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RESEARCH ARTICLE

Development, Phytochemical Screening, and Evaluation of Herbal Sunscreen Cream Containing *Musa paradisiaca* L. Extract

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Abstract: Exposure to solar ultraviolet radiation is one of the primary environmental factors for dermatological conditions, including actinic keratosis, premature photoaging, and various forms of cutaneous malignancies. While synthetic ultraviolet filters are widely utilized, growing concerns regarding their potential for systemic absorption and environmental persistence have shifted scientific focus toward botanical alternatives rich in secondary metabolites. The present research involves the formulation of a topical herbal sunscreen utilizing an extract derived from the peels of *Musa paradisiaca* L. (Kepok banana). The formulation was developed by utilizing the banana peel extract into an emulsion base enriched with natural lipids, including *Cocos nucifera, Prunus dulcis*, and *Vitellaria paradoxa*. Physicochemical characterization of the prepared herbal cream showed optimal pH compatibility with the human acid mantle, ranging between 5.82 and 6.5, alongside high spreadability and structural homogeneity. Spectrophotometric analysis revealed a Sun Protection Factor (SPF) value of 36.4, indicating significant efficacy in attenuating UVB-induced damage. The presence of specific flavonoids and phenolic compounds in the extract suggests a dual mechanism of action involving both physical UV absorption and biochemical neutralization of reactive oxygen species. The stable organoleptic properties and lack of phase separation over accelerated stability cycles suggest that botanical extracts from *Musa paradisiaca* is a viable, efficacious, and sustainable source for the development of high-performance photoprotective cosmeceuticals.

Keywords: *Musa paradisiaca*; Sun Protection Factor; Flavonoids; Photoprotection; Herbal Cosmeceuticals.

1. Introduction

The human skin functions as the primary biological interface between internal physiological systems and the external environment, providing a sophisticated barrier against mechanical trauma, pathogenic infiltration, and chemical pollutants [1]. Structurally, it is organized into the epidermis, dermis, and hypodermis, each contributing to the maintenance of homeostasis through thermoregulation, sensory perception, and immune surveillance [2]. However, the structural integrity of this barrier is constantly challenged by solar radiation, specifically the ultraviolet (UV) spectrum. UV radiation is classified into three distinct bands: UVA (315–400 nm), UVB (280–315 nm), and UVC (100–280 nm). While UVC is largely attenuated by the stratospheric ozone layer, UVA and UVB penetrate the atmosphere and exert profound effects on cutaneous biology [3].

UVA radiation, characterized by its longer wavelength, penetrates deep into the dermal layers, where it facilitates the generation of reactive oxygen species (ROS). These free radicals induce oxidative damage to fibroblasts and extracellular matrix components, such as collagen and elastin, leading to the clinical manifestations of photoaging [4]. In contrast, UVB radiation is primarily absorbed by the epidermis and is the chief causative agent for erythema (sunburn). More critically, UVB induces direct DNA damage through the formation of cyclobutane pyrimidine dimers (CPDs), which, if unrepaired, lead to mutagenic transformations and the subsequent development of basal cell carcinoma and melanoma [5].

To avoid these risks, the application of topical sunscreens has become a fundamental dermatological recommendation. Conventional formulations typically rely on chemical filters like oxybenzone or physical blockers like titanium dioxide. However, synthetic organic filters have been associated with contact dermatitis, hormonal disruption, and bioaccumulation in marine ecosystems [6]. This has led to the exploration of botanical "cosmeceuticals" that offer photoprotection through the high concentration of polyphenols, specifically flavonoids and tannins [7]. These phytochemicals serve as natural UV absorbers due to their aromatic rings and hydroxyl groups, while simultaneously providing antioxidant support to neutralize ROS generated during UV exposure [8].

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The primary bioactive constituent, *Musa paradisiaca*, commonly designated as the plantain or banana, serves as a significant source of secondary metabolites within the Musaceae family. While the fruit is globally recognized for its nutritional value, the non-edible peel constitutes a dense matrix of phytochemicals including anthocyanins, delphinidin, and cyanidin [13]. These polyphenolic compounds exhibit high absorbance in the ultraviolet region, particularly between 280 and 320 nm, which aligns with the UVB spectrum. The presence of lutein, a xanthophyll carotenoid, further contributes to its capacity for photoprotection by acting as a biological filter and a potent antioxidant [14]. Shea butter, derived from the kernels of the African shea tree, is characterized by a high fraction of unsaponifiable matter, notably triterpene alcohols and cinnamic acid esters. These components provide a basal level of UV absorption while the stearic and oleic acid content ensures deep hydration and restoration of the lipid barrier [15].

