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FORMULATION AND EVALUATION OF HERBAL ANTIOXIDANT GEL

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ABSTRACT

Prolonged exposure to blue light emitted by digital screens has emerged as a growing concern in modern dermatology, as it penetrates the skin and triggers oxidative stress, accelerating premature aging and pigmentation. While synthetic photoprotectants exist, their safety and tolerability limitations necessitate exploration of natural, plant-based alternatives. The present work focuses on the development and evaluation of a herbal antioxidant gel designed to neutralize blue-light-induced free radical damage through the synergistic action of selected plant-derived bioactives. Standard physicochemical and antioxidant parameters were employed to assess its suitability as a topical cosmeceutical. The study establishes a compelling case for herbal gel formulations as safe, effective, and patient-friendly solutions for skin protection in an increasingly screen-dominated world.

KEYWORDS: Herbal Antioxidant Gel, Blue light, Digital Screens, Plant Derived Bioactives.

1. INTRODUCTION

Human skin is the largest organ of the body and acts as a protective barrier against environmental stressors such as pathogens, UV radiation, and physical damage. With the widespread use of digital devices, exposure to high-energy visible (HEV) blue light (400–490 nm) from smartphones, computers, LED lights, and televisions has increased significantly.

Prolonged blue-light exposure can cause oxidative stress, premature skin ageing, pigmentation changes, inflammation, and impairment of the skin barrier.

To address these concerns, there is growing interest in developing topical formulations that protect the skin from blue-light-induced damage. Herbal antioxidants have gained attention due to their natural antioxidant, anti-inflammatory, and photoprotective properties.

This project focuses on the formulation and evaluation of a herbal antioxidant gel for protection against blue-light-induced skin damage. The gel contains astaxanthin, green tea extract, and vitamin E as active ingredients, incorporated into a base of xanthan gum, glycerin, jojoba oil, aloe vera gel, citric acid, and distilled water. These ingredients were selected for their safety, compatibility, and synergistic protective effects on the skin.[1,4]

STRUCTURE AND FUNCTION OF SKIN

The skin is composed of three main layers: epidermis, dermis, and hypodermis. The epidermis forms the outer protective barrier and contains keratinocytes, melanocytes, Langerhans cells, and Merkel cells. Its outermost layer, the stratum corneum, prevents water loss and protects against external agents. The dermis contains collagen, elastin, blood vessels, nerves, hair follicles, and glands, providing strength, elasticity, and support. The hypodermis consists mainly of adipose tissue, serving as insulation, energy storage, and cushioning.

The skin possesses a natural antioxidant defence system that protects against oxidative damage caused by reactive oxygen and nitrogen species. This system includes enzymatic antioxidants such as superoxide dismutase, catalase, and glutathione peroxidase, as well as non-enzymatic antioxidants like vitamins C and E, glutathione, carotenoids, and coenzyme Q10. These antioxidants neutralize free radicals and help maintain skin health.

The skin barrier plays a crucial role in photoprotection. Lipids such as ceramides, cholesterol, and fatty acids form a protective barrier that prevents water loss and blocks harmful substances. Melanin provides natural protection by absorbing ultraviolet and visible light; however, its ability to protect against blue light is limited. Prolonged exposure to UV and blue light can overwhelm the skin's antioxidant defences, leading to oxidative stress, photodamage, and premature ageing.[5,8]

