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ANTIOXIDANT TEST OF TONER IN SKINCARE PACKAGES CIRCULATING IN INDONESIAN SOCIETY

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Abstract

Toner has the function of an antioxidant because it can shrink pores and make skin fresher to ward off symptoms of premature aging. In 2021, the use of facial care or skincare products, especially toners, has greatly increased among the public based on online sales results on e-commerce (Shopee and Tokopedia). The purpose of this study was to determine the IC50 value obtained in toner in the skincare package. This study used five toner samples with 5 concentration variations (50 ppm, 100 ppm, 150 ppm, 200 ppm, 250 ppm) and measured antioxidant activity using a UV-Vis Spectrophotometer instrument with the DPPH method. The results showed that the best IC50 value was ascorbic acid (vitamin C) as a positive control with an IC50 value of 7.768 ppm and entered the very strong category. Toner 1 had an IC50 value of 62.218 ppm and was categorised as a strong antioxidant. Toner 2 had an IC50 value of 128 ppm and was categorised as a medium antioxidant. Toner 3 IC50 value of 158.972 was categorised as a weak antioxidant, and toner 4 IC50 value of 91.017 ppm is categorised as a strong antioxidant. At the same time, the one with the lowest IC50 value is toner 5, which has an IC50 value of 170.64 and is included in the weak antioxidant category. Of the five toner samples that have the best IC50 value is toner 1, with an IC50 value of 62.218 ppm.

Keywords: Free radical; Antioxidant; DPPH; Toner; IC50; Ascorbic acid

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INTRODUCTION

Currently, in Indonesia, the need for beauty products is increasing because of people's awareness of appearance, especially the face. Both women and men compete to improve their appearance and look more attractive. Sales of locally made skincare brands are arguably quite impressive, according to published data.[1] Currently, the use of facial care or skincare products, especially toners, is very increasing among the public. According to Kompas, in 2021,[2] local toners have good sales data on e-commerce (Shopee and Tokopedia), reaching IDR 30.3 billion with approximately 556 thousand products sold.[2] In the period April to June 2022, there were 3.8 million total transactions in the marketplace, with total sales reaching Rp 292.4 billion. The top ten skincare brands in Indonesia are all different, according to market share data provided by Shopee and Tokopedia.[3] The formula or

composition of a toner usually consists of: solvents (water or mixtures with alcohol), humectants (glycerol, propylene glycol, AHA, urea, and hyaluronic acid), pH adjusters to raise pH (acidic or alkaline), preservatives, active substances, aesthetic colourants, perfumes.[3] After washing your face with soap and water, use toner as a cosmetic. In addition to making the skin look fresher, toner serves to shrink pores.[4] The function of toner is to perfect skin cleansing by removing dust, pollution, and dirt that is still left after cleaning with cleanser because cleansers usually contain ingredients such as oil that can be left on the face.[5] Toners are divided into 2 types, namely Exfoliating Toner and Hydrating Toner. Exfoliating toner is a type of toner whose main function is to exfoliate the skin by removing the epidermis, or the topmost layer of skin, and dead skin cells. This particular toner will remove any dirt or makeup residue left behind from the previous step, as well as any remaining impurities from the previous step. Exfoliating toners are made using beta-hydroxy acids (BHAs) and alpha-hydroxy acids (AHAs), as well as their chemical derivatives. Certain types of toners that are used primarily to rehydrate facial skin are known as hydrating toners. By increasing the skin's inherent water content, hydrating toners help prepare your skin for the use of further skincare products.[6]

Premature aging is the process of skin aging that occurs ahead of its time. The causes of premature skin ageing are environmental factors and internal factors of one's personality. The most common cause is exposure to free radicals from ultraviolet light.[7] The causes of premature ageing include internal and external factors. Internal factors include heredity, psychology, health, and immunity. This internal factor, of course, cannot be avoided because it is a natural process in humans. This is also triggered by hormonal changes and stress levels experienced by a person. External factors include sunlight, free radicals, smoking, excessive alcohol consumption, poor diet, and sleeping position. Quoting from Dr. Oz Indonesia (2015).[7] Premature ageing can happen to anyone, especially in Indonesia, which has a tropical climate with abundant sunlight. Degenerative processes occur faster in skin that is too often exposed to ultraviolet light.[8] The aging process is usually characterised by the appearance of fine lines or wrinkles on the face. However, the aging process itself is more complex than just facial wrinkles. Ageing is a process of deterioration or degeneration that causes the body to lose its functions and capabilities, including causing the appearance of wrinkles and fine lines on the face or other parts of the body.[9]

