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Original Research Article

Analysis of Antioxidant, Sunscreen, and Antibacterial Activity of Three Rhizome Extracts of *Curcuma* as Potential Natural Ingredient Cosmetic

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ABSTRACT

Rhizomes of the genus *Curcuma* such as *C. longa*, *C. xanthorrhiza*, and *C. zedoaria* are widely known in traditional medicine for their bioactive potential. Despite the widespread recognition, there is limited integrated research on antioxidant, sunscreen, and antibacterial activities for developing natural cosmetic ingredients. Therefore, this research aimed to evaluate the potency of *C. longa*, *C. xanthorrhiza*, and *C. zedoaria* bioactivity as well as determine the relationship between parameters. Samples of Curcuma rhizomes were extracted using a 95% ethanol solvent. An analysis was carried out to determine the extract yield, flavonoid, phenolic levels, and antioxidant activity using the DPPH and ABTS methods. In vitro sunscreen tests with SPF value parameters and antibacterial activity against *P. acnes*, *S. aureus*, and *S. epidermidis* were also carried out. The results showed that the highest total flavonoid levels in *C. longa* were 665.44 ± 6.03 mg QE/g, and phenolic were 215.47 ± 0.38 mg GAE/g. The antioxidant activity of *C. longa* was the strongest, with IC_{50} values of DPPH (58.61 ± 4.87 µg/mL) and ABTS (3.48 ± 0.37 µg/mL). The sunscreen activity test of *C. longa* extract at a concentration of 1,000 µg/mL showed the highest SPF value of 38.14. Regarding antibacterial activity, *C. longa* showed the largest inhibitory zone diameter against *S. aureus* and *P. acnes*, but *C. zedoaria* also has the best ability to inhibit *S. epidermidis*. Furthermore, a correlation analysis between variables and the Spearman test was carried out. The results showed a strong relationship between flavonoid levels, phenolics, DPPH test, and SPF value variables.

Keywords: Antibacterial, Antioxidant, Curcuma, Sunscreen activity.

Introduction

Skin protection against damage caused by ultraviolet (UV) exposure is gaining significant attention alongside the treatment of infections in the development of health products and cosmetics.[1] Overexposure to UV radiation is one of the main causes of skin damage in the globe and is linked to a number of skin issues, such as cancer, pigmentation, as well as premature aging.[2] Although synthetic active ingredients in skin care products and topical medications have increased, there are concerns regarding potential side effects, including irritation, allergies, and other adverse reactions.[3] Therefore, this research promotes the search for safer and more effective natural ingredients in addressing skin problems, such as premature aging, damage from UV radiation, and bacterial infections.[4] Among the various natural ingredients, plants of the *genus Curcuma* have long been known for their therapeutic properties, particularly in traditional medicine.[5]

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Plants of the *genus Curcuma*, specifically *C. longa*, *C. xanthorrhiza*, and *C. zedoaria*, have a variety of bioactive properties, suggesting their potential as attractive ingredients in health and skin care. *C. longa* (kunyit) is rich in curcumin, a polyphenol compound widely known as a powerful antioxidant[5]. The substance works effectively to lessen oxidative stress, which is a major contributor to both UV-induced damage and early skin aging. Furthermore, because of its anti-inflammatory, antibacterial, and antifungal qualities, C. longa is thought to be useful in the treatment of skin infections as well as inflammation.[6] *C. xanthorrhiza* (temulawak) has active components such as xanthorrhizole, which is known as an antioxidant and antimicrobial compound. Prior studies shown curcuma's photoprotective capabilities, shielding the skin from UV ray damage and lowering inflammation in sensitive skin conditions.[7] Moreover, *C. zedoaria* (temu putih) is frequently used in traditional medicine due to the presence of sesquiterpenoid-like compounds that function as antibacterial and anti-inflammatory agents. Extracts from *C. zedoaria* effectively treat skin infections caused by pathogenic bacteria which potentially prevent tissue damage due to free radical exposure[5]. In traditional medicines, these three species *of Curcuma* are widely recognized with significant potential in modern dermatological applications, particularly in manufacturing more natural, effective, and safe skincare products. Due to their wide range of therapeutic properties, species of Curcuma are invaluable alternatives in dealing with skin problems related to infections, aging, and damage caused by UV radiation. Regarding antioxidant and photoprotective activity, several investigations have been conducted to explore the bioactive potential of Curcuma species[8]. Previous research showed that *C. longa extract* had significant antioxidant activity derived from curcumin. The results showed that the compound could ward off free radicals and protect the skin from damage caused by oxidative stress. Similar research suggested that *C. xanthorrhiza* had photoprotective properties capable of reducing DNA

