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Research

Natural Photoprotection in Tropical Indonesia: In Vitro Sunscreen Activity of Kleinhovia Hospita Leaf Extract

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ABSTRACT

Excessive exposure to ultraviolet (UV) radiation is associated with various adverse skin effects, including erythema, hyperpigmentation, premature aging, and skin cancer, highlighting the need for effective photoprotective agents. Growing interest in natural-based sunscreen products has encouraged the investigation of plant-derived compounds with potential UV-protective activity. Paliasa (*Kleinhovia hospita Linn.*) leaves contain bioactive constituents, particularly flavonoids and polyphenols, which may contribute to photoprotective effects. This study aimed to evaluate the potential of paliasa leaf extract as a natural sunscreen using an in vitro approach. Sunscreen activity was assessed by determining the Sun Protection Factor (SPF), percentage of erythema transmission (%Te), and percentage of pigmentation transmission (%Tp) at extract concentrations of 100, 300, 500, 700, and 900 ppm. The results showed a concentration-dependent increase in SPF values, ranging from 22.40 at 100 ppm to 42.62 at 900 ppm. The %Te values ranged from 0.64% to 0.27%, indicating a total-block category across all tested concentrations. Similarly, %Tp values ranged from 0.57% to 0.25% and were also classified within the total-block category. These findings demonstrate that paliasa leaf extract exhibits substantial in vitro photoprotective activity against both UVB- and UVA-associated effects. Therefore, K. hospita leaf extract has promising potential as a natural active ingredient for the development of sunscreen formulations.

1. Introduction

Indonesia is a tropical country with relatively high levels of solar radiation throughout the year, resulting in continuous exposure of the population to ultraviolet (UV) radiation. Although human skin possesses intrinsic defense mechanisms, including epidermal thickening and increased

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pigmentation, these protective responses are limited when exposure to UV radiation becomes excessive. Prolonged or intense UV exposure may increase the production of reactive oxygen species and induce oxidative stress in cutaneous tissues, thereby contributing to various adverse effects, including erythema and other forms of skin damage (Desti I et al., 2020). From a public health perspective, persistent exposure to UV radiation is particularly relevant in tropical regions because cumulative exposure may contribute to both acute and chronic dermatological disorders.

Sunburn is an acute inflammatory skin response characterized by erythema and, in more severe cases, vesicle formation following excessive exposure to UV radiation. Ultraviolet radiation may originate from sunlight, phototherapy lamps, and other artificial sources. Mild sunburn generally resolves spontaneously; however, severe cases, although uncommon, may be associated with dehydration, secondary infection, and considerable discomfort. More importantly, repeated episodes of sunburn and cumulative UV exposure are associated with an increased risk of long-term skin damage, including skin cancer (Roy et al., 2018). These consequences highlight the importance of preventive strategies aimed at reducing excessive UV exposure and strengthening skin photoprotection.

The skin naturally protects itself against the harmful effects of UV radiation through several mechanisms, including sweating, melanin production, and thickening of the stratum corneum. However, these physiological defenses may be insufficient when the intensity or duration of UV exposure exceeds the skin's protective capacity. Various environmental factors may also progressively impair skin integrity and increase susceptibility to UV-induced damage. Therefore, additional protection is required, particularly through the appropriate use of sunscreen preparations (Desti I et al., 2020).

Sunscreens are topical products designed to protect the skin by reducing the penetration and harmful effects of UV radiation. They are commercially available in various dosage forms, including lotions, creams, ointments, gels, and sprays. Sunscreen products are generally labeled with a Sun Protection Factor (SPF), which indicates their relative capacity to protect the skin against UV-induced erythema, particularly that caused by UVB radiation. SPF values commonly vary among products and provide an indication of the degree of photoprotection when the sunscreen is used appropriately (Isfardiyana et al., 2014). The effectiveness of sunscreen preparations is therefore an important consideration in preventing acute skin responses and reducing cumulative UV-related damage.