An antioxidant is any substance that can delay or stop oxidative damage to target molecules. In general, antioxidants work by preventing the oxidation of fat molecules. Superoxide dismutase (SOD), catalase, and glutathione peroxidase are examples of antioxidant enzymes. Vitamins E, C, A, and ß-carotene are examples of antioxidant vitamins. Flavonoids, albumin, bilirubin, ceruloplasmin, and other compounds are examples of other substances. Antioxidant vitamins belong to the vitamin E, C, and A

groups. Antioxidants are chemicals that can stop the oxidation process in its tracks. By sticking to highly reactive chemicals and free radicals, they do just that, ultimately causing less cell damage. Flavonoids, oligoresveratrol, and phenolic acids are some examples of bioactive compounds that are included in the phenol group and have the ability to function as antioxidants. One of the uses of antioxidants is as an antidote to the symptoms of premature aging or anti-aging. This symptom is characterised by a decrease in skin moisture and elasticity because the skin's elasticity and ability to retain water decreases. As a result, the face looks wrinkled, the skin becomes dry and rough, and there are black spots, which are very easily experienced by women, especially those aged 40 years and over.[8] Antioxidants are compounds that can inhibit oxidation reactions by binding free radicals and highly reactive molecules. As a result, cell damage can be inhibited. The antioxidant activity of phenol compounds is mainly due to the oxidation-reduction reaction, which plays an important role in absorbing and neutralising free radicals, reducing singlet and triplet oxygen, and decomposing peroxides.[9]

The peroxidation reaction is a chain reaction that regenerates free radicals, resulting in the subsequent peroxidation reaction of unsaturated fatty acids in cell membrane phospholipids. As a result, the fluidity and lipid permeability of the cell membrane will decrease. This decrease will cause a decrease in insulin binding by the insulin receptor, as well as a decrease in the activity of the Na+/K+ ATPase enzyme, which will trigger a decrease in the active transport system of glucose and amino acids and an increase in plasma insulin levels. As a result, the speed of cell energy production and biosynthesis of cell macromolecules and other development units also decreases.[10]

A number of techniques, including FRAP, ABTS, and DPPH procedures, can be used to test for antioxidants. The DPPH method was used in this particular assay because it has the advantage of being a simple, rapid, and uncomplicated analytical procedure and is sensitive to samples that include low amounts (Karadag).[11] The DPPH method provides information about the reactivity of a substance with stable radicals. The rich purple colour of DPPH is accompanied by strong absorption at wavelengths between 516 and 520 nm. The capture of free radicals, according to Sayuti,[12] leads to paired electrons, which cause a colour change proportional to the number of electrons removed. Since hydrogen atoms (H) are often released by substances that are potential radical scavengers, DPPH radicals (hydrazine) can capture those H atoms and convert them into a neutral state (Hydrazine). ABTS and FRAP techniques are two other methods to measure antioxidant activity besides DPPH. Antioxidants can reduce ABTS, which then changes from an active radical form to a non-radical form and becomes colourless. The nitrogen-based radical known as ABTS is characterised by a distinctive blue-green colour. The preparation of ABTS itself requires an incubation time of 12-16 hours, which is carried out in a dark atmosphere because the ABTS technique is very sensitive to the

presence of light.[13] This study aims to determine whether the toner products tested have antioxidants and to determine the levels or IC50 values obtained on toners in skincare packaging.

METHODS

Materials

The materials used in this study consist of five different face toner samples, obtained both online through e-commerce platforms and offline from official brand stores to ensure authenticity. The toner samples analyzed include Something (Toner 1), Scarlett (Toner 2), Emina (Toner 3), Whitelab (Toner 4), and Wardah (Toner 5), each selected based on their formulation focus and market presence. To evaluate their antioxidant activity, several chemical reagents were utilized, including vitamin C (S311401, pro analysis) as a reference antioxidant due to its well-known free radical-scavenging properties, methanol p.a (I1108609, pro analysis) as a high-purity solvent for extracting active compounds, and DPPH powder p.a (STBJ3113, pro analysis), a stable free radical compound used in the DPPH assay to measure antioxidant capacity.

Research Procedure

The first step was to make a 0.05 mM DPPH solution. The DPPH powder material was weighed at 1.97 mg using a digital analytical balance and dissolved in a 100 mL measuring flask. Then methanol was added, and the mixture was shaken until homogeneous to produce DPPH, which had a concentration of 0.05 mM. This is done to produce a DPPH solution with a concentration of 0.05 mM.

The next step is to determine the maximum absorption wavelength of DPPH. The longest wavelength must be sought to get the highest absorption. The maximum wavelength was determined by measuring the absorbance of 4 mL of DPPH solution in a cuvette of the appropriate size using a UV-Vis spectrophotometer in the wavelength range of 400-600 nm. The highest absorption value can be used to determine the longest wavelength.

Then, the Operating Time was measured by combining 50 µL of test toner solution 1 to 5 with vitamin C, adding 4.0 ml of 0.05 mM DPPH solution, vortexing the mixture, and measuring at intervals of 0 minutes, 5, 10, 15, 20, 25 minutes, and 30 minutes at the maximum wavelength set during the previous wavelength determination, the operating time is calculated. Mulangsri et al. (2017) the time required to obtain the most stable absorption (0.2-0.8) from soaking DPPH free radicals is the operating time.