Coconut oil serves as a critical emollient and penetration enhancer within the emulsion. Its high concentration of medium-chain fatty acids, specifically lauric acid, facilitates the formation of a protective film on the stratum corneum, reducing transepidermal water loss (TEWL) and providing inherent antimicrobial properties [16]. Almond oil is incorporated for its high α-tocopherol (Vitamin E) content. Vitamin E acts as a chain-breaking antioxidant that protects cell membranes from lipid peroxidation induced by UV-generated free radicals, thereby mitigating the secondary effects of solar exposure [17].

Grape seed oil is exceptionally rich in proanthocyanidins, which are flavonoids with antioxidant capacities significantly higher than those of Vitamin C or E. These molecules assist in stabilizing the collagen matrix and provide a broad-spectrum antioxidant defense [18]. Included for its medicinal properties, tea tree oil contains terpinen-4-ol, which provides antiseptic and anti-inflammatory benefits. This is particularly relevant for post-exposure recovery, as it helps suppress the inflammatory cascade associated with UV-induced erythema [19]. Beeswax acts as a natural emulsifier and stiffening agent, providing the required consistency and thermal stability to the cream. Rose water serves as the aqueous phase, contributing phenolic antioxidants and a natural fragrance while maintaining the acidic pH of the formulation [20].

Musa paradisiaca L., commonly known as the banana plant, produces significant quantities of agricultural byproduct in the form of peels. These peels are recognized as a rich reservoir of potassium, lutein, and various phenolic acids [9]. Previous investigations indicate that the Kepok variety of banana contains specific flavonoids capable of chelating metal ions and scavenging free radicals, making it an ideal candidate for topical photoprotective applications [10]. It is possible to develop a formulation that provides a multi-faceted defense against solar radiation while maintaining skin hydration and barrier function [11]. The present study focuses on the systematic development and evaluation of an herbal sunscreen cream derived from *Musa paradisiaca*. The research encompasses the pre-formulation characterization of the botanical powder, the optimization of the emulsion base using natural waxes and oils, and the quantitative assessment of the Sun Protection Factor (SPF) using UV-Visible spectrophotometry [12]. Through rigorous physicochemical and antimicrobial testing, this work seeks to establish a scientific framework for the utilization of fruit-waste-derived bioactives in high-SPF dermatological products

2. Materials and Methods

The primary plant material, *Musa paradisiaca* peels, was procured from local agricultural sources in Loha, Maharashtra, and authenticated at the N.E.S. Science College, Nanded. High-purity beeswax, shea butter, and various botanical oils (Coconut, Almond, Grape seed, Tea tree) were utilized as the lipid phase. Analytical grade reagents were used for all physicochemical and phytochemical assessments.

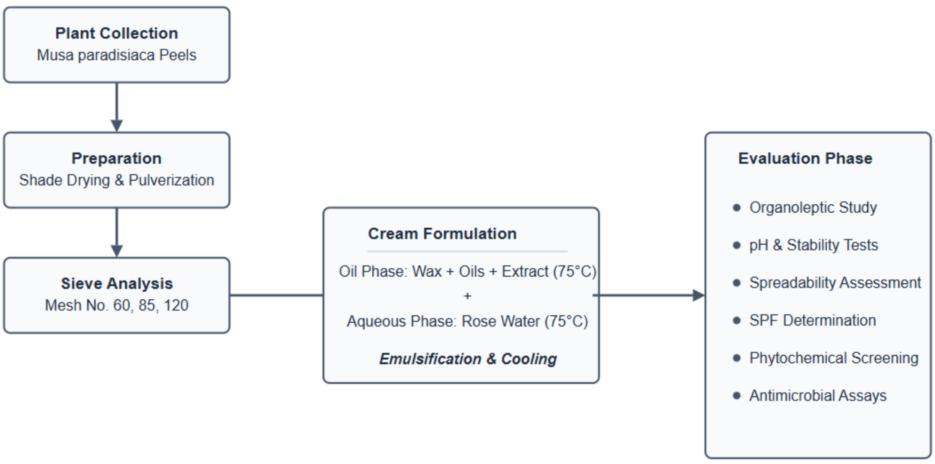

Figure 1. Experimental Design

2.1. Processing of Plants

The extraction of bioactives from *Musa paradisiaca* involved a systematic drying and pulverization process to preserve thermolabile compounds.