The photoprotective capacity of sunscreen materials can be evaluated using in vitro methods. Two major approaches are commonly applied. The first involves measuring the absorption or transmission of UV radiation through a sunscreen layer applied to quartz plates or biomembranes. The second involves spectrophotometric analysis of the UV absorption characteristics of sunscreen samples after appropriate dilution (Adawiyah et al., 2019). In vitro approaches are frequently used in preliminary sunscreen research because they are relatively practical, reproducible, and do not expose human participants directly to potentially harmful UV radiation. UV–visible spectrophotometry can provide an initial assessment of the ability of a substance to absorb or attenuate UV radiation and, consequently, its potential for use as a photoprotective agent (Adawiyah et al., 2019).

Unprotected UV exposure may cause both erythema and pigmentation. Erythema is primarily associated with UVB-induced inflammatory responses and cellular DNA damage, whereas pigmentation represents an adaptive response to UV exposure involving increased melanin production. UVA radiation plays an important role in persistent pigmentation and penetrates more deeply into the skin, contributing to photoaging and oxidative damage. Repeated exposure to UV radiation may also contribute to pigmentation disorders, including melasma and hyperpigmentation, reinforcing the importance of adequate photoprotection in populations with high levels of sun exposure (Ahmad, 2023).

Excessive UV exposure is also associated with premature skin aging, sunburn, and an increased risk of skin cancer. These health concerns have contributed to growing demand for sunscreen products that are safe, effective, and environmentally sustainable. However, many commercially available sunscreens rely on synthetic UV-filtering compounds, some of which have raised concerns regarding skin tolerability and potential environmental effects, particularly in aquatic ecosystems. Consequently, increasing scientific attention has been directed toward identifying natural bioactive compounds that may serve as alternative or complementary sunscreen ingredients (Desti I et al., 2020). This approach is also relevant to broader public health and sustainability priorities, particularly Sustainable Development Goal 3 on good health and well-being and Sustainable Development Goal 12 on responsible consumption and production.

One potentially valuable natural source of photoprotective compounds is paliasa (*Kleinhovia hospita* Linn.), a tropical plant distributed across several regions of Indonesia. The species belongs to the family Sterculiaceae and has long been used in traditional medicine, particularly in South Sulawesi. Paliasa leaves have traditionally been used for several health purposes, including the management of jaundice, hypercholesterolemia, hypertension, diabetes, and liver-related disorders. Phytochemical investigations have identified several classes of compounds in *K. hospita*, including cyanogenic compounds, alkaloids, proanthocyanidins, cyanidins, flavonoids, kaempferol, quercetin, and saponins (Hasanuddin & Andini, 2017).

Previous studies have further demonstrated the phytochemical richness of paliasa leaves. Ethanol extracts of *K. hospita* leaves have been reported to contain flavonoids, alkaloids, saponins, steroids, and tannins, whereas triterpenoids were not detected (Desiana et al., 2018). Another phytochemical screening study reported that paliasa leaves contained alkaloids at 2.83%, flavonoids at 19.78%, and saponins at 14.23% (Suryani et al., 2017). The relatively high flavonoid content is particularly important because flavonoids are known for their antioxidant and UV-absorbing properties, which may contribute to their potential use as natural photoprotective agents.

Flavonoids are among the major phytochemical constituents considered relevant to sunscreen activity. Their conjugated molecular structures contain chromophoric groups capable of absorbing electromagnetic radiation within the UVA and UVB regions, thereby potentially reducing the intensity of UV radiation reaching the skin. In addition, their antioxidant activity may contribute to the mitigation of oxidative stress induced by UV exposure. Ethanol at a concentration of 70% is commonly used as an extraction solvent for plant-derived flavonoids because it can effectively extract a broad range of polar and semipolar bioactive compounds. This solvent has consequently

been used in studies examining flavonoid content and the sunscreen potential of botanical extracts (Sari et al., 2022).

Despite evidence demonstrating the presence of flavonoids and other bioactive constituents in paliasa leaves, information regarding their quantitative in vitro sunscreen activity remains limited. In particular, evaluation based simultaneously on SPF, erythema transmission, and pigmentation transmission across different extract concentrations has not been sufficiently characterized. Therefore, this study aimed to evaluate the in vitro sunscreen potential of paliasa (*Kleinhovia hospita* Linn.) leaf extract by determining its Sun Protection Factor, percentage of erythema transmission, and percentage of pigmentation transmission at different concentrations. The findings are expected to provide scientific evidence supporting the potential development of paliasa leaf extract as a natural photoprotective ingredient for sunscreen formulations.