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damage caused by UV rays, thereby serving as a promising candidate for skin care formulations.[7,9] Several methods have been used to capture various free radicals removal capacities from different plants, including 1,1-diphenyl-2-picrylhydrazyl (DPPH) as well as 2.2-azinobis-3-ethylbenzothiazoline-6-sulfonic acid (ABTS). This is because DPPH is more sensitive to water-soluble compounds, while ABTS includes water- and oil-soluble compounds. Furthermore, in vitro Sun Protection Factor (SPF) testing methods are designed to evaluate photoprotective potential, which is important for cosmetic applications. The Kirby-Bauer disc diffusion method of antibacterial testing makes it possible to evaluate the activity spectrum against certain skin pathogens, such *P. acnes*, *S. aureus*, and *S. epidermidis*, which are important for anti-acne formulations.

Despite the significant potential of the methods, their application is limited to one type of plant without directly comparing with *other Curcuma* species. *C. longa* has shown significant antibacterial properties, particularly in ethanol extracts, against bacteria such as *Staphylococcus aureus* and *Escherichia coli*.[10] However, direct comparisons between the three *Curcuma species* regarding a combination of antioxidant, photoprotective, and antibacterial activity are still very scarce in the literature. Inconsistent extraction methods such as solvent type and limited direct comparisons across species hinder definitive conclusions about relative antioxidant efficacy. Data on SPF potential for *C. xanthorrhiza* and *C. zedoaria* are lacking, making comparative assessments impossible. Previous research has also tended to use different methods, thereby limiting consistent conclusions regarding comparing the effectiveness of the species in a broader and integrated context. According to the description, the objective of this study was to thoroughly investigate and contrast the *C. longa*, *C. xanthorrhiza*, and *C. zedoaria* bioactive activities. The *compa*rison was conducted in three main aspects, namely antioxidant, sunscreen, and antibacterial activity, particularly those related to using natural ingredients in developing safer and more effective dermatological as well as therapeutic products. The analysis focused on the relationship between antioxidant activity (DPPH and ABTS), in vitro SPF value, antibacterial activity (*S. aureus, P. acnes* and *S. epidermidis),* and total flavonoid as well as phenolic content in *C. longa, C. xanthorrhiza,* and *C. zedoaria* rhizome ethanol extracts.

Materials and Methods

Collection of materials and preparation of simplicia
Material collection as well as simplicia preparation were conducted at the Center for Research and Development of Medicinal Plants and Traditional Medicines (B2P2TOOT) in Tawangmangu, Karanganyar, Central Java in June 2023. The sample consisted of three different types of rhizomes of the genus Curcuma, provided by the assisted farmers. The identification was carried out by the B2P2TOOT as follows: *Curcuma zedoaria* (Voucher No. PE/IX/2024/52), *Curcuma xanthorrhiza* (PE/IX/2024/53)*,* and *Curcuma longa* (PE/IX/2024/55).
Gathering the raw ingredients, wet sorting, washing, slicing, and sun-drying while covered with a black cloth were the first steps in making simplicia. The simplicia was then crushed into a powder once dry sorting as well as packing were completed. In this research, all reagents used are derived from Sigma-Aldrich.