2.1.1. Collection and Decontamination

Fresh peels were manually separated and subjected to rigorous washing with deionized water to remove exogenous contaminants and microbial flora. The cleaned material was air-dried under controlled conditions to eliminate surface moisture.

2.1.2. Desiccation and Pulverization

The peels were dried in a ventilated, shaded environment to prevent the photodegradation of phenolic constituents. Following complete desiccation, the material was pulverized using a mechanical grinder to achieve a fine powder. The resulting powder was passed through standardized sieves (Mesh No. 60, 85, and 120) to ensure uniform particle size distribution, which is critical for the homogeneity of the final topical product.

2.2. Pre-formulation Studies

2.2.1. Micromeritic Properties

The flow potential of the *Musa paradisiaca* powder was assessed by determining bulk density, tapped density, Carr's compressibility index, and Hausner's ratio using a standardized tapping apparatus [21]. The internal friction was quantified via the angle of repose using the fixed-funnel method.

2.2.2. Physicochemical Properties and Ash Values

Total ash, acid-insoluble ash, and water-soluble ash values were determined by gravimetric analysis after incineration in a muffle furnace at 450°C to assess inorganic impurities [22].

2.2.3. Solubility

The solubility of the powder was qualitatively evaluated in a range of polar and non-polar solvents, including distilled water, ethanol, and ethyl acetate, to determine the optimal phase for bioactive dispersion.

2.3. Phytochemical Screening Protocols

The presence of secondary metabolites was verified through qualitative chemical tests. Flavonoids were identified using the Shinoda and Lead Acetate tests. Proteins and amino acids were screened via Millon's and Ninhydrin tests, while phenolic compounds were detected using the Ferric Chloride test [23].

2.4. Development of the Herbal Sunscreen Formulation

The formulation was developed using a fusion-emulsification technique. The oil phase, consisting of beeswax, shea butter, almond oil, coconut oil, and the bioactive banana peel powder, was heated to 75°C to ensure complete melting and dispersion. Simultaneously, the aqueous phase (rose water) was heated to an identical temperature. The aqueous phase was then gradually integrated into the oil phase with continuous, high-shear stirring. The addition of volatile components like tea tree oil was performed during the cooling phase (below 40°C) to prevent evaporation. Stirring continued until a smooth, homogenous cream was formed at room temperature.

Table 1. Composition of Herbal Sunscreen Formulations

Ingredients	Function	F1 (per 20g)	F2 (per 20g)	F3 (per 20g)
Musa paradisiaca extract	Active Ingredient (UV Filter)	6.0 g	6.0 g	5.5 g
Shea Butter (*Vitellaria paradoxa*)	Emollient / Lipid Base	5.0 g	4.0 g	5.0 g
Beeswax (*Cera alba*)	Emulsifier / Thickener	2.0 g	3.0 g	2.0 g
Almond Oil (*Prunus dulcis*)	Antioxidant Carrier	2.0 mL	1.5 mL	1.0 mL
Coconut Oil (*Cocos nucifera*)	Skin Barrier Repair	2.0 mL	3.0 mL	2.0 mL
Tea Tree Oil (*Melaleuca alternifolia*)	Antiseptic	1.0 mL	1.0 mL	1.0 mL
Grape Seed Oil (*Vitis vinifera*)	Antioxidant / Stabilizer	1.0 mL	1.0 mL	1.0 mL
Rose Water (*Rosa damascena*)	Aqueous Phase	1.0 mL	0.5 mL	1.5 mL

2.5. Physicochemical Evaluation

The stability of the formulations was monitored through physical appearance, homogeneity, and organoleptic characterization. Quantitative assessments included pH measurement using a digital pH meter, moisture content determination via the loss-on-drying (LOD) method, and spreadability analysis using the parallel plate method [25].

