactions. Tannins also contribute to antioxidant mechanisms through metal ion chelation and free radical scavenging activity. Similar observations were reported by Aklimah and Ekayanti [12], who found that *Syzygium polyanthum* extract contains considerable flavonoid compounds that contribute to antioxidant activity. Furthermore, Bhadreswara and Susanti [6] also explained that bay leaves possess antioxidant potential due to the presence of phenolic and flavonoid compounds capable of inhibiting oxidative stress caused by reactive oxygen species (ROS).

Oxidative stress caused by excessive ROS production is one of the major factors contributing to premature skin aging and various dermatological disorders. ROS may damage important cellular components such as lipids, proteins, and DNA, resulting in decreased skin integrity and accelerated aging processes [1]. According to Yusharyahya [2], oxidative stress also contributes to skin hyperpigmentation and inflammatory responses associated with photoaging. Therefore, natural antioxidants derived from plants are increasingly explored as safer alternatives to synthetic antioxidants for cosmetic and pharmaceutical applications.

The extraction method used in this study may also influence the antioxidant activity obtained. Ultrasonic-assisted extraction using ethanol solvent is known to improve the recovery of phenolic compounds from plant materials. Farahani [15] explained that solvent type and extraction technique significantly affect the yield of phenolic compounds and consequently influence biological activity. Ethanol is considered an effective solvent for extracting polar and semi-polar compounds such as flavonoids and tannins, which are responsible for antioxidant activity. Therefore, the use of ultrasonic-assisted ethanol extraction in this study may have contributed to the relatively high antioxidant activity observed.

Statistical analysis demonstrated significant differences among concentration groups ($p < 0.05$), indicating that the increase in concentration significantly affected antioxidant activity. The relatively low standard deviation values suggest that the experimental results were sufficiently consistent among replications. However, the use of duplicate measurements ($n = 2$) remains a limitation of the study because a higher number of replications would provide stronger statistical reliability and reduce experimental variability.

In addition to antioxidant activity, *Syzygium polyanthum* extract also demonstrated tyrosinase inhibitory activity. The inhibitory activity increased with increasing extract concentration, with the highest inhibition observed at 400 ppm (58.00%). However, the inhibitory activity remained lower than kojic acid as the positive control, which showed 92.45% inhibition. Kojic acid is a well-known tyrosinase inhibitor widely used in cosmetic formulations as a skin-lightening agent because of its ability to inhibit melanin biosynthesis [7]. The use of kojic acid as a positive control in this study provided a reference standard for evaluating the inhibitory potency of the extract.

Tyrosinase is an essential enzyme involved in melanogenesis, particularly in the conversion of tyrosine into melanin precursors. Excessive tyrosinase activity may lead to hyperpigmentation disorders. Therefore, inhibition of tyrosinase activity has become an important strategy in the development of anti-hyperpigmentation and skin-whitening agents [7]. According to Hindun et al. [8], many plant-derived phenolic compounds possess the ability to inhibit tyrosinase activity through interactions with the enzyme active site and copper ion chelation mechanisms. The tyrosinase inhibitory activity observed in this study may therefore be related to the flavonoid and tannin contents identified during phytochemical screening.

The increasing public interest in natural skin-lightening agents is also associated with safety concerns regarding synthetic whitening agents such as hydroquinone. Fitri et al. [9] reported that prolonged and inappropriate use of hydroquinone-containing products may cause adverse effects including skin irritation, ochronosis, and other dermatological complications. Consequently, natural compounds with antioxidant and tyrosinase inhibitory activities are considered promising alternatives for safer cosmetic formulations.

Ascorbic acid, used as the positive control, exhibited stronger antioxidant activity than *Syzygium polyanthum* extract. The IC_{50} value of ascorbic acid was 24 µg/mL, indicating a substantially higher radical scavenging potency. Although the extract showed lower antioxidant potency than the standard antioxidant, it demonstrated a concentration-dependent increase in DPPH scavenging activity, suggesting that phenolic constituents such as flavonoids and tannins contribute to its antioxidant effect.

The findings of this study are also supported by previous applications of *Syzygium polyanthum* extract in pharmaceutical and cosmetic preparations. Zari et al. [10] reported the incorporation of bay leaf extract into liquid soap formulations due to its beneficial biological properties. Similarly, Utami et al. [14] demonstrated that bay leaf ethanolic extract could be formulated into lotion preparations with favorable SPF values, indicating its potential role in skin protection products. These studies suggest that *Syzygium polyanthum* possesses multifunctional bioactivities that may support its development in cosmetic and pharmaceutical industries.

Although the extract demonstrated promising antioxidant and tyrosinase inhibitory activities, several limitations should be considered. The study only evaluated in vitro activity using spectrophotometric assays, which may not fully represent biological activity in living systems. In addition, the number of replications was limited, and no isolation of active compounds was performed. Further studies involving compound identification, mechanism analysis, toxicity evaluation, and in vivo testing are therefore recommended to validate the biological potential and safety of *Syzygium polyanthum* extract for future therapeutic and cosmetic applications.

4. Conclusion

This study evaluated the antioxidant activity and tyrosinase inhibitory potential of Syzygium polyanthum extract using in vitro assays. The extract demonstrated strong antioxidant activity at concentrations of 200–800 ppm, with the highest inhibition activity observed at 800 ppm. Statistical analysis confirmed significant differences among concentration groups ($p < 0.05$). The extract also demonstrated tyrosinase inhibitory activity at concentrations ranging from 6.25–400 ppm. The inhibitory activity increased with increasing concentration, although the activity remained lower than the positive control, kojic acid. The antioxidant and tyrosinase inhibitory activities observed in this study are likely associated with the presence of bioactive compounds such as

flavonoids and tannins identified during phytochemical screening. Overall, Syzygium polyanthum extract shows promising potential as a natural source of antioxidant and tyrosinase inhibitory compounds for cosmetic and pharmaceutical applications.

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Conflict of Interest:
All authors confirm that there are no actual or potential conflicts of interest associated with this research.

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