Extraction Process
Each rhizome *from C. longa, C. xanthorrhiza*, and *C. zedoaria* was extracted using the maceration process with approximately 1000 grams of simplicia and a solvent ratio of 1:10, consisting of 95% ethanol. During re-maceration, precisely the right amount of solvent was employed to create a liquid extract, which was then condensed using a rotary evaporator (Basis Hei-VAP Heidolph, Germany) and a water bath at a temperature of 60°C. The final result was a viscous extract whose yield was calculated in percent.

Analysis of Total Flavonoid Content (TFC) and Total Phenol Content (TPC)
The analysis was performed using the UV-Vis spectrophotometry (UV-1800 Shimadzu, Japan) method regarding the previous research with slight modifications. Quercetin was used as a comparison compound to determine TFC in the extract. Initially, a stock quercetin solution of 400 µg/ml was made followed by sample stock solution of 1,000 µg/ml. The standard series solution of quercetin concentrations were 25, 50, 75, 100, and 125 µg/ml. Each of the standard series solution (Galic acid) and test solution (extract) were taken 0.5 ml in a test tube, 2.5 mL of Folin-Ciocalteu dilution (7.5% in water) was added, 2 mL of 1% sodium hydroxide, and incubated for 30 minutes. The absorbance of each solution was measured at a maximum wavelength of 435 nm using blanks without the addition of a sample solution. The calibration curve and linear regression equation y = bx + a are obtained. By replacing the y value as the absorbance of the sample, the TFC (x) can be calculated using the following formula:

$$TFC = \frac{C.V}{m}$$

where V is the volume of the sample solution (ml), m is the weight of the ethanolic plant extract (g), and C is the sample concentration (x), as shown by the calibration curve (µg/ml). The TFC level findings are expressed in mg QE/g extract.

In determining the total phenol level, stock gallic acid solution of 400 µg/ml was made, followed by sample stock solution of 1,000 µg/ml. The standard series solution of quercetin concentrations used were 5, 15, 30, 50, 70, and 100 µg/ml. Each of the standard series solution (Galic acid) and test solution (extract) were taken 1 mL in a 10 ml measuring flask, added with 3 mL of ethanol P, 0.2 mL of aluminum chloride P 10%, 0.2 mL of sodium acetate 1 M, and aquadest to limit mark. The solution was allowed to stand for 30 minutes at room temperature. Measurement of absorbance was performed at a maximum wavelength of 740 nm using blanks without the addition of a sample solution. The calibration curve and linear regression equation y = bx + a are obtained. By replacing the y value as the absorbance of the sample, the TPC (x) can be calculated using the following formula:

$$TPC = \frac{C.V}{m}$$

where V is the volume of the sample solution (ml), m is the weight of the ethanolic plant extract (g), and C is the sample concentration (x), as determined by the calibration curve (µg/ml). Moreover, mg GAE/g extract is used to express TPC levels.

Analysis of Antioxidant Activity
The methods used in determining antioxidant activity were DPPH and ABTS. The DPPH approach involved mixing 2.0 ml of DPPH 40 µg/ml with around 1.0 ml of various extract concentrations (10, 20, 30, 40, & 50 µg/ml) and ascorbic acid as a comparison (2, 4, 6, 8, and & 10 µg/ml). For half an hour, the mixture was allowed to stand at room temperature in the dark. The absorbance was then measured against ethanol at a maximum wavelength of 518 nm using a spectrophotometer. The mean ± SD was used to express the findings of the triple experiment. The following equation was used to estimate the % DPPH.

$$\text{DPPH scavenged (\%)} = \frac{\text{Blank Absorbance} - \text{Sample absorbance}}{\text{Blank Absorbance}} \times 100\%$$

By entering the concentration value as the x-axis and DPPH scavenged (%) as the y-axis, the linear regression equation y = bx + a is obtained. The calculation of IC_{50} was performed by substituting the value of y to 50 for the value of x to known as IC_{50}. Antioxidant activity was expressed with an IC_{50} value with calculations following previous research and repeated three times.[11,12]
The $K_2S_2O_8$ solution 2.6 mM (0.0175 g/50 mL aquades) and 7.4 mM (0.1014 g/50 mL aquades) were prepared using the ABTS method. To create the ABTS stock solution, the mixture was combined and allowed to stand in a dark area for 12 to 16 hours. Subsequently, approximately 1 mL of the ABTS stock solution was pipetted in a measuring flask and diluted with 95% ethanol. A 5,000 µg/ml stock solution was used to create a sample series solution with a concentration of 0.1–0.5 µg/ml, which was measured at a maximum wavelength of 748 nm. The same

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experimental procedures were used for DPPH method and the IC_{50} calculation.