The next step is to make a blank solution by adding two milliliters of methanol at room temperature after adding two milliliters of DPPH solution (0.05 mM) into a test tube using a pipette. Use aluminum foil to cover everything. The mixture was then homogenised using a vortex and left for the required time in a dark environment. The amount of light absorbed is then determined using the maximum wavelength and the results of previous measurements.

The next preparation is making a solution and measuring the antioxidant activity of Vitamin C. The application of ascorbic acid acts as a positive control in the

experiment. An ascorbic acid solution with a concentration of 100 ppm is prepared by dissolving up to 10 mg of ascorbic acid in 100 mL of methanol. Next, the concentration of the ascorbic acid solution was varied by 1 ppm, 2 ppm, 3 ppm, 4 ppm, and 5 ppm in a volumetric flask, and the volume was sufficient by adding methanol little by little to 5 mL. Each concentration was repeated three times. Each test tube was filled with an equal amount, measured in milliliters (mL), of a reference solution containing vitamin C. The mixture was thoroughly mixed by vortexing after adding 2 mL of DPPH solution containing 0.05 mM. It is then kept in a dim room during the procedure. The amount of light absorbed is then determined using the maximum wavelength and the results of previous measurements.

Proceed to the next step, namely Preparing the Toner Antioxidant Activity and Toner Solution. First, prepare 10 mg of the toner solution by pipetting the toner solution and weighing it using a watch glass on a digital analytical scale, then dissolving it in 10 mL of methanol pa. until the mixture is homogeneous, resulting in a concentration of 1000 ppm. Then, the concentration was made to 50 ppm, 100 ppm, 150 ppm, 200 ppm, and 250 ppm. The ascorbic acid solution and toner solution were pipetted in 4 milliliters with various concentrations during the experiment. Each was given 2 mL of DPPH solution. Then, the mixture was stirred until homogeneous. All solutions were left in the incubator at room temperature for 30 minutes after adding the DPPH solution to the samples. After that, the longest wavelength of the DPPH spectrum is used to calculate the degree of absorption. The experiment was run three times, often called triplicate.

After the absorbance is obtained, the inhibition is calculated by the following formula:

$$\%\ inhibisi = \frac{A.blank - A.sample}{A.blank}\ x\ 100\%$$

Information:

A = Absorbance value

The IC_{50} value is a number that indicates the concentration of the test sample in which free radicals can be captured by 50%. The linear regression line equation, which describes the relationship between the concentration of the test substance (x-axis) and the percent of radical entanglement activity/% of inhibition (y-axis), yields this value. This observation yields the equation y = bx + an, where a is the intersection and b is the slope. The letter r stands for the value of the correlation coefficient. The acceptable r value is close to -1 or +1, depending on the slope value obtained. The value of IC_{50} can be calculated using the formula:

$$y = bx + a$$

$$50 = bx + a$$

$$50 = b(IC50) + a$$

The above equation can be formulated into:

$$IC50 = \frac{50 - a}{b}$$

RESULTS AND DISCUSSION

The antioxidant activity of a substance can be quantified using the IC_{50} value, which is determined through linear regression analysis. By plotting the percentage of inhibition for each sample and deriving the linear regression equation (y = bx + a), the IC_{50} value is obtained by solving for x, representing the concentration required to inhibit 50% of free radicals.

In this study, the antioxidant potential of five toner samples and a vitamin C reference was evaluated using the DPPH method and analyzed with a UV-Vis spectrophotometer. The resulting data, as presented in **Table 1**, illustrate the variations in antioxidant effectiveness across different formulations, highlighting the significant role of specific active ingredients in determining free radical scavenging capacity.

Table 1. Test Results of Antioxidant Fifth Toner and Vitamin C

Sample	Linear regression equation	R	IC_{50} (ppm)	Information	Scale (ppm)
Toner 1	y = 0.064x + 46.018	0.999	62.218	Strong	50-100
Toner 2	y = 0.080x + 41.373	0.999	128	Keep	101-150
Toner 3	y = 0.036x + 44.277	0.998	158.972	Weak	150-200
Toner 4	y = 0.058x + 44.721	0.998	91.017	Strong	50-100
Toner 5	y = 0.050x + 41.468	0.999	170.64	Weak	150-200
Vitamin C	y = 3.107x + 25.864	0.998	7.768	Very Powerfull	<50

Based on **Table IV.3**, the IC_{50} values were obtained from antioxidant tests conducted with three repetitions to ensure accuracy and reliability. IC_{50} value below 50 ppm is classified as a very strong antioxidant, while a value exceeding 200 ppm is considered weak. The results indicate that ascorbic acid (vitamin C), used as a positive control, exhibited the strongest antioxidant activity with an IC_{50} value of 7.768 ppm, placing it in the very strong antioxidant category. Among the toner samples, Toner 1 demonstrated the highest antioxidant activity with an IC_{50} value of 62.218 ppm, categorizing it as a strong antioxidant. Similarly, Toner 4 exhibited notable antioxidant properties with an IC_{50} of 91.017 ppm, while Toner 2, with an IC_{50} of 128 ppm, fell into the medium antioxidant category. In contrast,

Toner 3 and Toner 5 had significantly weaker antioxidant capacities, with IC_{50} values of 158.972 ppm and 170.64 ppm, respectively, classifying them as weak antioxidants. The observed differences in IC_{50} values can be attributed to the distinct formulations of brightening and anti-acne toners. Brightening toners, including Toner 1, Toner 2, and Toner 4, contained higher concentrations of antioxidant-rich ingredients such as vitamin C derivatives and polyphenols, leading to better antioxidant performance compared to anti-acne toners like Toner 3 and Toner 5, which primarily focused on anti-inflammatory and sebum-regulating components.