2. Method

This study employed a quantitative laboratory experimental design to evaluate the in vitro sunscreen potential of paliasa (*Kleinhovia hospita* Linn.) leaf extract. The photoprotective activity of the extract was assessed using UV–Vis spectrophotometry by determining the Sun Protection Factor (SPF), percentage of erythema transmission (%Te), and percentage of pigmentation transmission (%Tp) at different extract concentrations.

The study was conducted at the Pharmaceutical Biology Laboratory, Pharmaceutics Laboratory, and Pharmaceutical Chemistry Laboratory, Faculty of Medicine and Health Sciences, Alauddin Islamic University of Makassar, Indonesia. The research was carried out from April to June 2025.

The primary study material was paliasa (*Kleinhovia hospita* Linn.) leaves. The reagents used included 70% ethanol as the extraction solvent and analytical-grade ethanol as the solvent for preparation of test solutions and spectrophotometric analysis. Additional materials included aluminum foil and filter paper.

The laboratory equipment used included glass stirring rods, beakers, amber bottles, glass funnels, porcelain evaporating dishes, crucible tongs, cuvettes, micropipettes, a rotary evaporator, spatulas, maceration equipment, a water bath, a UV–Vis spectrophotometer, an analytical balance, and glass vials.

Collected paliasa leaves were washed thoroughly under running water to remove adhering impurities. The leaves were subsequently cut into small pieces and dried in a drying cabinet. After complete drying, the plant material was ground into powder to obtain dried crude leaf material. The powdered sample was then weighed before extraction, following the general preparation procedure described by Auliasari and Siarumtias (2020).

Paliasa leaf extract was prepared by maceration. A total of 500 g of dried leaf powder was immersed in 15 L of 70% ethanol for 3 × 24 h in a closed container protected from direct sunlight. The mixture was stirred intermittently to improve contact between the plant material and extraction solvent. The liquid extract was separated from the plant residue and subsequently concentrated using a rotary evaporator until a viscous extract was obtained (Cahyani & Widiastuti, 2020).

The percentage extraction yield was calculated using the following equation:

$$\text{Extraction yield (\%)} = \frac{\text{weight of concentrated extract (g)}}{\text{weight of dried plant material (g)}} \times 100$$

A stock solution at a concentration of 1000 ppm was prepared by accurately weighing 0.025 g of the concentrated paliasa leaf extract and dissolving it in analytical-grade ethanol to a final volume of 25 mL. The stock solution was subsequently diluted to obtain test concentrations of 100, 300, 500, 700, and 900 ppm. Analytical-grade ethanol was used as the blank during spectrophotometric measurements.

The SPF values were determined using UV–Vis spectrophotometry. The absorbance of each test solution was measured over the wavelength range of 290–320 nm at 5-nm intervals. Each concentration was measured in triplicate. SPF values were calculated using the Mansur equation (Cahyani et al., 2021; Rinatha et al., 2023):

$$\text{SPF} = CF \times \sum_{\lambda=290}^{320} EE(\lambda) \times I(\lambda) \times Abs(\lambda)$$

where (CF/lambda)) is the erythemal effect spectrum at wavelength (EE) is the solar intensity spectrum, (Abs) is the measured absorbance of the sample, and (CF) is the correction factor, with a value of 10.

The mean SPF value from three measurements was used to characterize the photoprotective activity of each extract concentration.

The percentage of erythema transmission (%Te) was determined from spectrophotometric transmittance values within the erythemogenic wavelength range. Measurements were evaluated at 5-nm intervals between 292.5 and 317.5 nm. For each wavelength, the transmittance value ((T)) was multiplied by the corresponding erythemal flux ((Fe)).

The total transmitted erythemal flux was calculated as:

$$E_e = \sum (T \times F_e)$$

The percentage of erythema transmission was calculated as:

$$\%T_e = \frac{\sum (T \times F_e)}{\sum F_e} \times 100$$

where (T) represents sample transmittance, (Fe) represents erythemal flux, and (Ee) represents the total erythemal flux transmitted through the test solution. Lower ∑Te values indicate greater attenuation of radiation associated with UV-induced erythema.