Analysis of Sun Protection Factor (SPF)
The SPF value was determined in vitro utilizing UV-Vis spectrophotometry (UV-1800 Shimadzu, Japan) based on its absorption. At wavelengths between 290 and 320 nm with a 5-nm interval, absorbance was measured for a solution containing 1,000 µg/mL of the extract against 95% ethanol. The procedure as well as calculations refer to previous research and the test was repeated three times.[12]

Analysis of Antibacterial Activity
Antibacterial activity tests were conducted on three bacteria, such as *Staphylococcus epidermidis* ATCC*, Propionibacterium acnes* ATCC, as well as *Staphylococcus aureus* ATCC. Samples in the form of Curcuma rhizome extract were made with concentration variations of 40, 60, and 80% in a 10 mL measuring flask. The method used was the Kirby Bauer well diffusion by isolating bacterial suspense on MHA media, followed by dividing into four parts on a plate. In each zone, a hole would be filled with a sample of Curcuma rhizome extract at concentrations of 40%, 60%, and 80%, with positive control (chloramphenicol 1%), and negative control (DMSO). This was followed by incubating petri dishes at 37^0C for 1x24 hours and the test was repeated three times. Following incubation, measurements were taken of the clear zone's diameter, which represents the area where bacterial growth is inhibited.[13]

Statistical Analysis
The data of the test results were TFC, TPC, antioxidant activity of DPPH and ABTS methods, SPF values, and bacterial inhibition (*P. acnes* ATCC, *S. aureus* ATCC, and *S. epidermidis* ATCC). Three replications were used for each test, and the mean ± SD was used to express the results. Minitab® 21.4 was used to perform the statistical analysis. A normality and homogenity test were carried out followed by the Spearman test to determine the correlation between the variables. A non-parametric test that assesses the strength of the association between two variables without supposing a particular distribution is the Spearman rank correlation coefficient. The correlation coefficient value can be decoded as follows r = ±1 (perfect correlation), 0.8-0.9 (strong), 0.6-0.7 (moderate), 0.3-0.5 (fair), 0.1-0.2 (weak), as well as at r = 0 (no correlation).

Results and Discussion

The exploration of natural ingredients, such as rhizome extracts, for developing cosmetics is essential because of their potential to offer safe and practical benefits. Natural compounds are rich in bioactive compounds capable of providing antioxidant, anti-inflammatory, and antimicrobial properties that offer anti-aging and skin protection, which are highly desirable in cosmetic formulations. Recently, the demand for natural and sustainable products has increased significantly, showing the need for further research.[14]
In this research, the experiment carried out included the preparation of three Curcuma samples, namely *C. longa, C. xanthorhiza, and C. zedoaria* rhizomes, followed by manufacturing extracts through maceration with 95% ethanol solvent. Based on the yield results in Table 1, the analysis of the 95% ethanol extract from various types of rhizomes of the genus Curcuma showed significant variations, with *C. xanthorrhiza* producing the highest at 14.04%. Compared to previous research which obtained 11.86%, this result was higher[15] due to the influence of genetics, environmental factors, and the extraction method.[7] The high yield of ethanol extract from *C. xanthorrhiza* showed the existence of significant bioactive compounds, namely curcuminoids, phenolic, as well as essential oils. These compounds are widely recognized for their therapeutic properties, with antioxidant, antibacterial, antifungal, and hepatoprotective activities, suggesting potential health benefits.[16]

