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A Research Article: Formulation and Evaluation Studies of Zinc Oxide-Infused Tinted Sunscreen

Maneeza Jahan[1]; Mifrah Fatima[2]; Dr. Shahid Mohammmed[3]

[3]Co-Author

[1,2,3]Department of Pharmaceutics, Deccan School of Pharmacy, Hyderabad, Telangana

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Abstract: Tinted sunscreens have emerged as a multifunctional skincare product offering both photoprotection and cosmetic benefits. While broad-spectrum sunscreens are effective against ultraviolet (UV) radiation, they fall short in protecting the skin from visible light, which also has harmful effects. Traditional Broad-spectrum sunscreens guard against uv radiation but offer limited defence against visible light. For to effectively shield the skin from visible light, a sunscreen must remain visible on the surface. Inorganic filters (also known as mineral filters), like zinc oxide and titanium dioxide, are tipically used in nanoparticles form in sunscreens to avoid leaving a white residue; however, this compromises their ability to block visible light as such, they do not protect against visible light. Tinted sunscreens overcome this limitation by useing different formulations and concentrations of iron oxides and pigmentary titanium dioxide to provide protection against visible light and a more even skin tone. This article aims in the formulation and evaluation of tinted sunscreens, emphasizing their role in protecting sensitive skin types, such as post-inflammatory hyperpigmentation.

Keywords: *Tinted Sunscreen, Photoprotection, Visible Light Protection, Iron Oxide, Acne Prone Skin, Cosmetic Benefits, Post Inflammatory Hyperpigmentation.*

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I. INTRODUCTION

Sunlight exposes the skin to harmful ultraviolet radiation (UVR). Prolonged exposure can lead to skin cells and DNA damage, increasing the risk of skin cancers and various other skin conditions.[1] Sunscreens are those agents which functions by absorbing or reflecting harmful UV radiation to block the damaging effects of ultraviolet (UV) radiation of sunlight. [2] The wavelengths of sunlight consist of spectrum of radiation range from ultraviolet to visible light. UVA (320–400 nm) UV-A is most responsible radiation for immediate tanning or darkening of the skin due to excess production of melanin, UVB (290–320 nm) UV-B radiations are known as burning rays as they are 1000 times more capable of causing sunburn than UV-A .UVB rays primarily affect the outer layers of the skin and are the main cause of sunburn . [3]

Sunburned skin is a major risk factor for both melanoma and non-melanoma skin cancer, and UVC (100–290 nm) rays does not penetrate through the atmosphere layer.

Although UVC is the shortest and most energetic wavelength, it is the most dangerous type of UV ray because it can cause serious adverse effects such as mutagenic and carcinogenic effects. There are the three categories of ultraviolet (UV) light[4,5]. A sunscreen contains combination of ingredient where some provide protection against UVA and other shield the skin against UVB.[6]

Sunscreen are primerly evaluated and marketed by its sun protection factor (SPF) that measures the fraction of how well it protects from sunburn [7].The effectiveness of a sunscreen is usually expressed by the sun protection factor (SPF) [8] Sunlight plays an essential for physiological functions like producing Vitamin D and mood regulations but overexposure of sun can also be harmful to the skin [9] Conventional sunscreens protect against UV radiation but offer minimal shielding against visible light, which leads to hyperpigmentation, especially in darker skin types. Conventional sunscreen may also leave a white cast, which reduces cosmetic acceptance and adherence. Tinted sunscreens address these drawbacks by offering added protection against visible light and improved aesthetic appeal.[10]. In this paper we have attempted to develop and characterize a tinted sunscreen formulation.This study seeks to evaluate its efficacy in providing broad-spectrum protection against ultraviolet and visible light, with an emphasis on improving photoprotection for pigmentary disorders while ensuring enhanced cosmetic acceptability and user adherence.

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Tinted sunscreens are topical photoprotective formulations that incorporate UV filters with pigments, most comonly iron oxides, to diliver broad-spectrum protection against ultraviolet (UVA and UVB) and visible light (VL), especialy againt harmful blue light (400–500 nm).unlike regular sunscreens tinted sunscreen is different in their content of iron oxide and pigmentary titanium dioxide, which physically block UV rays and provide color to a formulation[11] They tinted base coverage is achieved by incorporating a blend of black, red, and yellow iron oxides (IOs) and/or pigmentary titanium dioxide (PTD) (titanium dioxide [TD] that is not nanosized). Because TSs provides an instant glow and protect the skin from both sun and blue light , as a result they have gained popularity and have been incorporated into makeup and skin care products to facilitate daily use.[12] .

