



Review Article

Natural Plant-Based Bioactive for Skin Anti-Ageing: A Review of Antioxidant, Anti-Inflammatory, Collagen-Protective and Photoprotective Properties

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ABSTRACT

Skin ageing is influenced by intrinsic biological changes and external stressors such as ultraviolet radiation and environmental pollution. Excessive reactive oxygen species, inflammation, collagen degradation, and impaired skin barrier function contribute to wrinkles, pigmentation, loss of elasticity, and other visible signs of ageing. This review highlights the potential of selected plant-derived bioactives, including Terminalia chebula, bakuchiol from Psoralea corylifolia, Centella asiatica, Glycyrrhiza glabra, and Matricaria chamomilla, in combating skin ageing. Their reported activities include antioxidant and anti-inflammatory effects, inhibition of matrix metalloproteinases, protection of collagen, photoprotection, and support of skin barrier integrity. These bioactives may act through multiple pathways associated with oxidative stress, inflammatory signalling, extracellular matrix degradation, and collagen maintenance. Overall, plant-derived compounds represent promising multifunctional candidates for natural anti-ageing and cosmeceutical applications. However, further standardized mechanistic studies and well-designed clinical investigations are needed to establish their efficacy, safety, and practical therapeutic potential.

KEYWORDS: Skin ageing; Natural products; Phytochemicals; Anti-ageing; Oxidative stress; Collagen; Matrix metalloproteinases; Photoprotection; Skin barrier; Cosmeceuticals; Medicinal plants; Bioactive compounds.

INTRODUCTION

Sensitive skin ageing is most visible sign of ageing and sensitive skin is very closely to come under the ageing before the age. The modification is characterized by the fine lines, wrinkles, photoaging, rough texture, loose elasticity and these are associated with uneven pigmentation. The most important surface barrier is the skin which provide the extremely protection to the human from the external factors including chemical, biological, physical irritants (most common UV radiation) and others. External factors ride directly or indirectly the production of reactive oxygen species (ROS) and cooperate with the redox imbalances which is common for the generation of free oxygen radicals, actively participate in series of pathological and physiological skin processes. (Federica et al. 2022)

The external and internal factors both leads to the damage of skin barrier which possess the loss of

equilibrium in oxidants and antioxidants balance and enhances the excessive ROS production. The mechanism is including DNA damage, inflammation, inhibition of collagen production, NF-κB pathways. During the ageing process augmented the reactive oxygen species and decrease the level of enzymatic and non-enzymatic benefactors. The antioxidant therapy may be powerful when applied on ageing skin. (Weng Zheng et al. 2017) In this section we discuss about the mechanistic approaches of the potent antioxidant Terminalia chebula (Chebula) and Psoralea corylifolia (Bakuchiol), both are diminishing visible signs of existing damage but also help defend skin against environmental pollutant which caused by chronic exposure. (Gupta PC et al. 2011) (Nizam et al. 2023)

Terminalia Chebula

Chebula, also known as Terminalia chebula, is a plant species that belongs to the Combretaceae family. It is

native to Southeast Asia and India, where it's been used for thousands of years in Ayurvedic medicine to treat TONS of health conditions. The fruit of the Chebula plant, also known as Haritaki, is the most commonly used part of the plant in Ayurvedic medicine. It is a small, yellowish-green fruit that grows on the tree, harvested in the autumn months. The fruit is rich in phytochemicals, including tannins, flavonoids, and polyphenols, responsible for its many health benefits. (Bhattacharya SK et al. 2013)

Mechanistic Approaches of Terminalia Chebula on sensitive ageing skin

External aggressors mediate the role of ageing skin by inducing the surplus levels of reactive oxygen species,

inflammation, other most champion factors are UV radiation and environmental pollutants which are more damage the skin layer undergo the pigmentation as well as photoaging. The study shown that Terminalia Chebula fruit extract display the anti-bacterial, anti-fungal, antioxidants and anti-inflammatory properties. (Singh P et al. 2017) (Rubini B et al. 2013)