Antioxidant activity in cosmetic products, including toners, plays a critical role in protecting the skin from oxidative stress, which accelerates aging and cellular damage. The DPPH method, employed in this study, is a widely accepted technique for assessing the free radical scavenging ability of various skincare formulations. The IC_{50} value serves as a benchmark for antioxidant efficacy, with lower values indicating stronger antioxidant potential. Antioxidants in cosmetic formulations are essential in neutralising reactive oxygen species (ROS), which contribute to skin damage, inflammation, and premature aging.[14] Additionally, research by Mostafa et al. (2021) highlights that certain plant-derived flavonoids and phenolic compounds incorporated into skincare products enhance their protective effects against environmental aggressors.[15]

The study results demonstrated significant variations in antioxidant activity among the five toner samples tested. Toner 1 and Toner 4 exhibited the strongest antioxidant potential, with IC50 values of 62.218 ppm and 91.017 ppm, respectively. These findings are consistent with Mostafa et al. (2021), who emphasized that flavonoids and polyphenols play a crucial role in enhancing the antioxidant properties of cosmetic formulations.[15] The presence of these bioactive compounds in brightening toners may contribute to their superior antioxidant efficacy. In contrast, Toner 3 and Toner 5 had higher IC50 values, measuring 158.972 ppm and 170.64 ppm, respectively, classifying them as weak antioxidants. The weaker antioxidant performance of these toners suggests differences in their formulations, particularly in the concentration of active antioxidant compounds such as plant-based extracts and vitamin derivatives. Plant-derived antioxidants such as cucumber extract and flavonol glycosides have been shown to significantly enhance free radical scavenging activity in cosmetic preparations, which may explain the superior performance of brightening toners over anti-acne variants.[18]

The observed differences in antioxidant activity among toner samples can be directly linked to their ingredient composition, particularly the presence of bioactive plant-based compounds and vitamin derivatives. Alkaloids, flavonoids, and phenolic compounds are widely used in cosmeceutical formulations due to their potent antioxidant effects, contributing to skin protection and anti-aging benefits.[16]

The brightening toners (Toner 1, Toner 2, and Toner 4) demonstrated significantly higher antioxidant activity compared to

anti-acne toners (Toner 3 and Toner 5). This discrepancy is likely attributed to the inclusion of brightening agents such as licorice extract, niacinamide, and vitamin C derivatives, which have been extensively reported to exhibit strong radical-scavenging properties.[17] On the other hand, anti-acne toners may prioritize antibacterial and sebum-regulating ingredients such as salicylic acid and tea tree oil over antioxidant-rich compounds, leading to lower free radical scavenging potential.

The formulation techniques used in cosmetic products play a crucial role in determining their antioxidant effectiveness. The extraction method and solvent concentration significantly influence the potency of natural antioxidants in skincare formulations. In this study, the stronger antioxidant activity observed in Toner 1 and Toner 4 may be attributed to the presence of ethanol-extracted plant materials, which are known to enhance the bioavailability of active compounds.[18] Conversely, differences in solvent type and concentration in Toner 3 and Toner 5 could have contributed to their relatively weaker antioxidant performance. These findings align with previous studies indicating that polar solvents such as ethanol and methanol can extract higher concentrations of flavonoids and polyphenols, thereby increasing antioxidant capacity. Furthermore, the formulation process itself, including pH adjustment, emulsification techniques, and ingredient interactions, can also impact antioxidant stability and effectiveness. This suggests that optimizing formulation techniques are just as critical as selecting high-quality raw materials when developing antioxidant-rich cosmetic products.

Vitamin C, widely recognized for its potent antioxidant properties, served as a positive control in this study, yielding an IC50 value of 7.768 ppm—classifying it as a very strong antioxidant. This result aligns with[19], who emphasized that vitamin C is one of the most effective antioxidant agents in skincare, with benefits such as neutralizing free radicals, brightening skin, and reducing pigmentation. Given that an IC50 value below 50 ppm indicates a very strong antioxidant, the superior performance of vitamin C further solidifies its role as a benchmark for antioxidant efficacy in cosmetic formulations. Moreover, vitamin C's ability to enhance collagen synthesis and repair UV-induced skin damage makes it a highly desirable ingredient in anti-aging and brightening skincare products. However, despite its effectiveness, its application in formulations requires careful consideration due to stability challenges.