C. zedoaria showed a lower yield of 13.14% due to the processing and storage of simplicia, which could affect the quality of raw materials.[17] *C. longa*, with a yield of 12.99%, also showed significant potential. In comparison, the yield of *C. longa* was higher than previous results, with values ranging from 6.62-8.19%.[18] The variation in results was attributed to different solvents, such as alcoholic water mixtures, which significantly affected the extractability of curcuminoids. A 50% ethanol solvent could extract approximately 32.2 mg/g of curcuminoid, showing the importance of solvent selection.[19] Moreover, the yield analysis provided insights into various Curcuma rhizomes' extraction efficiency and bioactivity potential. Higher yields suggested greater availability of bioactive compounds, which could be further explored for developing herbal and pharmaceutical products.

Determination of TFC and TPC
Determination of TFC and TPC from plant extracts is essential to assess their potential health and bioactivity benefits. Curcuma species are generally well-known for their antibacterial, anti-inflammatory, as well as antioxidant qualities. In light of the findings at Table 2, the TFC and TPC of 95% ethanol extracts of the genus Curcuma varied significantly. This suggested the different bioactivity potentials among the rhizome types tested. *C. longa*, with the highest flavonoid levels of 665.44 ± 6.03 mg QE/g extract showed a potential source. Furthermore, TPC in *C. longa* reached 215.47 ± 0.38 mg of GAE/g extract, which showed great potential in providing health effects.

Table 1: Extract Yield Analysis

Sample	Yield (%)
Curcuma longa	12.99
Curcuma xanthorrhiza	14.04
Curcuma zedoaria	13.14

Table 2: Levels of Total Flavonoids and Phenolics

Sample	Average Flavonoid Levels (mg QE/g extract)	Average Phenolic Levels (mg GAE/g extract)
Curcuma longa	665.44 ± 6.03	215.47 ± 0.38
Curcuma xanthorrhiza	168.08 ± 0.81	108.39 ± 1.80
Curcuma zedoaria	25.27 ± 0.62	35.14 ± 0.06

Previous research using 70% ethanol obtained a TFC of 243.50 QE/g and a TPC of 93.44 mg GAE/g. The variation in results that the difference in the concentration of ethanol solvents used would affect TFC and TPC values. An experiment conducted on *C. longa* from the East Coast of Peninsular Malaysia obtained lower phenolic levels of 155.31 ± 1.78 mg GAE/g as well as 151.00 ± 8.35 mg QE/g flavonoids.[20] The results showed that high concentrations of phenolics and flavonoids correlated with enhanced protective effects against skin aging and disease. This study aids in the discovery of novel bioactive compound sources for use in the food, cosmetic, as well as pharmaceutical sectors.[21]
Phenolic compounds can reduce oxidative stress, playing an essential role in preventing various chronic diseases. The antioxidant properties show potential to counteract free radicals as well as reactive oxygen species (ROS), controlling cell damage. Furthermore, phenolic compounds have the ability to boost antioxidant enzyme activity like catalase and superoxide dismutase, confirming their protective function against oxidative stress, which includes cardiovascular disease and cancer.[22] The rhizomes of the *C. longa* plant have a high content of flavonoids, contributing to antioxidant activity and a strong sunscreen.[12]

Regarding the genus Curcuma, there are unique compounds that differ from one species to another. *C. xanthorhiza* is known for xanthorrhizole

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content, a significant metabolite not found in *C. longa*. *C. zedoaria* contains a variety of sesquiterpenes and curcuminoids but does not have xanthorrhizole. These differences show the importance of understanding the unique biochemical profiles of each species and their potential applications in traditional and modern medicine. Furthermore, phytochemical content and pharmacological activity vary due to genetic variability and environmental factors.[23]

Antioxidant Activity

A popular technique for assessing antioxidants' capacity to fend off free radicals is the DPPH test. Meanwhile, ABTS test is carried out to assess antioxidant activity, often used with DPPH for comprehensive evaluation. These methods help determine the potential of Curcuma extracts to act as antioxidant, with the results shown in Table 3.