In 1991, Kaye et al.15 demonstrated that tinted sunscreens with iron oxide significantly reduced visible light transmission more effectively than regular sunscreens with either inorganic (titanium dioxide, zinc oxide) or organic filters (oxybenzone, cinnamate)[13]. Later, it was reinforced by Dumbuya et al. that two tinted sunscreens, one with iron oxide only and another with iron oxide plus titanium dioxide, protected equally against VL-induced pigmentation, while a regular higher SPF 950+)sunscreen allowed pigmentation similar to untreated skin.[14]. It not only offer protection against UVA and UVB but also visible light, especially blue light were as the regular sunscreens do not. Hence they are more effective in managing melasma, post-inflammatory hyperpigmentation (PIH), rosacea, and acne-prone skin, additionally they are more useful in preventing PIH, offering cosmetic camouflage, and minimizing the need for pore-clogging makeup making them a multifunctional choice for both protection and cosmetic appearance. tinted formulation improves cosmetic acceptability, reduces the white cast, and enhances user compliance , particularly in darker skin tones.[15,16]

Fig 1 Tinted Sunscreen Perks

➢ *"Tinted Sunscreen: Why People Love It—And What to Watch Out for"*

There are a few pros and cons to using tinted sunscreen.

➢ *Pros:*

- It help to even out your skin complexion and provides a more natural look.
- It can also be helpful conceal imperfections like blemishes or scars.
- It provides an additional protective layer against the visible light including blue light.[10]

➢ *Cons:*

- Limited Shade Range Many products are available in few shades, which may not suit all skin tones.
- if you have oily or acne-prone skin. It's essential to choose a noncomedogenic formula .
- It can wear off easily due to sweatorrubbing so you may need to reapply it often throughout the day.[17]

➢ *Why Tinted Sunscreen Is a Game-Changer for Acne-Prone Skin ?*

Tinted sunscreens provide several benifits for individuals with acne-prone skin. As they offer broad-

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spectrum protection not only against ultraviolet (UVA and UVB) radiation but also visible light, particularly high-energy blue light, which has been linked to worsen post-inflammatory hyperpigmentation (PIH) commonly seen after acne lesions heal (Mahmoud et al., 2010; Zhou et al., 2024). The presence of iron oxides in tinted formulations is effective against blocking visible light, helping to minimize dark spots and uneven skin pigmentation. Since, many tinted sunscreens are designed to be non-comedogenic, meaning they do not clog pores or trigger acne breakouts. This makes them a safer choice for acne-prone skin compared to some heavy or oily cosmetic products. Additionally, the subtle coverage tinted sunscreens provides can help camouflage active blemishes and discoloration, reducing the need for makeup that might irritate or worsen acne prone skin. Some tinted sunscreen formulations contain soothing or anti-inflammatory ingredients, such as niacinamide or zinc oxide, which can be benificial to sensitive or inflamed skin. Overall, tinted sunscreens function as a multifunctional product that combines effective photoprotection with cosmetic benefits, making it a better options in acne-prone individuals[15]. The inclusion of pigments in tinted sunscreen help to even out the complexion and cover up imperfections[10]. making it ideal for people who want to avoid looking like they're wearing a heavy layer of sunscreen on their face.

When choosing a tinted sunscreen, be sure to opt for noncomedogenic and oil-free formula to avoid the possibility of clogging pores.[18] additionally, for optimal sun protection, search for a product with an SPF of 30 or higher.

➢ *Formulation and preparation of tinted sunscreen:*

Table 1 composition of preferred formulation

s.no	Ingredients	Quantity
	Phase –A	
1.	Zinc oxide	15g
2.	Titanium oxide	3g
3.	Cetearyl alcohol	1.5ml
4.	PEG 100	1.2ml
	Phase-B	
5.	Purified water	100ml
6.	glycerin	3ml
7.	Disodium EDTA	0.1g
	Phase -C	
8.	Potassium sorbate	0.2g
9.	Vitamin E	0.5ml
10.	Fragrance	0.2ml

➢ *Preparation:*

- Use a homogenizer or high speed stirrer to disperse zinc oxide and iron oxides in the oil phase ingredients (Phase A) .
- Both Phase A and Phase B where heated separately at 70–75°C.
- Phase A is added into Phase B slowly with constant stirring to form an uniform emulsion.
- Cool down the emulsion to below 40°C with continues gentle stirring .
- Add Phase C ingredients one by one.
- if necessary. adjust pH to ~6.5 .
- Transfer the final formulation into a suitable opaque tube or airless pump.