2.6. *In vitro* Photoprotective Assessment (SPF)

The Sun Protection Factor (SPF) was determined spectrophotometrically. Diluted cream samples were scanned in the UV-B range (290–320 nm) using a UV-Vis spectrophotometer. The SPF was calculated based on the Mansur equation, correlating absorbance with the erythemal effect of solar radiation [26].

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

2.7. Antimicrobial Activity

The antibacterial potential was evaluated against *Staphylococcus aureus* and *Escherichia coli* using the agar well diffusion method. Zones of inhibition were measured after 24 hours of incubation at 37°C to determine the efficacy of the botanical preservatives and active extracts [27, 28].

3. Results and Discussion

3.1. Pre-formulation

3.1.1. Micromeritic and Flow Properties

The micromeritic analysis revealed that Batch B (passed through sieve No. 85) exhibited the most favorable flow characteristics. The Hausner ratio of 1.09 and an angle of repose of 20.36° indicate excellent flowability, facilitating uniform dispersion within the cream base.

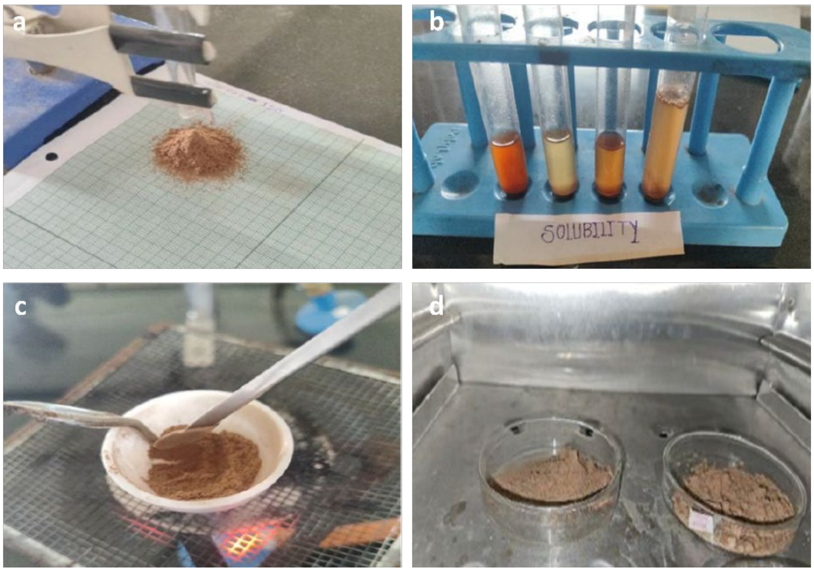

Figure 2. Determination of a. Angle of Repose b. Solubility c. Ash Value and d. Loss on Drying

3.1.2. Ash Values and Solubility

The total ash value (64.0%) and low acid-insoluble ash (5.2%) confirmed the purity of the botanical source. Solubility studies indicated high affinity for the aqueous phase, which guided the partition of the extract during emulsification.

Table 2. Solubility and Purity of Plant Materials

Solvent/Test	Observation / Value	Inference
Distilled Water	Highly Soluble	Aqueous phase compatibility
Ethanol (95%)	Moderately Soluble	Polyphenol extraction potential
Ethyl Acetate	Insoluble	Low non-polar affinity
Total Ash Value (%)	64.0 ± 2.1	Inorganic mineral content
Acid Insoluble Ash (%)	5.2 ± 0.4	Low earthy matter contamination
Water Soluble Ash (%)	12.5 ± 1.2	Standard purity range

3.2. Phytochemical Screening Results

Qualitative analysis confirmed a high density of flavonoids and phenolics in the *Musa paradisiaca* extract. These compounds are known to facilitate UV absorption through their conjugated aromatic systems.