Table 3. Results of the Sunscreen Activity Test

Sample	SPF (1,000 µg/mL)
Curcuma longa	38.14 ± 0.71
Curcuma xanthorrhiza	13.84 ± 0.18
Curcuma zedoaria	8.20 ± 0.07

The antioxidant activity of rhizome extracts of the genus *Curcuma* showed significant results, with *C. longa* demonstrating the best ability to inhibit free radicals. In this research, *C. longa* had the lowest IC_{50} values in the DPPH (58.61 ± 4.87 µg/mL) and ABTS (3.48 ± 0.37 µg/mL) tests, which showed higher activity than others. The IC_{50} value of the previous research used 70% ethanol solvent with the DPPH (78.79 µg/mL) and ABTS (0.43 µg/mL) methods. The results found that when ethanol concentrations increased, curcuminoid levels and antioxidant activity in the powder rose significantly (p-value < 0.05). Antioxidant power as well as ethanol concentration were also shown to be positively correlated,[24] suggesting that solvent concentration substantially affected the antioxidant power of Curcuma extract. These results showed that the antioxidant power differed significantly from *C. longa* on the East Coast of Peninsular Malaysia, with the DPPH method of 88.65 ± 0.6 µg/mL.[25] Curcumin, the main turmeric compound, showed various biological effects, including counteracting oxidative stress as well as increasing the endogenous antioxidant enzymes activity.[26]

The mechanism by which antioxidants counteract DPPH radicals in polar solvents includes several pathways, mainly focusing on hydrogen atom transfer (HAT) and electron transfer processes. The solvent's polarity influences this mechanism and has an impact on the reaction's kinetics as well as thermodynamics. The Sequential Proton-Loss Electron-Transfer (SPLET) mechanism, comprising the first loss of a proton followed by an electron transfer across the solvent environment, is frequently selected thermodynamically in polar solvents. [27]

The IC_{50} value can be affected by the concentration of the DPPH solution used in the test.[28] Based on classification, antioxidants are categorized as potent, weak, and feeble, with IC_{50} values of less than 50 µg/mL, between 50-100 µg/mL, and greater than 200 µg/mL.[29] The high content of phenolic compounds and flavonoids correlates with increased antioxidant activity.[12] In this research, *C. xanthorrhiza* showed significant antioxidant activity, although not the same as *C. longa*.

Sunscreen Activity (SPF Value)

The SPF value is a metric used to assess how well sunscreen shields the skin from ultraviolet radiation, especially UVB rays. The SPF value indicates how long a person can be exposed to the sun without sunburn compared to unprotected skin. The results of the sunscreen activity test through SPF value are shown in Table 4.

Table 4: Antibacterial Activity Test Results

Sample	Concentration (%)	Diameter of the inhibition zone (mm)		
		P. acnes	*S.* aureus	*S. epidermidis*
C. longa	40	0.0 ± 0.0	9.2 ± 0.4	0.0 ± 0.0
	60	9.2 ± 0.1	13.9 ± 0.2	0.0 ± 0.0
	80	13.9 ± 0.4	16.5 ± 0.5	0.0 ± 0.0
C. xanthorrhiza	40	8.2 ± 0.2	0.0 ± 0.0	7.5 ± 0.4
	60	9.7 ± 0.1	8.6 ± 0.4	10.0 ± 0.2
	80	11.5 ± 0.0	10.2 ± 0.3	13.2 ± 0.1
C. zedoaria	40	9.2 ± 0.2	9.8 ± 0.7	7.1 ± 0.3
	60	12.4 ± 0.1	13.2 ± 0.1	10.5 ± 0.1
	80	14.6 ± 0.9	16.4 ± 0.1	14.9 ± 0.2
Chloramphenicol 1% (+)		32.0 ± 1.0	22.5 ± 0.3	36.2 ± 0.7
DMSO (-)		0.0 ± 0.0	0.0 ± 0.0	0.0 ± 0.0