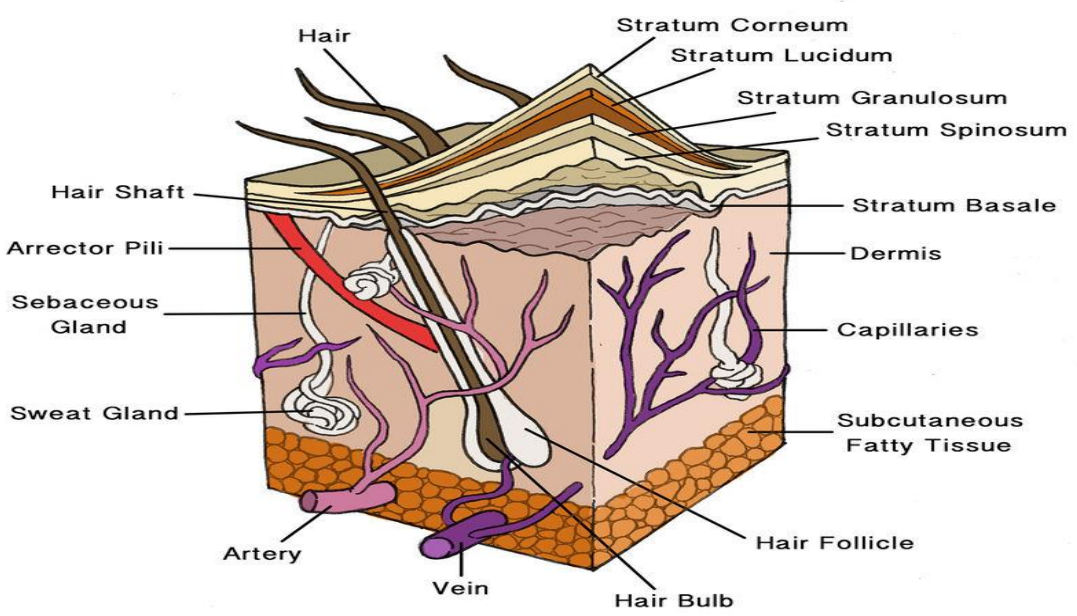

Fig. 1: Anatomical Cross-Section of Human Skin — Layers, Structures and Components.

Blue Light – Sources, Characteristics, and Skin Penetration

Blue light is a high-energy visible (HEV) light with wavelengths ranging from 400–490 nm. It is part of the visible light spectrum (380–780 nm) and possesses higher energy than longer-wavelength visible light. Due to its high photon energy, blue light can trigger photochemical reactions and generate reactive oxygen species (ROS), leading to oxidative stress in the skin.

Blue light originates from both natural and artificial sources. The sun is the primary natural source, while artificial sources include smartphones, tablets, computers, televisions, LED lighting, fluorescent lamps, and digital screens. Modern LED devices emit a concentrated blue-light peak around 450 nm, and prolonged use of these devices has significantly increased daily blue-light exposure. Since digital screens are often used close to the face, facial skin receives continuous localized exposure.

Blue light penetrates the skin more deeply than ultraviolet radiation, reaching the mid-to-deep dermis and sometimes the subcutaneous tissue. This deep penetration allows it to interact with chromophores such as flavins, porphyrins, and advanced glycation end-products (AGEs), resulting in ROS production and oxidative damage. Because of this, topical antioxidant formulations are considered important for protecting the skin from blue-light-induced photodamage.[9,12]