Table 3. Phytochemical Screening of *Musa paradisiaca* Peel Extract

Phytochemical Constituent	Standard Test	Result	Observation
Flavonoids	Shinoda Test	+++	Magenta/Deep Red coloration
	Lead Acetate Test	++	Yellow precipitate formation
Phenolics	Ferric Chloride Test	+++	Bluish-black coloration
Proteins	Millon's Test	+	White/Red precipitate
Amino Acids	Ninhydrin Test	++	Purple/Blue coloration
Carbohydrates	Molisch's Test	++	Violet ring at junction

(+++) Highly Present; (++) Present; (+) Trace; (-) Absent

3.3. Physicochemical Evaluation Results

The pH values (5.82–6.50) were compatible with the cutaneous acid mantle. Batch F1 showed optimal spreadability (12.45 g.cm/sec), ensuring a consistent photoprotective film on the skin. Moisture content was maintained within the range of 5.91% to 8.10%, supporting the formulation's emollient properties.

Table 4. Physicochemical Evaluation of Formulations

Parameter	F1	F2	F3
Physical Appearance	Homogenous Cream	Homogenous Cream	Slightly Viscous
Color	Dark Brown	Brown	Light Brown
pH (Mean ± SEM)	5.82 ± 0.04	6.20 ± 0.06	6.50 ± 0.03
Moisture Content (%)	5.91 ± 0.25	6.70 ± 0.18	8.10 ± 0.32
Spreadability (g.cm/sec)	12.45 ± 0.50	10.82 ± 0.44	9.15 ± 0.61
Phase Separation	None	None	Trace (after centrifugation)

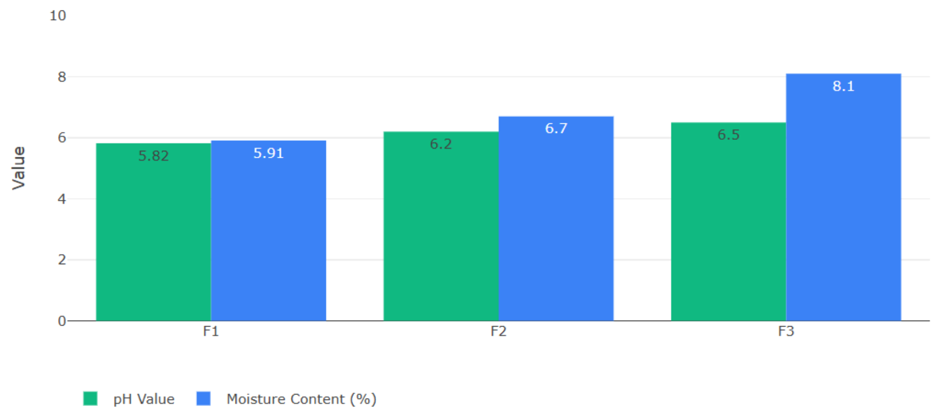

Figure 3. Comparison of Physicochemical Parameters

3.4. *In vitro* Photoprotective Efficacy (SPF)

The formulation achieved a maximum SPF of 36.4. The absorbance spectra showed intense activity in the UVB region (290–320 nm), confirming the efficiency of the secondary metabolites in attenuating damaging solar radiation.

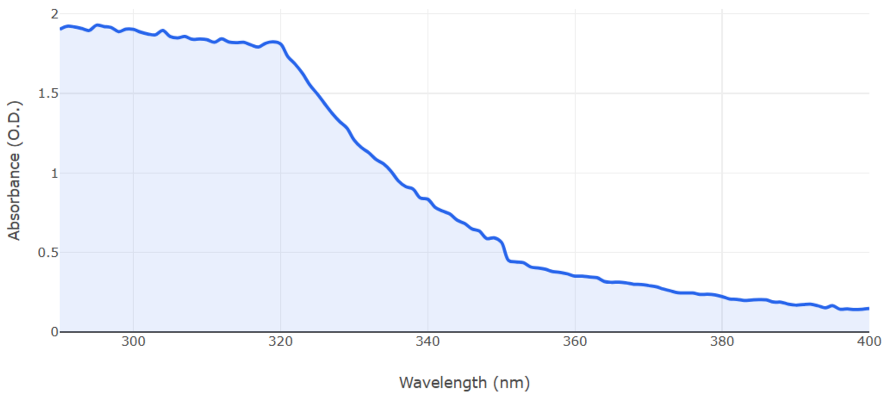

Figure 4. UV Absorbance Spectrum of Musa paradisiaca Formulation

3.5. Antimicrobial Activity

Significant zones of inhibition were observed against both Gram-positive and Gram-negative pathogens. The inhibitory effect against *S. aureus* (22.0 mm) highlights the formulation's secondary benefit in preventing infections in UV-stressed skin.

