Chapter 1

Introduction

1.1 Background

Sunlight emits broad-spectrum electromagnetic radiation (EMR) that consists of UVB (290-320 nm), UVA2 (320-340 nm), UVA1 (340-400 nm), visible light (400-700 nm), and infrared (700 nm-1 mm). Prolonged UV exposure can result in erythema, immune suppression, chronic consequences such as photoaging, hyperpigmentation, and risk of skin cancers (Gabros & Zito, 2019). Half of the EMR that reaches the earth's surface is made up of visible light and it can penetrate the skin deeper than UV radiation. This deeper penetration can induce hyperpigmentation in human skin (Geisler et al., 2021). According to Kerob et al. (2024), post-inflammatory hyperpigmentation (PIH) affects 15% of the population, yet only 33% are aware that sun exposure can worsen their condition. Furthermore, indoor visible light such as that emitted from gadget screens can interact with photo allergens and exacerbate hyperpigmentation (Zhou et al., 2024). High-energy visible light (HEVL) or blue light is able to activate the opsin3 (OPN3) receptor (photoreceptive chromophore) that stimulates the formation of tyrosinase, the rate-limiting enzyme of melanogenesis (He et al., 2023). The formation is due to the activation of CAMKII, CREB, ERK, and p37, which leading to the upregulation of microphthalmia-associated transcription factor (MITF), an important regulator for the development of melanogenesis and melanocytes (Regazzetti et al., 2018).

Sunscreens are widely used as a photoprotective agent to prevent the occurrence of melasma and PIH. However, conventional sunscreens that contain UV filters (organic and inorganic) are formulated to protect against UV radiation but lack visible light protection (Dewi, 2022). Additionally, traditional cream-based sunscreens are often associated with aesthetic drawbacks such as a white cast and a heavy, greasy feel, particularly due to the use of physical filters (Addae & Weiss, 2024). To address these limitations, sunscreen serum has emerged as an innovative formulation offering both cosmetic

elegance and functional performance. With its lightweight, water-based or gel-like texture, sunscreen serum absorbs more easily into the skin, leaving a non-greasy finish and improving user comfort. Moreover, serums typically contain higher concentrations of active ingredients up to ten times more than creams, enabling deeper skin penetration and providing additional therapeutic benefits (Asthana et al., 2025). Therefore, it can be combined with other active ingredients, such as ingredients X and Y to add protection against visible light.

Ingredient X is a protecting and brightening agent that prevents pigmentation disorders due to UV rays and visible light (Le Maire et al., 2019). It contains sclareol derivatives that can be obtained from clary sage stems, leaves, and flowers (Salvia sclarea) (Cheng et al., 2023). Meanwhile, ingredient Y is a naturally existing dipeptide that consist of beta-alanine and L-histidine. Known for its antioxidant, anti-aging, and free radical-scavenging properties, ingredient Y also exhibits photoprotective activity (Jukić et al., 2021). Both ingredients are used to prevent and ameliorate hyperpigmentation, preferably the one induced by visible light radiation. A combination of ingredients X and Y with UV filters is known to provide synergistically improved prevention or treatment of hyperpigmentation, thus enhancing the performance of the individual ingredients. In addition, the combinations are well tolerated by human skin, which does not cause any redness, bleaching, or tanning of the skin. It is also non-irritating and does not dry out the skin (Le Maire et al., 2019).

By evaluating the effect of Ingredient X and Y on enhancing visible light protection in sunscreen serum formulations, this research is significant given the prevalence of visible light exposure in everyday life and its impact on the skin. Furthermore, implementing a robust approach such as factorial design will systematically evaluate the effects of ingredient X and Y concentration on the final products. It will ensure the formulation is optimized efficiently. The research holds value for developing an effective skincare formula that gives a potential solution for individuals suffering from hyperpigmentation, hence creating an advancement in cosmetics and photoprotection. Investigating this topic contributes

to a deeper understanding of sunscreen efficacy, addressing the gap in skin protection against visible light and providing insights for future product development in sun care.

1.2 Objective

The research aimed to evaluate the effect of Ingredient X and Y visible light protection in sunscreen formulations. Additionally, the study aimed to optimize the formulation and visible light protection by adjusting the concentrations of Ingredient X and Y in combination using a factorial design approach.

1.3 Hypothesis

It is hypothesized that the visible light protection of sunscreen serum will be significantly enhanced with the addition of ingredients X and Y in comparison with the placebo. Moreover, it is also hypothesized that the formulation of sunscreen serum with ingredients X and Y concentration variation can be optimized using factorial design.