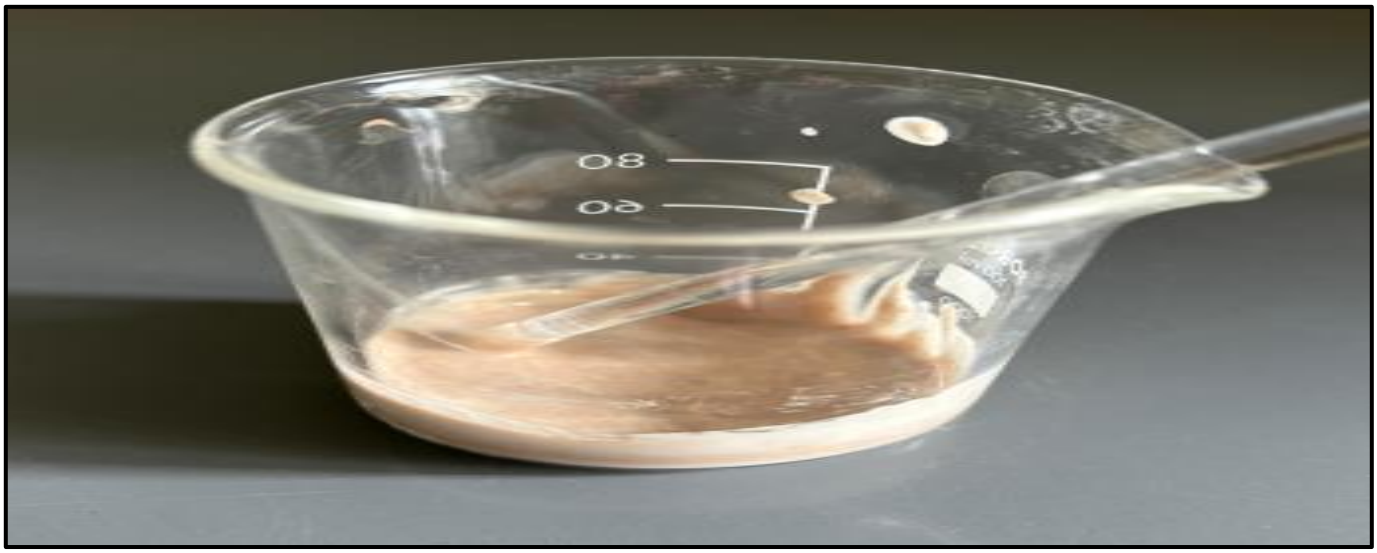

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Fig 2 Prepared Tinted Sunscreen

II. EVALUATION OF TINTED SUNSCREEN

➢ *Physical Evaluation:*

- *Colour:*

The formulation color was visually examined and recoeded.

- *Odour:*

The fregrance of the formulation was assessed by applying the preparation on hand and evaluate the scent.

- *Texture:*

The smoothness or greasiness, was assessed by applying it to the skin.

➢ *Ph Evaluation:*

By usising a digital pH meter the pH of tinted sunscreens was measured. The pH was measured by dissolving 1 g of the formulation in 100 ml of newly prepared distilled water for 2 hours. This study is to ensure that the pH of the prepared tinted sunscreens is compatible with the pH of the skin after 24 hours of use. The results was recorded.

➢ *Spreadability Evaluation:*

The spreadability of tinted sunscreens was evaluated for its ease of application which influence their therapeutic efficiency. An appropriate amount of tinted sunscreen was applied between two slides, and specific weight was applied the time (in sec) required by the slides to seperate was recorded. Spreadability was defined as the amount of time it takes to separate two slides in less time.