Stability remains a key concern in vitamin C-based formulations, as ascorbic acid is highly prone to oxidation when exposed to light, heat, and air. Pure vitamin C degrades rapidly, leading to reduced potency and potential discoloration in cosmetic products.[20] To address this issue, many skincare manufacturers incorporate stabilised vitamin C derivatives, such as ascorbyl glucoside and magnesium ascorbyl phosphate, which provide prolonged stability while maintaining antioxidant efficacy. These derivatives not only extend the shelf life of the product

but also offer enhanced skin penetration and reduced irritation, making them suitable for various skin types. Additionally, encapsulation techniques, such as liposomal and microemulsion delivery systems, have been developed to further protect vitamin C from degradation while improving its absorption into the skin.

From a market perspective, the growing awareness of skincare benefits has driven a significant rise in the demand for antioxidant-rich cosmetic products, particularly those containing natural plant extracts. Consumers are increasingly prioritising skincare formulations that provide protective and restorative effects against environmental stressors such as pollution and UV radiation. Local plants have become valuable ingredients in MSME beauty products, offering cost-effective and sustainable alternatives to synthetic antioxidants.[21] This trend aligns with the increasing preference for natural and organic skincare, which has become a dominant factor influencing purchasing decisions. In particular, formulations enriched with bioactive plant compounds such as flavonoids, polyphenols, and carotenoids have gained recognition for their ability to enhance skin health while maintaining safety and sustainability.

The shift toward natural antioxidants has also been reinforced by regulatory changes and consumer advocacy for cleaner beauty standards. Many cosmetic brands now emphasise transparency in ingredient sourcing and manufacturing practices, responding to consumer demand for chemical-free and eco-friendly formulations. This suggests that toners with strong antioxidant activity, such as Toner 1 and Toner 4, could have significant advantages in the competitive skincare industry, particularly among consumers seeking effective yet natural formulations. Additionally, the efficacy of plant-based antioxidants in preventing oxidative damage supports their role in anti-aging, brightening, and skin-repairing formulations, further driving interest in these products.

The behavioral aspect of consumer choices plays a crucial role in the selection and success of skincare products. Modern consumers are not only drawn to product claims but also rely on scientific evidence and personal testimonials to assess effectiveness. The growing preference for K-Beauty products among Indonesian women and found that key factors influencing product selection include high antioxidant claims, brightening effects, and overall skin health benefits. K-Beauty, known for its innovative formulations and incorporation of botanical extracts, has set new industry standards, making antioxidant-rich toners highly desirable. The findings from this study reinforce this trend, as toners marketed for brightening demonstrated better antioxidant performance compared to those formulated specifically for acne treatment.

This suggests that marketing strategies should emphasise not only the antioxidant efficacy of toners but also their additional benefits, such as hydration, anti-inflammatory properties, and long-term skin protection. Highlighting key ingredients, their sources, and scientific backing in promotional campaigns could

strengthen consumer trust and drive higher engagement. Furthermore, the increasing reliance on digital platforms for skincare education means that brands must optimise their communication strategies to provide clear, evidence-based claims regarding antioxidant benefits. The growing influence of social media, beauty influencers, and dermatological endorsements further contributes to consumer confidence in antioxidant-rich formulations, reinforcing the need for well-researched and transparently marketed skincare solutions.

The antioxidant activity of facial toners is crucial in protecting the skin from oxidative stress caused by free radicals, which are a major contributor to premature aging, inflammation, and skin disorders. Based on the IC50 values obtained through the DPPH method, toner samples were categorized into different antioxidant strength classifications, which serve as an important indicator of their effectiveness. Toner 1 (62.218 ppm) and Toner 4 (91.017 ppm) exhibited strong antioxidant activity (50-100 ppm), making them highly beneficial for preventing oxidative damage and promoting skin resilience. Meanwhile, Toner 2 (128 ppm) fell into the medium category (101-150 ppm), indicating a moderate level of free radical scavenging potential.

In contrast, Toner 3 (158.972 ppm) and Toner 5 (170.64 ppm) showed weaker antioxidant activity (150-200 ppm), suggesting that their formulations might lack sufficient concentrations of highly potent antioxidant compounds. This difference in efficacy can be attributed to variations in ingredient composition, formulation stability, and extraction methods used in developing each toner. Cosmeceutical formulations with well-optimised antioxidant properties play a vital role in neutralising oxidative damage, reducing hyperpigmentation, and maintaining overall skin health.[18]

Antioxidants play a fundamental role in modern skincare, offering protection against premature aging, hyperpigmentation, and environmental pollutants such as UV radiation and air pollution. These oxidative stressors contribute to skin damage, accelerating the breakdown of collagen and elastin, which are essential for maintaining skin firmness and elasticity. Strong antioxidants, such as flavonoids, polyphenols, and vitamin C derivatives, have been widely studied for their ability to neutralize free radicals and reduce oxidative stress, helping to maintain youthful and healthy skin.