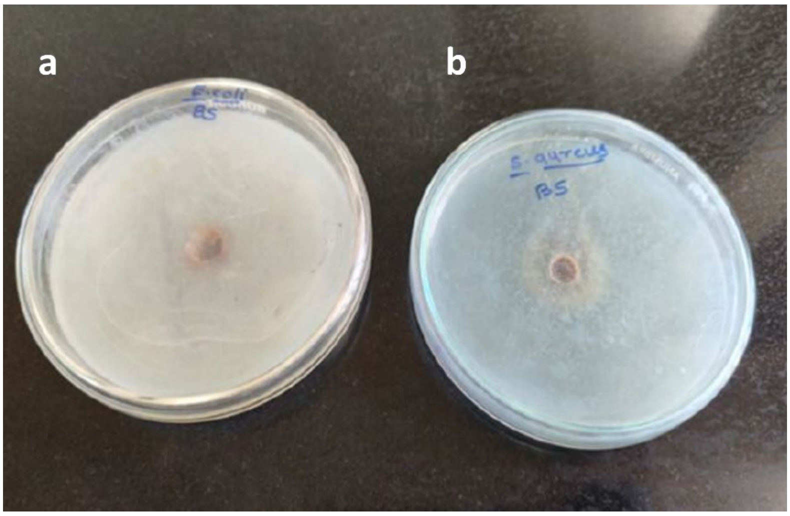

Figure 5. Antimicrobial Activity of Formulation agains a. *E.coli* and b. *S. aureus*

Table 5. *In Vitro* SPF Efficacy and Antimicrobial Zones of Inhibition

Efficacy Parameter	Result Value	Statistical Significance
SPF (*In Vitro*)	36.4 ± 1.2	$p < 0.05$ (High Protection)
UVB Blockage (%)	97.2 ± 0.3	Equivalent to SPF 35+ standards
Z.O.I (*S. aureus*)	22.0 ± 1.5 mm	Effective antibacterial activity
Z.O.I (*E. coli*)	18.5 ± 1.2 mm	Moderate antibacterial activity

Z.O.I = Zone of Inhibition; SPF measured at 290-320 nm range.

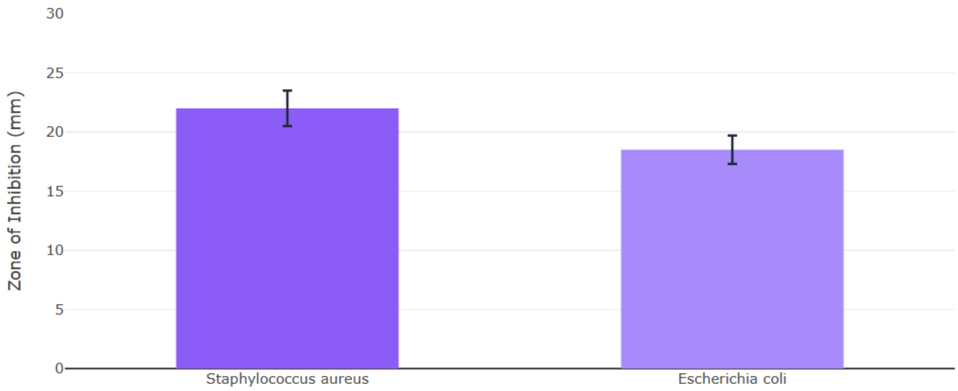

Figure 6. Zones of inhibition (mm) of Prepared Formulation Against *S. aureus* and *E. coli*.

4. Conclusion

The development of herbal sunscreen using *Musa paradisiaca* peel extract could be a natural solution that successfully bridges the gap between high photoprotective efficacy (SPF 36.4) and the utilization of agricultural byproducts. The stable physicochemical properties, combined with the presence of potent antioxidant flavonoids, suggests that this cream not only attenuates UV-induced damage but also supports the skin's intrinsic repair mechanisms. Evaluation of long-term stability under varying climatic conditions and larger-scale clinical safety determination are recommended to establish this botanical formulation as a viable alternative to synthetic ultraviolet filters.

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