The percentage of pigmentation transmission (%Tp) was determined from transmittance measurements over the wavelength range of 322.5–372.5 nm at 5-nm intervals. For each wavelength, the transmittance value ((T)) was multiplied by the corresponding pigmentation flux ((Fp)).

The total transmitted pigmentation flux was calculated as:

$$E_p = \sum (T \times F_p)$$

The percentage of pigmentation transmission was calculated using:

$$\%T_p = \frac{\sum(T \times F_p)}{\sum F_p} \times 100$$

where (T) represents sample transmittance, (Fp) represents pigmentation flux, and (Ep) represents the total pigmentation-associated UV flux transmitted through the sample (Susanti et al., 2019). Lower %Tp values indicate a greater ability to attenuate radiation associated with UV-induced pigmentation.

The primary data consisted of absorbance and transmittance values obtained from UV–Vis spectrophotometric measurements. All SPF measurements were performed in triplicate. Absorbance data were used to calculate SPF, whereas transmittance data were used to determine %Te and %Tp. The results were analyzed descriptively by comparing the values obtained at different extract concentrations and examining the concentration-dependent pattern of photoprotective activity.

The findings were presented as extraction yield, mean SPF values, percentage erythema transmission, and percentage pigmentation transmission. Higher SPF values and lower %Te and %Tp values were interpreted as indicating stronger in vitro photoprotective activity.

The study consisted exclusively of laboratory-based analysis of plant extract and did not involve human participants, human biological specimens, or experimental animals. Therefore, informed consent was not applicable. The study procedures included preparation of plant material, extraction, preparation of test concentrations, spectrophotometric measurement, calculation of SPF, %Te, and %Tp, and descriptive interpretation of the resulting photoprotective parameters.

3. Results & Discussion

Maceration of 500 g of dried paliasa (*Kleinhovia hospita* Linn.) leaf powder with 70% ethanol produced 115.6 g of concentrated extract, corresponding to an extraction yield of 23.12% (Table 1). The relatively high recovery indicates that hydroethanolic maceration was able to extract a substantial proportion of soluble constituents from the dried leaves. The 23.12% extraction yield provided sufficient concentrated extract for subsequent preparation of the 1000-ppm stock solution and serial dilution into five test concentrations. The extraction procedure therefore generated an adequate amount of material for evaluation of concentration-dependent photoprotective activity.

Paliasa leaf extract exhibited measurable sunscreen activity at all tested concentrations. The SPF value increased progressively from 22.40 at 100 ppm to 36.05 at 300 ppm, 39.73 at 500 ppm, 41.29 at 700 ppm, and 42.62 at 900 ppm (Table 2). Based on the classification applied in this study, the 100-ppm concentration demonstrated moderate protection, whereas concentrations of 300–900 ppm demonstrated high protection. The largest increase in SPF occurred between 100 and 300 ppm, with an increase of 13.65 SPF units. Further increases were smaller, reaching 3.68 units between 300 and 500 ppm, 1.56 units between 500 and 700 ppm, and 1.33 units between 700 and 900 ppm. This pattern indicates that photoprotective activity increased with concentration but tended to rise more gradually at the higher concentration range. Overall, the findings showed a positive concentration-response relationship between paliasa leaf extract concentration and SPF value. The lowest

concentration already produced an SPF above 20, while all concentrations of 300 ppm or greater produced SPF values above 30. The maximum SPF value was observed at 900 ppm, indicating the strongest UVB-related photoprotective activity among the concentrations evaluated.

The greatest reduction in %Te occurred between 100 and 300 ppm, when erythema transmission decreased by 0.28 percentage points. At concentrations above 300 ppm, additional reductions were smaller but remained consistent. These findings indicate that even the lowest concentration substantially reduced transmission of erythemogenic radiation, while increasing concentration further enhanced this effect.

An inverse concentration-response pattern was observed for %Te. Increasing paliasa leaf extract concentration was associated with progressively lower erythema transmission, with the lowest value observed at 900 ppm. This trend was the reverse of the SPF pattern and therefore provided complementary evidence of increasing UVB-related photoprotective activity at higher concentrations. The percentage of pigmentation transmission (%Tp) also decreased with increasing concentration of paliasa leaf extract. The %Tp values were 0.57% at 100 ppm, 0.35% at 300 ppm, 0.29% at 500 ppm, 0.26% at 700 ppm, and 0.25% at 900 ppm (Table 4). All tested concentrations produced %Tp values below 1% and were categorized as total block.