Terminalia chebula fruit extract has ability to protect skin cells from oxidative and inflammatory stress which is increase by particulate matter pollution. It improves visible signs of ageing which damage by high pollution environment in an 8-week clinical study (Manpreet et al. 2021)

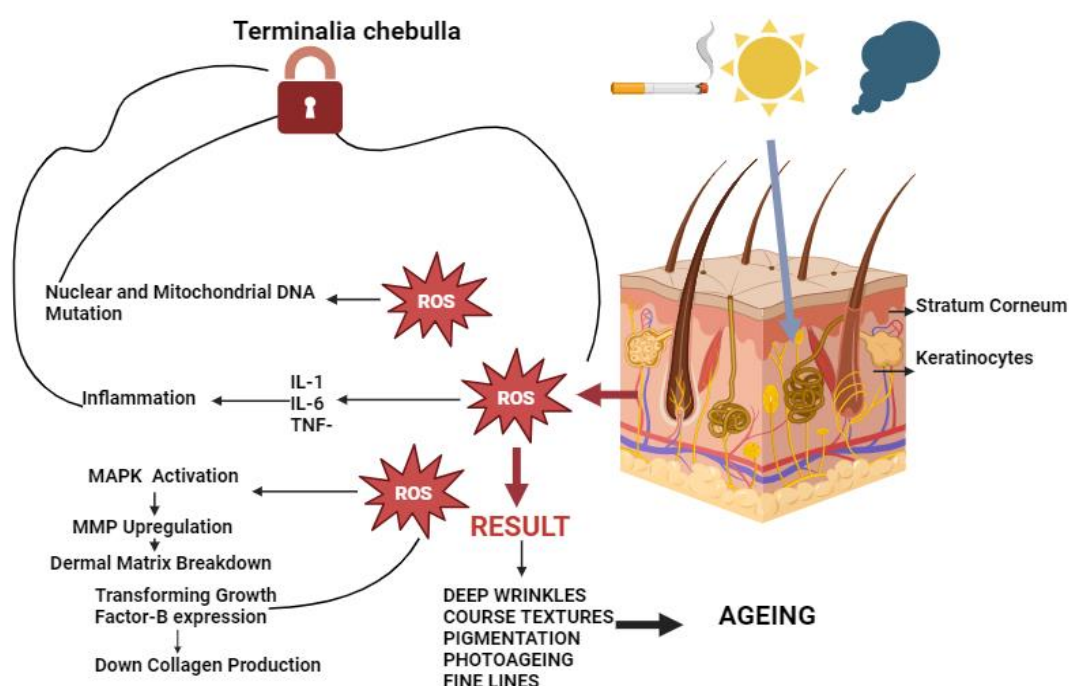


Figure 1: Schematic illustration of the multidirectional effects of Terminalia chebula counteracting sensitive skin ageing processes.

The mechanism of Terminalia chebula neutralize all the reactive form of reactive oxygen species as an antioxidant, inhibiting the matrix metalloproteinase (MMP), diminish the formation of advanced glycation end product actively accumulate on collagen and elastin with ageing. It also inhibits melanin formation that manage the hyperpigmentation which is beneficial for more even skin tone. (Swindell WR et al.2020)

Psoralea corylifolia (Bakuchiol)

Psoralea corylifolia is an erect annual herb which found in India in winter season, in every part of the Himalayan region of Pakistan, China (Sarah et al.2022). Bakuchiol is an emerging skin care agent with promising anti-agent, anti-inflammatory and anti-bacterial properties. It is meroterpene that has a great interest in cosmeceutical industry. (Nizam et al.2023). Bakuchiol was suggested to retinol like functions, in contrast retinal has been used

for skin care product since 1984. Both show similar gene expression pattern in vitro and improve the cutaneous photodamage in vivo. (Chaudhary RK et al.2014) (Dhaliwal et al.2019) Hence Bakuchiol plants also referred to as a retinoid's analogue. (Sadgrove NJ et al. 2021).