The formula for calculating it is:

$$S = M \times L / t$$

Where, M = weight the upper slide

L = length of glass slide

T = time taken to separate the slides

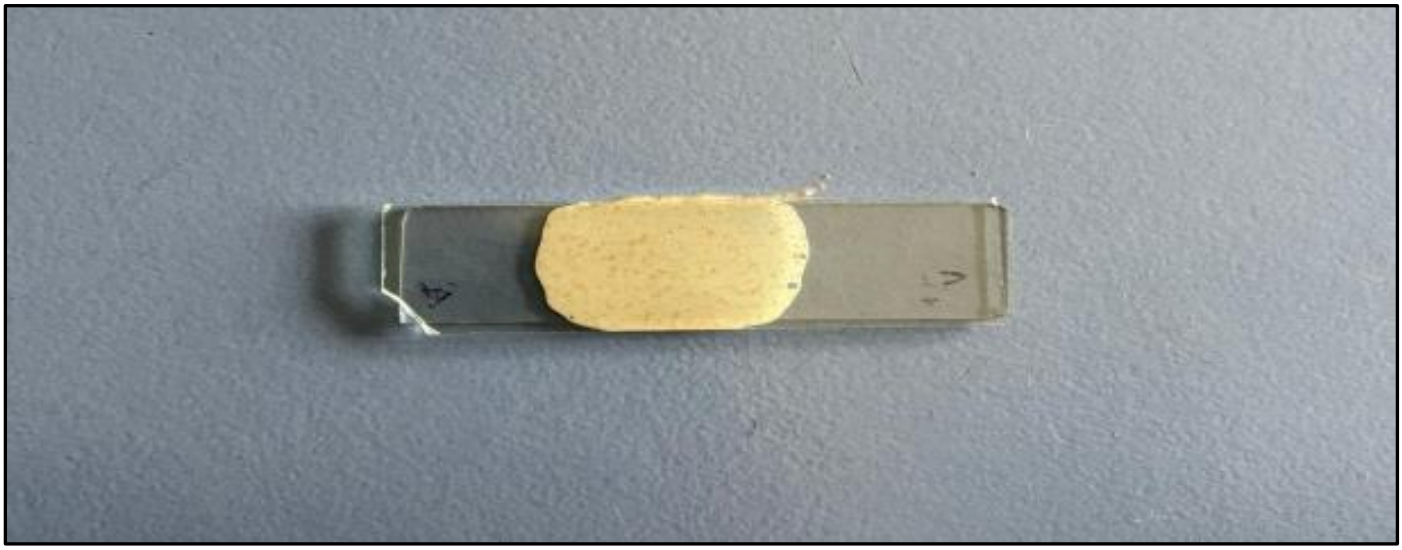

Fig 3 Spreadability Evaluation

➢ *Skin Irritancy Test:*

An area (one sq. cm) is marked on the left hand. The tinted sunscreen was applied to the this area and time was noted. This test helps evaluate Irritancy, erythema, edema.

➢ *In-vitro SPF evaluation:*

To examine the in-vitro efficacy of tinted sunscreens a UV Visible spectrophotometer was used.1 g of the tinted sunscreen is dissolved it in 100 mL of ethanol and absorbance is measured in the wavelength range of 290 and 320 nm, at 5 nm intervals. SPF was calculated using Mansur equation based on the collected absorbance values.

SPF = CF∑EE(λ) × I(λ) × A(λ) 320 290 (3) Whereas,

CF= Correction factor;

EE= Erythemogenic effect;

I= Intensity of solar light of wavelength;

A= Absorbance

➢ *Stability evaluation Test:*

The prepared formulation underwent Stability testing at both room temp and higher temperature, at room temperature the formulation was monitered for 7 days . And then the formulation was studied at 45 ±1°C for 20 days . The formulation was observed on 0th , 5th , 10th , 15th and 20th day to check for any changes in the properties.

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III. RESULT AND DISCUSSION

Table 2 Result Obtained by Various Evaluation Parameters

Sno.	Parameters	Formulation
1.	Color	Medium beige
2.	Odor	Pleasent
3.	Texture	Non greasy, light weaight
4.	pH	5.7
5.	Spreadability	12.3cm/min
6.	Irritancy	No irritation
7.	SPF	24.6
8.	Stability	No change

Fig 4 Final Tinted Sunscreen with Tint and Protection

IV. CONCLUSION

With growing awareness of the need for protection against harmful UVA and UVB rays, has created significant market potential for tinted sunscreen. Theis study attempted to formulate and evaluate tinted sunscreen which not only provides protection against harmful UV rays but also enhances cosmetic acceptability. The tinted sunscreen formulation provided light to medium coverage with smooth blending, making it suitable for a wide range of skin . Stability studies and microbial analysis confirmed that the product remained safe and effective under various storage conditions. The tinted sunscreen thus combines dermatological protection with aesthetic benefits, addressing the limitations of traditional sunscreens

Overall, the findings validate that the formulation's potential as a multifunctional skincare product that ensures sun protection, evens out skin tone, and consumer acceptability, making it a strong contender for future commercial development.

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