Chapter 1

Introduction

1.1 Background

Indonesia is a country located on the equator, which makes it exposed to sunlight for longer hours and gives it a higher ultraviolet (UV) index (Fauziyyah et al., 2023). Based on Hamdi (2019), who studied ultraviolet (UV) exposure in Bandung in 2017, the daily sunshine lasted 4.1–8 hours about half of the year, the ultraviolet index (UVI) was above 10 in 46% of the days, the average maximum UVB radiation was 1.22 W/m², and the highest UVB reached 2.17 W/m². This high UV exposure increases the risk of skin aging in Indonesians, especially extrinsic aging caused by long-term UV radiation (Hidayati et al., 2023). The thinning ozone layer increases UVB exposure, leading to excess reactive oxygen species (ROS) and inflammation that disrupts skin cell balance and accelerates aging (Adaninggar & Sumarawati, 2025). The persistent high UVB exposure in Indonesia shows the need for preventive strategies to protect the skin and lower the risk of UV-related damage.

The skin acts as the body's main protective barrier and is constantly exposed to environmental stress, including UV radiation, which is one of the major causes of skin damage. UVB rays penetrate the epidermis and upper dermis, causing oxidative stress, inflammation, and DNA damage (Cavinato et al., 2017). UVB rays can directly damage DNA by forming lesions like cyclobutane pyrimidine dimers (CPDs), while UVB can also cause indirect damage by producing reactive oxygen species (ROS) that harm DNA, lipids, and proteins. Persistent DNA damage and oxidative stress impair epidermal stem cells (ESCs), disrupt their microenvironment, and trigger cellular checkpoints, leading to photoaging (Panich et al., 2016).

Current UVB preventive strategies include reducing sun exposure by avoiding midday sun, wearing protective clothing and hats, staying in the shade, and using sunscreen to prevent photoaging and skin cancer (Fauziyyah et al., 2023). However, shade or sun avoidance may limit outdoor activity and vitamin D, and potentially cause some people to develop excessive fear of the sun. Sunscreen can also cause skin reactions, specifically irritant, allergic, phototoxic, or photoallergic. Nanoparticles in physical sunscreens and spray forms can add risks from free radicals, inhalation, or flammability (Gabros et al., 2023). Therefore, while prevention is most effective, essential oils (EOs) offer a natural option with antioxidant, anti-aging, and anti-inflammatory properties (Poon et al., 2015). Although essential oils have many benefits for skin health, there is still not enough strong evidence that they can effectively protect against UVB damage, and more cell-based studies are needed to confirm their preventive effects on photoaging and UV-related skin damage.

In this study, two essential oils were investigated for their ability to protect skin cells from damage caused by UV exposure, focusing on their ability to reduce oxidative stress and inflammation induced by ultraviolet radiation. Among them, *Boswellia carterii* and *Cistus ladanifer* were selected for comparative in-vitro evaluation of their ability to prevent or reduce UVB-induced damage in human keratinocytes. *Boswellia carterii,* also called frankincense (FEO), contains α-pinene and linalool that suppress COX-2 and NF-κB activity, reducing inflammation and oxidative stress (Kotb et al., 2023). *Cistus ladanifer*, also called labdanum cistus (LCEO), has extracts rich in polyphenols like myricitrin and epigallocatechin gallate that provide strong photoprotective and antioxidant effects (Kielar et al., 2025).

This study focuses on examining the preventive ability of selected essential oils, chosen for their potential antioxidant, anti-inflammatory, and photoprotective properties, to maintain cell viability and protect HaCaT keratinocytes from UVB-induced stress through a preliminary in vitro screening. In a study by Maciel et al. (2019), keratinocytes were identified as key epidermal cells for in vitro studies

on skin irradiation. The HaCaT cell line, known for its stability and strong antioxidant defenses, is more UV-resistant than 3T3 fibroblasts, making it suitable for assessing protective effects against UV damage. Essential oils show antioxidant, anti-inflammatory, and photoprotective properties that reduce ROS, improve cell survival, and activate Nrf2/HO-1 pathways (Lin et al., 2025). Although many essential oils have been studied for their antioxidant and skin-protective effects, few studies have directly compared *Cistus ladanifer* and *Boswellia carterii* in the same UVB-induced damage model using HaCaT keratinocytes. Therefore, this study aims to address this gap by evaluating the effects of these essential oils under the same experimental conditions, using concentrations that are effective yet non-toxic to the cells.

1.2 Objective

This study aims to investigate the preventive potential of FEO and LCEO in protecting HaCaT keratinocytes from UVB-induced damage. It will assess how both essential oils affect cell viability using the MTS assay and trypan blue exclusion assay, then migration using the scratch assay after UVB exposure. The study will also determine non-toxic concentrations of FEO and LCEO, examine their preventive effects using an in vitro UVB-damaged HaCaT keratinocyte model.

1.3 Hypothesis

It is hypothesized that FEO and LCEO will exert a preventive effect in UVB-induced damage HaCaT keratinocytes, improving cell viability and cell migration compared with UVB-only group.