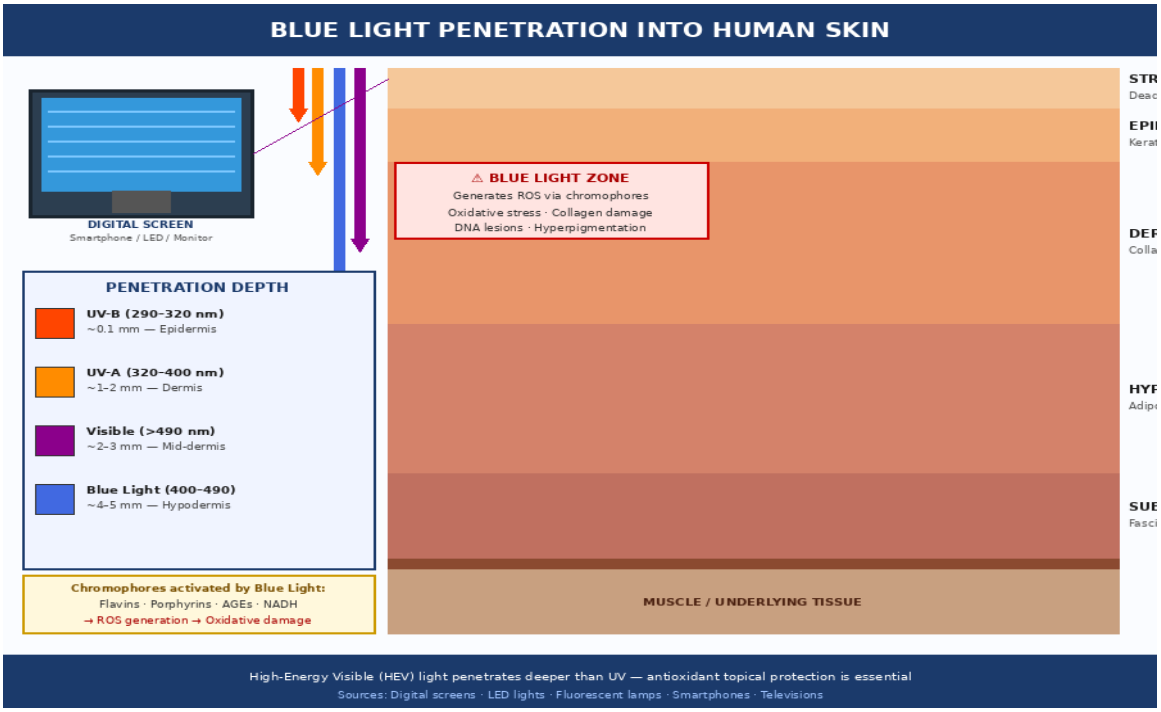

Fig. 2: Blue Light (400–490 nm) Penetration Depth into Human Skin Layers.

Mechanisms of Blue-Light-Induced Skin Damage

Blue light damages the skin primarily by generating reactive oxygen species (ROS) through the activation of natural skin chromophores such as flavins, porphyrins, melanin intermediates, and advanced glycation end-products. Excessive ROS production causes oxidative stress, disrupts mitochondrial function, and initiates cellular damage.

Blue light can indirectly damage DNA through ROS-mediated oxidation, leading to the formation of oxidative lesions such as 8-oxo-guanine, DNA strand breaks, and mutations. Over time, the accumulation of such damage may contribute to premature ageing and increase the risk of skin disorders.

ROS also trigger lipid peroxidation in cell membranes, particularly affecting polyunsaturated fatty acids. This process generates harmful by-products that damage skin cells, weaken the skin barrier, increase water loss, and make the skin more vulnerable to further photodamage.

In addition, blue light causes protein oxidation and stimulates the production of matrix metalloproteinases (MMPs), enzymes that degrade collagen and elastin. This leads to reduced skin elasticity, wrinkle formation, and accelerated photoageing.

Blue-light-induced oxidative stress activates inflammatory pathways, increasing the release of cytokines such as IL-1β, IL-6, IL-8, and TNF-α. Chronic inflammation further enhances oxidative damage and contributes to roughness, loss of firmness, and skin ageing.

Another major effect of blue light is hyperpigmentation. Blue light stimulates melanocytes through activation of the Opsin-3 (OPN3) receptor, increasing tyrosinase activity and melanin production. This results in persistent pigmentation and uneven skin tone, especially in individuals with darker skin types.

Overall, blue light promotes oxidative stress, DNA damage, lipid and protein degradation, inflammation, collagen breakdown, and hyperpigmentation, all of which contribute to skin ageing and photodamage.[13,15]