Mechanistic Approaches of Psoralea corylifolia (Bakuchiol) on sensitive ageing skin

Bakuchiol showed that high antioxidative power it decreases the oxidative stress and prevent mitochondrial lipid peroxidation which protect the mitochondria. Due to UV rays and pollution, the induction of ROS leads to inflammatory stress and also enhance the expression of proinflammatory cytokines like PGE2 and MIF. (Shim JH et al. 2019) PGE2 is generate major amount of prostaglandin in human skin and enhance matrix metalloproteinase 1(MMP-1) in fibroblast and this

process undergo in cutaneous ageing mechanism. (Li Y et al. 2015) Bakuchiol significantly reduces PGE2 level in dose dependent manner (Anika Bluemke et al. 2022)

MIF is another proinflammatory cytokines that's special role in cell proliferation, angiogenesis and differentiation. In ageing, both UVA and UVB radiation increases the MIF secretion by Keratinocytes and dermal Fibroblast. Bakuchiol has anti-inflammatory property which reduces the MIF protein. (Araujo et al. 2019)

Novel research show that bakuchiol might support skin regeneration and repair processes by directly upregulating keratinocyte and indirectly increasing fibroblast proliferation. Bakuchiol thereby acts against the decline of growth factor levels that occurs during ageing. (Anika Bluemke et al. 2022)

Another impact of bakuchiol is regenerate the potential of skin which associate with the ageing by reducing growth rate of dermal fibroblast, an increase in WST-1 metabolism indicates an improved cell viability, proliferation, and metabolic activity. (Yin LM et al. 2013)

COL1A1 and COL7A1 is structural protein most abundantly found in skin. During ageing, fibroblast display a reduce capacity of both collagen protein synthesis. Maintain level of COL1A1 enhances the mechanical skin stability and reduce level of COL7A1 promote weak bond between dermis and epidermis. Bakuchiol significantly enhances expression levels of COL1 mRNA and significantly reduces MMP-1 mRNA levels. COL1A1 and COL7A1 protein expression are increased by bakuchiol. (Anika Bluemke et al. 2022)

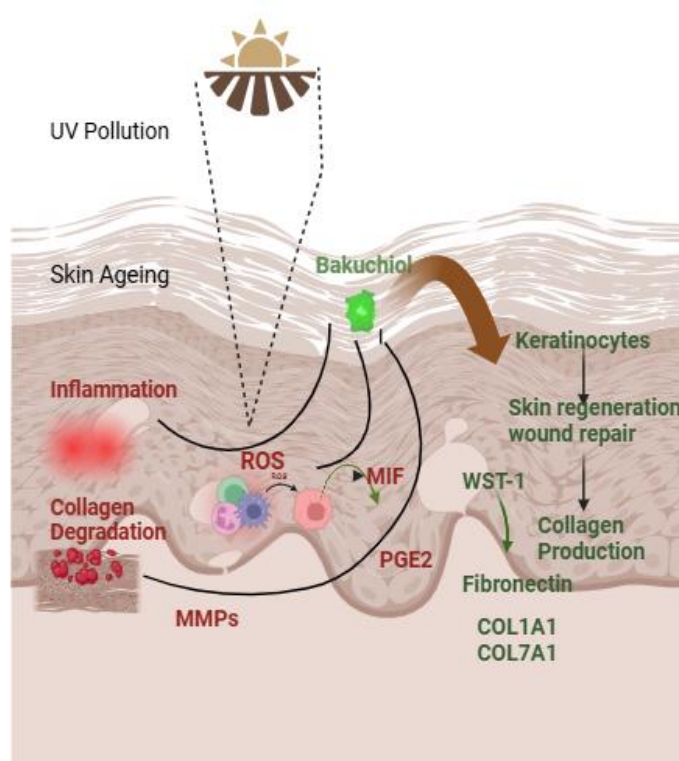


Figure 2: Schematic illustration of the multidirectional effects of bakuchiol counteracting sensitive skin ageing processes. (Red colour alphabet show inhibition and green colour alphabet show stimulation).