The findings demonstrated that curcuma extract, with an SPF value of 38.14 (1,000 ppm), has a considerable potential for UV protection. This value showed that Curcuma could serve as an effective sunscreen agent. The results obtained are not much different from previous research using 70% ethanol solvents with SPF values of 31.55 (500 ppm) and 37.46 (1,000 ppm).[12] The SPF values of 70% ethanol extract from another Curcuma species, namely *C. manga*, were obtained as 9.19 (1,250 ppm), 19.81 (2,500 ppm), 25.23 (3,750 ppm), and 35.12 (5,000) ppm [30]. Curcumin has been shown to have potent antioxidant activity, which is essential for photoprotection and neutralizes free radicals produced by UV rays. By lowering inflammation cause by UV exposure, bisdemethoxycurcumin as well as curcuma's anti-inflammatory qualities, help to provide the curcuma's photoprotective benefits. [5 31]

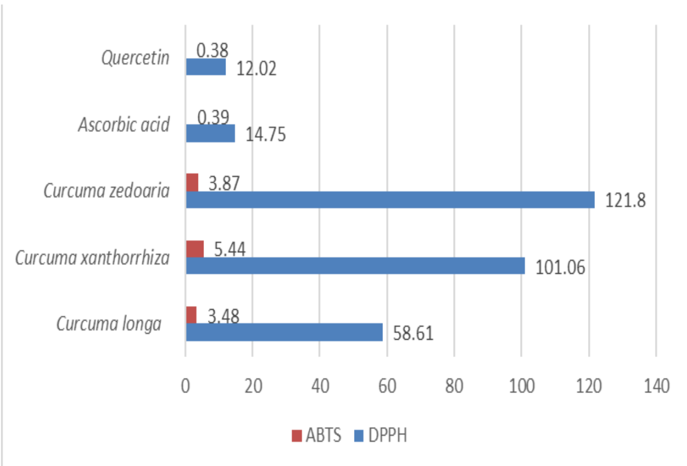

Figure 1: The value of IC_{50}

Antibacterial Activity

The antibacterial activity test of three Curcuma rhizome extracts, namely *C. longa*, *C. xanthorrhiza*, and *C. zedoaria,* was carried out on *P. acnes* ATCC, *S. aureus* ATCC, as well as *S. epidermidis* ATCC. The test results obtained are shown in Table 5. The findings showed the strong antibacterial activity of the genus *Curcuma*'s rhizome extract, especially against *P. acnes* and *S. aureus*. *C. longa,* with the highest inhibition zone diameter recorded at a concentration of 80%, showed better effectiveness than others, with a mean value of 13.9 ± 0.4 mm for *P. acnes* as well as 16.5 ± 0.5 mm for *S. aureus*. *C. xanthorrhiza* showed significant antibacterial activity, but not potent as *C. longa*. Because it contained less active chemicals, *C. zedoaria* performed worse in antibacterial testing. The extract's bioactive components are linked to its antibacterial activity. Previous research showed that *C. longa* and *C. xanthorrhiza* contained alkaloid secondary metabolite compounds, flavonoids, tannins, saponins, and terpenoids. However, it was reported that *C. zedoaria* did not contain terpenoids.[12]

Table 5: The value of the Spearman correlation coefficient between variables

Variables	**Correlation coefficient (r)**						
	Flavonoid	**Phenolic**	**DPPH ($1/IC_{50}$)**	**ABTS ($1/IC_{50}$)**	**SPF**	***P. acnes***	***S. aureus***
Phenolic	0.917						
DPPH	0.800	0.950					
ABTS	0.383	0.200	0.250				
SPF	0.917	1.000	0.950	0.200			
P. acnes	-0.243	-0.293	-0.176	0.603	-0.293		
S. aureus	0.079	-0.053	-0.035	0.694	-0.053	0.820	
S. epidermidis	-0.911	-0.928	-0.851	-0.255	-0.928	0.235	0.027