The reduction in %Tp was most pronounced between 100 and 300 ppm, decreasing by 0.22 percentage points. A gradual decline continued at higher concentrations. The consistently low %Tp values indicate strong attenuation of pigmentation-associated UV radiation across the entire concentration range tested. The three photoprotective parameters showed a consistent pattern. As extract concentration increased from 100 to 900 ppm, SPF increased from 22.40 to 42.62, while %Te decreased from 0.64% to 0.27% and %Tp decreased from 0.57% to 0.25%. The strongest overall in vitro sunscreen activity was therefore observed at 900 ppm. The concordant increase in SPF and decrease in both transmission parameters provides complementary evidence that paliasa leaf extract possesses concentration-dependent photoprotective properties.

The present study demonstrated that 70% ethanolic maceration of paliasa leaves produced an extraction yield of 23.12%, indicating efficient recovery of soluble phytochemical constituents from the plant material. This finding is relevant because extraction efficiency influences the concentration and diversity of secondary metabolites subsequently available for biological activity. The use of maceration was appropriate for this study because the technique does not require intensive heating and may therefore reduce degradation of thermolabile compounds, including certain flavonoids (Riwanti et al., 2020).

Hydroethanolic solvents are widely used to recover phenolic compounds, flavonoids, alkaloids, terpenoids, and other secondary metabolites from medicinal plants because the combination of ethanol and water can facilitate penetration of plant tissues and solubilization of compounds with different polarities (Andriani & Murstiwi, 2020). Previous phytochemical studies of *K. hospita* have identified flavonoids, alkaloids, saponins, steroids, tannins, kaempferol, quercetin, and other phenolic constituents (Hasanuddin & Andini, 2017; Desiana et al., 2018). Suryani et al. (2017) additionally reported a relatively substantial flavonoid content in paliasa leaves. The current extraction findings therefore provide a practical basis for subsequent photoprotection testing

because the selected extraction procedure is compatible with recovery of compounds previously associated with UV absorption.

From a product-development perspective, an adequate extraction yield is advantageous because it may improve the feasibility of producing sufficient botanical material for further formulation and standardization studies. Nevertheless, extraction yield does not directly indicate the concentration of the compounds responsible for sunscreen activity. A crude extract may contain both active and inactive constituents, and variation in plant origin, harvesting conditions, processing, and solvent composition can affect phytochemical composition. Future studies should therefore quantify total flavonoid and total phenolic contents and identify major compounds using appropriate chromatographic methods to determine which constituents are most strongly associated with the observed photoprotective activity.

The principal finding of this study was that paliasa leaf extract exhibited concentration-dependent in vitro sunscreen activity, with SPF values increasing from 22.40 at 100 ppm to 42.62 at 900 ppm. This finding directly answers the research question and demonstrates that paliasa leaves possess measurable potential as a botanical photoprotective material. The research objective was therefore achieved. The marked increase between 100 and 300 ppm followed by smaller increases at higher concentrations suggests that the relationship between concentration and photoprotection may become progressively less pronounced as the concentration rises.

The observed SPF activity can plausibly be attributed, at least in part, to the presence of flavonoids and other phenolic compounds in paliasa leaves. Flavonoids contain conjugated aromatic structures that can act as chromophores and absorb UV radiation. Following absorption, electronic excitation occurs and part of the absorbed energy may subsequently be dissipated in less harmful forms. This process can reduce the amount of UV radiation available to interact with skin structures. Flavonoids may also contribute indirectly through antioxidant and anti-inflammatory activity, including modulation of pathways associated with UV-induced inflammation (Amini et al., 2020).

The concentration-dependent increase in SPF observed in this study is consistent with Bani et al. (2024), who reported that botanical extracts rich in flavonoids and polyphenols may exhibit increasing UV-protective activity as extract concentration rises. This relationship is scientifically plausible because a higher concentration increases the abundance of UV-absorbing molecules within the optical pathway, thereby increasing absorbance and calculated SPF.