Flavonol glycosides in skincare formulations significantly improved skin resilience against oxidative damage by stabilizing cell membranes and preventing lipid peroxidation.[15] This suggests that incorporating these compounds into toner formulations could provide enhanced protection, particularly in anti-aging and brightening products. Ethanol extracts from cucumber (*Cucumis sativus L.*) exhibited potent antioxidant activity, reinforcing the potential of plant-based ingredients in skincare.[18] The high water content and bioactive compounds found in cucumber make it an ideal ingredient for hydrating and soothing skin while

simultaneously offering antioxidant benefits.

Beyond traditional antioxidants, the skincare industry has seen an increasing interest in novel bioactive compounds derived from plants, marine organisms, and fermented extracts. Studies indicate that polyphenolic compounds from green tea, resveratrol from grapes, and astaxanthin from algae provide powerful antioxidant protection while delivering anti-inflammatory and skin-repairing properties. These emerging ingredients could be explored in future toner formulations to create even more effective skincare solutions.

While strong antioxidants offer significant protection, toner samples with medium antioxidant activity, such as Toner 2, still provide considerable skincare benefits. These formulations can serve as effective daily skincare products, particularly when combined with complementary ingredients that enhance their efficacy. Medium-strength antioxidants, including certain flavonoids, tannins, and carotenoids, may not provide the same level of free radical scavenging as stronger compounds but still contribute to skin health by reducing inflammation and promoting collagen synthesis.

To enhance the antioxidant potential of medium-strength formulations, incorporating additional bioactive ingredients can be beneficial. Alkaloid-based cosmeceuticals can augment the antioxidant capacity of skincare products, improving their overall effectiveness.[16] Alkaloids, found in plants such as Centella Asiatica, moringa, and licorice, not only offer antioxidant benefits but also exhibit wound-healing, antimicrobial, and skin-brightening properties. This suggests that combining medium-strength antioxidants with alkaloids or other synergistic compounds could significantly improve toner performance.

Furthermore, combining different antioxidant classes, such as vitamins, flavonoids, and peptides, can enhance skincare formulations through complementary mechanisms. Vitamin E, for instance, is a lipid-soluble antioxidant that works well with vitamin C, a water-soluble antioxidant, to provide comprehensive free radical protection. Additionally, incorporating hydrating agents like hyaluronic acid or glycerin can further improve toner efficacy by ensuring optimal skin hydration, which enhances the penetration and stability of antioxidants.

Beyond efficacy, consumer perception and market trends significantly influence product success. The behavioral political economy of beauty products in Indonesia, highlighting a growing preference for high-antioxidant formulations. This trend underscores the importance of scientific validation in skincare development to meet consumer expectations and regulatory standards. The sociocultural impact of skin whitening products, revealing how antioxidant-rich formulations play a role in consumer choices and perceptions of skin health.[20]

Formulation strategies should also consider the synergistic effects of multiple antioxidants to enhance toner effectiveness. Red spinach (*Amaranthus tricolor* L.) extract, when incorporated into cosmetic formulations, improved both

physical stability and antioxidant capacity.[17]

The formulation of face toners plays a crucial role in determining their antioxidant efficacy, as evidenced by the varying levels of antioxidant activity in brightening toners (Toner 1, Toner 2, and Toner 4) compared to anti-acne toners (Toner 3 and Toner 5). Brightening toners tend to exhibit superior antioxidant potential, primarily due to the presence of high concentrations of antioxidant-rich compounds such as vitamin C derivatives, polyphenols, flavonoids, and various plant-based extracts. On the other hand, anti-acne toners generally show weaker antioxidant properties, likely because their formulation prioritises anti-inflammatory and sebum-controlling agents rather than antioxidant efficacy.

Brightening toners frequently contain active ingredients like vitamin C, phenolic acids, and flavonoids, which are well-documented for their potent antioxidant effects. Flavonol glycosides derived from Prunus persica significantly enhance antioxidant activity, making them valuable additions to skincare formulations that aim to combat oxidative stress and improve skin luminosity.[15] Furthermore, the importance of alkaloids in cosmeceuticals, further supporting the efficacy of plant-based antioxidants in brightening toners.[16] The inclusion of niacinamide, licorice extract, and vitamin C derivatives in these formulations provides additional free-radical-scavenging benefits, which contribute to the overall effectiveness of brightening toners.

The incorporation of plant extracts in brightening toners is further supported by extensive research on natural antioxidants. The economic and sustainable advantages of utilizing local plant-based antioxidants in beauty product formulations.[21] They noted that natural antioxidants sourced from indigenous plants could enhance skincare efficacy while also promoting eco-friendly product development. Cucumber extract-based toners, particularly when processed using ethanol-based extractions, exhibit substantial antioxidant activity.[18]

In contrast, anti-acne toners are primarily formulated to reduce inflammation and control excess sebum rather than provide strong antioxidant effects. The formulation of acne-targeted skincare products, highlighting that ingredients such as salicylic acid, tea tree oil, and niacinamide are frequently included to mitigate acne-related inflammation and prevent bacterial proliferation.[20] While effective for acne-prone skin, these ingredients do not offer the same level of antioxidant protection as those commonly found in brightening toners.