The rhizome *of C. longa* contained bioactive compounds with antibacterial properties. The antibacterial test findings demonstrated that *C. longa* extract exhibited strong antibacterial activity against *S. aureus* and *E. coli*, with inhibition zones varying between 21.79 ± 1.04 mm and 30.13 ± 1.94 mm at 250 and 500 mg/m. The minimum inhibitory concentration (MIC) was 15.625 mg/mL, indicating effective bactericidal properties. These results supported the potential of *C. longa* as a skincare candidate, particularly for preventing infections caused by pathogenic bacteria.[32] In natural cosmetic research, testing for antibacterial activity in *P. acnes*, *S. aureus*, and *S. epidermidis* is crucial to determining how well extracts combat skin infections and bacteria that cause acne.[33] Testing ensures that extracts derived from the Curcuma genus have sufficient antibacterial activity to inhibit pathogens, thereby increasing users' therapeutic potential and safety. Based on the analysis of the three Curcuma rhizome extracts, including TFC, TPC, antioxidants, SPF values, and antibacterial, a correlation analysis between variables using the Spearman test was performed. The outcomes are displayed in Table 6.

A non-parametric test that assesses the strength of the association between two variables without supposing a particular distribution is the Spearman rank correlation coefficient. The coefficient value is deciphered as perfect, powerful, moderate, fair, wrong, and no correlation at r = ±1, 0.8-0.9, 0.6-0.7, 0.3-0.5, 0.1-0.2, and 0, respectively.[34] Based on the data, there is a strong and positive relationship between flavonoid, phenolic, DPPH, and SPF levels. This shows that a higher level of flavonoid and phenolic correlates with a significant increase in antioxidant activity (DPPH) and SPF value. The four variables also have a strong relationship but in opposite directions in the S. *epidermidis antibacterial test*. Meanwhile, the correlation of other parameters is classified as low-moderate.

This research evaluated the potential of rhizome extracts from three *Curcuma* species, for developing cosmetic ingredients and pharmaceutical products. In comparison to other samples, the results demonstrated the substantial potential of the C. longa rhizome extract. The highest yield of *C. longa* was 14.04%, showing the greatest levels of flavonoids (665.44 ± 6.03 mg QE/g) and phenolic (215.47 ± 0.38 mg GAE/g). The *C. longa* antioxidant activity was the strongest, with IC_{50} values of DPPH (58,61 ± 4,87 µg/mL) and ABTS (3.48 ± 0.37 µg/mL). According to the sunscreen activity test findings, C. longa achieved the greatest SPF value with 38.14 at the 1,000 µg/mL concentration. Regarding antibacterial activity, *C. longa* showed the largest inhibitory zone diameter against *S. aureus* and *P. acnes.* However, *C. zedoaria had the* best ability to inhibit *S. epidermidis.* This research showed a strong relationship between flavonoid levels, phenolics, DPPH test, and SPF value variables.

Conclusion

In conclusion, this study assessed the rhizome extract potentials from three Curcuma species (*C. zedoaria*, *C.* xanthorrhiza, and *C. longa*), for developing cosmetic ingredients and pharmaceutical products. The results showed that *C. longa* rhizome extract had significant potential compared to others. The highest TFC in *C. longa* was 665.44 ± 6.03 mg QE/g and TPC was 215.47 ± 0.38 mg GAE/g. The *C. longa* antioxidant activity was the strongest, with IC_{50} values of DPPH (58.61 ± 4.87 µg/mL) and ABTS (3.48 ± 0.37 µg/mL). According to the sunscreen activity test findings, C. longa achieved the greatest SPF value with 38.14 at the 1,000 µg/mL concentration. Regarding antibacterial activity, *C. longa* showed the largest inhibitory zone diameter against *S. aureus* and *P. acnes*, but C. *zedoaria* had the ability to inhibit *S. epidermidis.* The results of this study showed a strong relationship between flavonoid levels, phenolic compounds, DPPH test, and SPF values. Additionally, more investigation was suggested to examine the precise processes of bioactive activity as well as possible clinical uses of these extracts.

Conflicts of Interest

The authors declare no conflict of interest.

Author's Declaration

The authors hereby declare that the work presented in this article is original and that any liability for claim relating to the content of this article will be borne by them.

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