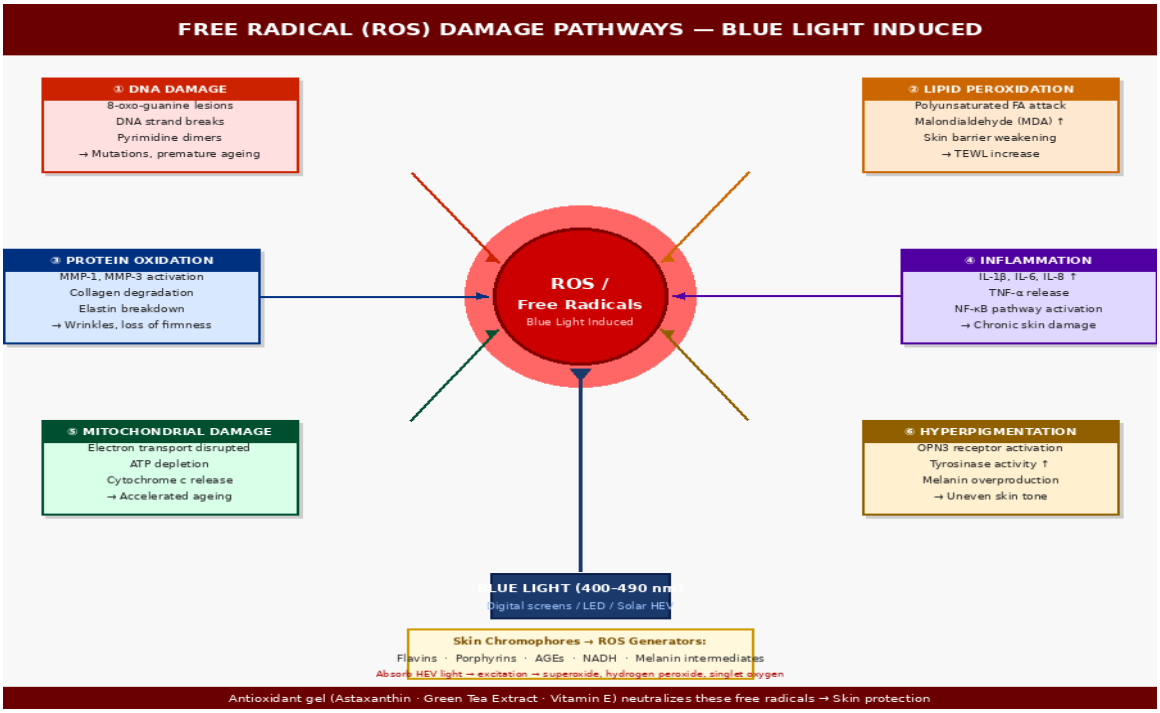

Fig. 3: Mechanisms of Free Radical (ROS) Damage Induced by Blue Light in Skin.

Rationale for a Herbal Antioxidant Gel Formulation

Conventional sunscreens are mainly designed to protect against UVA and UVB radiation and provide limited protection against high-energy visible (HEV) blue light. Since blue light causes oxidative stress through the generation of reactive oxygen species (ROS), antioxidant-based formulations offer a more effective approach by neutralizing free radicals, reducing inflammation, and preventing collagen degradation.

Herbal and natural antioxidants are attractive photoprotective agents because they possess strong antioxidant, anti-inflammatory, and photoprotective properties. Plant-derived compounds such as polyphenols, carotenoids, and tocopherols can target multiple mechanisms of skin damage simultaneously. They are generally considered safe, biocompatible, and may exhibit synergistic effects when combined, enhancing overall protective activity.

A gel formulation was selected as the delivery system due to its high water content, cooling effect, non-greasy nature, and good patient acceptability. Gels allow prolonged contact of active ingredients with the skin, improve penetration, and are suitable for daily use, especially on oily or acne-prone skin. They can effectively deliver both hydrophilic and lipophilic antioxidants, such as green tea extract, astaxanthin, and vitamin E.

The use of xanthan gum as a gelling agent provides suitable viscosity and spreadability, ensuring easy application and formation of a protective antioxidant film on the skin. Therefore, a herbal antioxidant gel represents an effective and user-friendly strategy for protecting the skin against blue-light-induced damage.[16]

Topical Gel Formulations in Dermatopharmaceutics

Gels are semisolid dosage forms consisting of a three-dimensional polymer network swollen with a liquid phase. Based on the dispersion medium, they are classified into hydrogels (water-based), organogels (organic solvent-based), and oleogels (oil-based). Hydrogels are the most commonly used type in topical pharmaceutical and cosmetic preparations due to their ease of application and patient acceptability.

Depending on the polymer used, gels may be prepared from natural polymers (xanthan gum, alginate, carrageenan), semi-synthetic polymers (HPMC, methylcellulose), or synthetic polymers (carbomers, polyvinyl alcohol). Gels exhibit viscoelastic properties, behaving like solids at rest and flowing easily when applied, which improves spreadability and skin adhesion.