Further insight into the formulation trade-offs between brightening and anti-acne toners, noting that while anti-acne products excel at reducing breakouts, they often fall short in terms of antioxidant defense.[19] This means that while acne-fighting toners effectively manage oil production and soothe irritation, they may leave the skin more vulnerable to environmental damage caused by oxidative stress. This suggests that incorporating additional antioxidant compounds into anti-acne toners could

enhance their protective benefits without compromising their primary function.

Another critical factor affecting antioxidant retention in skincare formulations is the choice of solvent extraction methods. Ethyl acetate fractions of okra seeds exhibited significant antioxidant activity, highlighting the impact of extraction techniques on antioxidant preservation.[14] This finding is particularly relevant for brightening toners, as advanced extraction processes are often employed to maintain the potency of natural antioxidants. The solvent type, extraction duration, and temperature conditions all contribute to the final antioxidant concentration in cosmetic formulations.

From a consumer perspective, the growing demand for antioxidant-rich skincare products, particularly those formulated with natural plant extracts, has reshaped market trends in the beauty industry. Aryaningtyas & Risyanti (2021) observed a substantial increase in the utilisation of locally sourced botanical ingredients in MSME beauty products, providing cost-effective and sustainable alternatives to synthetic antioxidants. This shift suggests that toners with strong antioxidant activity, such as Toner 1 and Toner 4, hold a competitive advantage in the skincare industry, especially among consumers who prioritize natural, plant-based formulations.

Consumer behavior also plays a significant role in product selection. Purchasing trends among Indonesian women and found that consumers are increasingly drawn to skincare products boasting high antioxidant benefits and skin-brightening claims. This aligns with the results of this study, where brightening toners demonstrated superior antioxidant performance compared to their anti-acne counterparts. As a result, marketing strategies emphasizing antioxidant efficacy and skin-brightening benefits could strongly influence consumer purchasing decisions.

The antioxidant properties of facial toners play a fundamental role in shielding the skin from oxidative stress caused by environmental aggressors. Based on the IC50 values obtained through the DPPH method, toner samples can be classified into different antioxidant strength categories. Toner 1 (62.218 ppm) and Toner 4 (91.017 ppm) exhibited strong antioxidant activity (50-100 ppm), while Toner 2 (128 ppm) fell into the medium category (101-150 ppm). Conversely, Toner 3 (158.972 ppm) and Toner 5 (170.64 ppm) displayed weak antioxidant activity (150-200 ppm). These classifications are consistent with previous research on cosmeceutical formulations and the role of antioxidants in skincare (18).

Strong antioxidants in skincare formulations offer enhanced protection against premature aging, hyperpigmentation, and environmental pollutants. Flavonol glycosides in skincare formulations significantly improved skin resilience against oxidative stress.[15] Ethanol extracts from cucumber (*Cucumis sativus* L.) exhibited potent antioxidant activity, reinforcing the potential of plant-based ingredients in toner formulations.[18] Additional complementary ingredients may be necessary to optimise the effectiveness of toners with medium

antioxidant activity, such as Toner 2. Alom et al. (2024) highlighted that alkaloid-based cosmeceuticals can enhance the antioxidant capacity of skincare products, improving their overall efficacy. Furthermore, The economic potential of utilising indigenous botanical resources for developing antioxidant-rich cosmetics, which could further improve the formulation of mid-range antioxidant toners.[21]

The relatively weak antioxidant activity observed in Toner 3 and Toner 5 suggests a need for reformulation to enhance their protective benefits. Insufficient antioxidant content in daily skincare formulations may result in reduced skin protection and increased susceptibility to environmental stressors.[19] Moreover, Ethyl acetate fractions from okra seeds exhibited moderate antioxidant properties, suggesting alternative botanical sources that could be incorporated into toner formulations to strengthen their antioxidant potential.[14]

The growing demand for effective brightening toners is driven by evolving consumer perceptions and industry trends, particularly in the wake of the pandemic. The behavioral political economy of K-beauty and K-health products, emphasising that skincare preferences have undergone significant changes in response to increased awareness of long-term skin health. The pandemic accelerated a shift toward skincare formulations that prioritise natural antioxidants, recognising their role in protecting the skin from environmental stressors, premature aging, and hyperpigmentation. This transition aligns with the growing reliance on key antioxidant ingredients such as vitamin C, polyphenols, and flavonoid-enriched toners, which have demonstrated superior efficacy in maintaining skin resilience.

Additionally, the increasing consumer demand for natural, plant-based skincare solutions has driven innovations in toner formulations. As a result, many brightening toners are now formulated with botanical extracts rich in phenolic compounds and flavonoids, reinforcing their antioxidant potential. The preference for clean beauty products, which eschew synthetic ingredients in favor of naturally derived compounds, has further propelled the popularity of brightening toners. Research suggests that consumers are more likely to invest in products that offer scientifically supported benefits, particularly those that emphasize both efficacy and sustainability. The increasing accessibility of research-backed skincare information through digital platforms and social media has empowered consumers to make informed decisions, contributing to a steady rise in demand for antioxidant-rich brightening toners.