Previous studies have similarly emphasized the relevance of flavonoids as natural sunscreen candidates because their conjugated structures permit absorption in UV regions (Sari et al., 2022). The present study extends this evidence specifically to *K. hospita*, a medicinal plant that has been more extensively investigated for its phytochemical and traditional therapeutic properties than for its quantitative sunscreen activity. An important advantage of the current study is that SPF was not assessed in isolation but was interpreted together with erythema and pigmentation transmission, providing a broader preliminary evaluation of photoprotection.

The SPF values should, however, not be interpreted as a direct measure of the number of minutes that an individual can safely remain in sunlight. SPF represents relative protection against UVB-induced erythema under standardized testing conditions. Real-world protection depends on formulation properties, applied amount, reapplication, sweating, water exposure, photostability,

and user behavior. Therefore, although the results demonstrate promising activity, direct claims regarding the duration of protection on human skin cannot be made from the present in vitro findings.

The findings have potential relevance for public health in tropical settings such as Indonesia, where substantial year-round solar exposure may increase cumulative UV exposure in outdoor workers, students, farmers, fishermen, and other population groups. Effective photoprotection is an important component of preventing acute sunburn and reducing long-term UV-related skin damage. Identification of locally available plants with photoprotective properties may broaden the range of potential materials available for sunscreen development and support investigation of affordable, culturally familiar, and locally sourced products.

The potential value of *K. hospita* is particularly relevant because it is already known within traditional medicinal practices in South Sulawesi. However, traditional use should not be interpreted as evidence of dermatological safety. Before paliasa extract can be considered for population-level use, its safety, standardization, formulation stability, and effectiveness on human skin must be established through validated studies.

The findings provide preliminary scientific support for investigating paliasa as a locally sourced botanical ingredient for photoprotective products. This is relevant to public health because UV-related skin damage is largely preventable, yet effective prevention depends on access, adherence, product acceptability, and appropriate risk communication. The development of locally derived sunscreen ingredients could potentially support innovation in affordable and sustainable preventive products, particularly for communities with frequent occupational or recreational sun exposure.

Future studies should characterize the chemical profile of paliasa extract, quantify total phenolic and flavonoid contents, and examine correlations between individual phytochemicals and photoprotective outcomes. Comparative testing against established UV filters should also be conducted. Subsequent research should evaluate photostability, antioxidant activity, cytotoxicity, dermal irritation, sensitization, and compatibility with topical formulations such as creams, lotions, or gels. Validated broad-spectrum testing and, where ethically appropriate, in vivo studies should then be performed to determine whether the in vitro activity translates into effective protection on human skin.

Overall, the findings indicate that paliasa (*Kleinhovia hospita* Linn.) leaf extract is a promising candidate for further investigation as a natural photoprotective ingredient. Its concentration-dependent SPF activity and consistently low erythema and pigmentation transmission values provide a scientific basis for continued development. From a public health perspective, such research may contribute to broader strategies aimed at preventing UV-related skin damage while promoting responsible utilization of locally available botanical resources.

4. Conclusion

Paliasa (*Kleinhovia hospita* Linn.) leaf extract demonstrated promising in vitro photoprotective activity, as indicated by a concentration-dependent increase in Sun Protection Factor and consistently low erythema and pigmentation transmission values. The SPF increased from 22.40 at 100 ppm to 42.62 at 900 ppm, representing moderate to high protection, while %Te decreased from

0.64% to 0.27% and %Tp from 0.57% to 0.25%. All %Te and %Tp values were below 1% and classified as total block according to the criteria applied in this study. These findings indicate that *K. hospita* leaf extract has the capacity to attenuate UV radiation associated with erythema and pigmentation and therefore has potential as a botanical ingredient for sunscreen development.

From a public health perspective, the study provides preliminary evidence supporting the exploration of locally available medicinal plants as potential resources for photoprotection, particularly in tropical populations with substantial year-round UV exposure. The findings expand current knowledge on the potential applications of *K. hospita* beyond its traditional medicinal use and support further development of plant-based photoprotective products. However, the present evidence is limited to in vitro spectrophotometric testing. Future studies should include phytochemical standardization, identification of the principal UV-absorbing compounds, photostability and toxicity assessments, formulation development, comparison with established sunscreen agents, and validated in vivo evaluation. Such investigations are required to determine whether the observed laboratory activity can be translated into safe, effective, affordable, and environmentally sustainable sunscreen products for broader public health use.

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