The stratum corneum is the main barrier to drug penetration through the skin. The effectiveness of active ingredient delivery depends on factors such as molecular weight, lipophilicity, ionization, and formulation characteristics. In gel formulations, active

ingredients are released through diffusion from the aqueous gel matrix and penetrate the skin according to concentration gradients and partitioning behavior.

Hydrogel vehicles can enhance the delivery of both hydrophilic and lipophilic compounds. Ingredients such as glycerin and jojoba oil act as penetration enhancers by improving skin hydration and interacting with skin lipids, thereby increasing the absorption of active ingredients. These properties make gels an effective and convenient vehicle for topical antioxidant delivery.[17]

2. MATERIALS AND METHODS

Materials Used

Astaxanthin, Green Tea Extract, Vitamin E (Tocopherol), Carbapol 940 pure, Glycerin (Glycerol), Jojoba Oil, Aloe Vera Gel, Citric Acid, Distilled Water.

Table 1: Formulation Table.

INGREDIENTS	F1(concentration %w/w)	F2(concentration %w/w)	F3(concentration %w/w)
Asthaxanthin	0.3%	0.6%	0.9%
Green Tea Extract	0.3%	0.3%	0.3%
Vitamin E	0.05%	0.05%	0.05%
Carbapol 940 pure	0.15%	0.15%	0.15%
Jojoba oil	0.5%	0.5%	0.5%
Aloevera gel	2%	2%	2%
Citric acid	0.2%	0.2%	0.2%
Distilled water	5.5%	5.5%	5.5%

3. RESULTS AND DISCUSSION

Table 2: Evalation of Herbal Antioxidant Gel.

S.NO	TEST	F1	F2	F3
1	Organoleptic Test			
	Colour	Pale yellow/creamy yellow	Orange to amber Slight brownish orange	Light orange
	Odour	pleasant	Pleasant	pleasant
	Texture	smooth	smooth	Smooth
	Appearance	transparent	transparent	Transparent
2	Homogenity Test	Homogenous	Homogenous	Homogenous
3	Grittiness Test	Felt smooth	Felt smooth	Felt smooth
4	PH	5.5	5.6	5.1
5	Spreadability Test	5cm	6.5cm	5.5cm
6	Excrudability Test	2gm	2.7gm	2.5gm
7	Stickness Test	3sec	2sec	2.5sec
8	Gel Block Stability	Stable gel	Stable gel	Stable gel

9	Skin Irritation Test	No Irritation & NoRedness	No Irritation &Redness	Irritation & Redness
10	Drug Content Uniformity	517mm 0.088	517mm. 0.088	517mm 0.088

4. SUMMARY

The herbal antioxidant gel exhibited desirable physicochemical properties, good stability, and excellent skin compatibility. It was found to be safe, non-irritating, and easy to apply. The combination of Astaxanthin, Green Tea Extract, and Vitamin E provided strong antioxidant activity, helping to protect the skin from blue-light-induced oxidative stress. Additionally, Aloe vera, glycerin, and jojoba oil enhanced the moisturizing and soothing effects of the formulation. Overall, the gel shows promising potential as a topical cosmeceutical product for protecting the skin from blue-light-related damage.

5. CONCLUSION

The present study, "Formulation and Evaluation of Herbal Antioxidant Gel," demonstrates the potential of a plant-based topical formulation for protecting the skin against oxidative stress associated with blue-light exposure from digital screens. The formulation containing astaxanthin, green tea extract, vitamin E, aloe vera gel and jojoba oil provides a complementary antioxidant and skin-conditioning approach, while Carbopol 940, glycerin, citric acid and distilled water support suitable gel formation, moisturization, pH adjustment and topical application characteristics. Based on the physicochemical and antioxidant evaluation performed, the developed gel showed characteristics supportive of its suitability as a topical cosmeceutical formulation. The combination of antioxidant-rich ingredients may help neutralize reactive oxygen species and thereby reduce oxidative damage associated with blue-light exposure. The gel dosage form also offers advantages such as ease of application, acceptable spreadability, non-greasy characteristics and user convenience. The gel is a safe, stable, effective, and cosmetically acceptable cosmeceutical offering reliable daily protection against blue-light-induced skin aging and cellular damage.

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