The potential of red spinach leaf ethanol extract to enhance antioxidant activity in facial serums.[17] Their findings suggest that incorporating potent plant-based antioxidants into brightening toners can further optimise their efficacy by increasing free radical scavenging activity. Given that oxidative stress is a leading cause of premature skin aging, hyperpigmentation, and loss of elasticity, the presence of high-potency natural antioxidants in brightening toners plays a

crucial role in maintaining skin health. Such findings underscore the importance of ingredient selection in ensuring the superior performance of antioxidant-rich skincare products. Beyond aesthetic improvements, these ingredients help to fortify the skin barrier, enhancing resilience against daily environmental aggressors such as UV radiation and pollution. The effectiveness of these formulations is largely determined by the quality and concentration of the antioxidant compounds used, further highlighting the importance of rigorous formulation processes in skincare development.

The results of this study highlight the crucial role of toner formulation in determining antioxidant potential. Brightening toners, formulated with high concentrations of antioxidant-rich ingredients such as vitamin C derivatives, polyphenols, and plant extracts, exhibit significantly stronger antioxidant activity. These findings align with[15], identified that flavonol glycosides in plant-based formulations enhance free radical scavenging abilities, thereby improving skin protection. The inclusion of high-potency antioxidants in these formulations contributes to their effectiveness in reducing oxidative damage and preventing skin dullness. Furthermore, cucumber extract-based face toners exhibit potent antioxidant effects due to the presence of phenolic compounds.[18] Such studies emphasise the importance of selecting antioxidant sources with proven efficacy, ensuring that brightening toners deliver tangible skin benefits.

Consumers seeking enhanced antioxidant protection should prioritise brightening toners, as they provide superior defense against oxidative stress, thereby contributing to long-term skin health improvements. These toners not only neutralise free radicals but also aid in skin repair and rejuvenation, reducing the appearance of fine lines, hyperpigmentation, and dullness. The inclusion of additional active ingredients, such as hyaluronic acid and peptides, can further enhance the hydration and anti-aging benefits of these formulations, making them a comprehensive solution for skincare concerns related to environmental damage.

On the other hand, anti-acne toners, despite their effectiveness in controlling sebum production and reducing inflammation, generally exhibit lower antioxidant activity. This is primarily due to their formulation focus, which prioritises antibacterial and anti-inflammatory agents rather than antioxidant compounds. While acne treatments often include active ingredients such as salicylic acid and benzoyl peroxide, these substances may not contribute significantly to neutralising free radicals.[19] As a result, anti-acne toners are more effective in addressing acne-related concerns rather than providing long-term skin protection against oxidative stress.

Additionally,[16] discuss the role of alkaloids in cosmeceutical applications, emphasising that while some alkaloids exhibit antimicrobial properties beneficial for acne-prone skin, their antioxidant potential is comparatively weaker. This

indicates that while anti-acne toners may successfully target breakouts and excess oil production, they may not provide the same level of overall skin protection as brightening toners. Consumers with acne-prone skin who are also concerned about oxidative stress may benefit from a skincare regimen that incorporates both acne-targeting ingredients and antioxidant-rich products to achieve a more balanced and comprehensive skincare routine.

These findings have important implications for consumer choices in skincare. The increasing demand for natural and effective cosmetic products, as highlighted by[21], underscores the need for awareness regarding product formulation. Further discuss the cultural preference for skin-whitening products, which has led to the proliferation of brightening toners enriched with powerful antioxidants.[20] The widespread popularity of brightening toners in markets such as East Asia and Southeast Asia suggests that consumer preferences are increasingly aligned with scientifically backed formulations that promise both brightening and protective benefits.

Additionally, the impact of post-pandemic beauty trends, wherein consumers are increasingly drawn to skincare products with long-term benefits rather than quick-fix solutions. As a result, brands that emphasise the efficacy of their formulations through clinical studies and scientific validation are more likely to gain consumer trust and loyalty. Given these trends, individuals should make informed decisions when selecting toners based on their skincare needs—whether prioritising antioxidant protection through brightening toners or acne management through specialised anti-acne formulations.

CONCLUSIONS

The five toner samples have antioxidant activity in both toners with anti-acne and brightening types, and of the five samples and ascorbic acid, the best IC_{50} value is ascorbic acid (vitamin C) as a positive control with an IC_{50} value of 7.768 ppm and is categorised as very strong. Toner 1 has an IC_{50} value of 62.218 ppm and is categorised as a strong antioxidant. Toner 2 has an IC_{50} value of 128 ppm is categorised as a medium antioxidant, toner 3 IC_{50} value of 158.972 ppm is categorised as a weak antioxidant, toner 4 IC_{50} value of 91.017 ppm is categorised as a strong antioxidant. In contrast, the one with the lowest IC_{50} value is toner 5, which has an IC_{50} value of 170.64 ppm and is included in the weak antioxidant category.

CONFLICT OF INTEREST

The authors have no conflicts of interest regarding this investigation.

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