Centella asiatica (Gotu Kola): Centella asiatica commonly known as Indian pennywort belong to family Apiaceae known as gotu kola. It is found in Southeast Asia and traditionally used as brain stimulating in ayurvedic medicine. Generally, Centella asiatica use in treating skin problem like wound healing, revatitized nerve and brain cell. It has potential antimicrobial, antioxidant, neuroprotective, anti-inflammatory, hepatoprotective, immunostimulant, cardio protective and other activities widely claimed in many reports. (Tiwari et al. 2024)

The scientific studied suggest that many biochemical components have found in Centalla asiatica. The

chemical constituents of Centella asiatica plant have important medicinal properties. It is known for the biologically active components of saponins and triterpenes. It is rich source of amino acids, phenols, corbohydrates. Centella asiatica contains traces amount of alkaloids. The dried part of the plant contains Hydrocotylin which has been extracted by Centella asiatica. The plants also contain 38% volatile oils and fatty acids like glycerides, stearic acid, linoleic acid, palmitic acid, oleic acid. (Tiwari et al. 2024).

Mechanistic Approaches of *Centella asiatica* (Gotu Kola) on sensitive ageing skin

Centella asiatica molecular mechanisms in combating aging skin involve several key pathways:

- 1. Collagen Synthesis:** Active compounds like asiaticoside and madecassoside stimulate fibroblasts to produce collagen, enhancing skin elasticity and firmness.
- 2. Antioxidant Activity:** The plant's antioxidants neutralize free radicals, reducing oxidative stress and cellular damage.
- 3. Anti-Inflammatory Effects:** Compounds in *Centella asiatica* reduce inflammation, promoting a healthier skin appearance.
- 4. Telomerase Activity:** It may increase telomerase activity, maintaining telomere length and delaying cellular aging.
- 5. Inhibition of MMP-9:** Reduces matrix metalloproteinase-9 activity, preserving collagen and reducing wrinkle formation.
- 6. Enhanced Barrier Function:** Improves the skin's barrier, preventing water loss and keeping it hydrated. (Witkowska et al. 2024)

Glycyrrhiza glabra (Licorice): Licorice is indeed a fascinating plant with a rich history and wide distribution. *Glycyrrhiza glabra*, commonly known as licorice, is found across various regions including Italy, Spain, Turkey, the Caucasus, western China, and Central Asia. This species is the most extensively dispersed. (Cerulli et al. 2022)

Licorice is believed to have originated in Iraq, and it has been used for its medicinal properties for centuries. Its presence throughout Asia and parts of Europe highlights its adaptability and significance in traditional medicine. The biological effects of *Glycyrrhiza* extracts are

especially ascribable to the occurrence of specialized metabolites belonging to the flavonoid class. *Glycyrrhiza* spp. (*G. glabra*, *G. uralensis*, and *G. inflata*) along with their cosmeceutical activities categorized as skin anti-aging, photoprotective, hair care, and anti-acne. The anti-aging effect of *Glycyrrhiza* extracts, three main flavonoids namely licochalcone A, glabridin, and dehydroglyasperin C are the most investigated compounds. It is suggested that other molecules from licorice show that have cosmeceutical effects. (Wahab et al 2021)

Mechanistic Approaches of *Glycyrrhiza glabra* (Licorice) on sensitive ageing skin

We already discussed the ageing of skin to ROS through several factors including UV, enhance the matrix metalloproteinases (MMPs) activity which breakdown the collagen fibres. Study reported antiwrinkle activity by anti-oxidant mechanism has been proved for *G. glabra* extract at the dose of 150 mg/kg/day (Hooda et al. 2015). Moreover, Ciganovic et al. highlighted for *G. glabra* extract, obtained by a green ultrasound assisted extraction method using glycerol/water mixtures, a good anti-oxidant activity, tyrosinase, and elastase inhibitory activity as well as anti-inflammatory activity, leading to excellent anti-aging properties (Ciganovic et al. 2019).

The mechanism of licorice on sensitive skin that these types of skin expose easily with UV and extrinsic factors which induces the reactive oxygen species interfere with the activation of MAPK Pathway which induces Matrix metalloproteinases activity enhance the collagen and fibres degradation via activation by modulating AP-1 and NF-KB signalling. The principal mechanism of licorice inhibiting UV-B mediated MMPs expression via suppression of MAPK and AP-1 signalling (Ciganovic et al. 2019) which shown in figure 4.

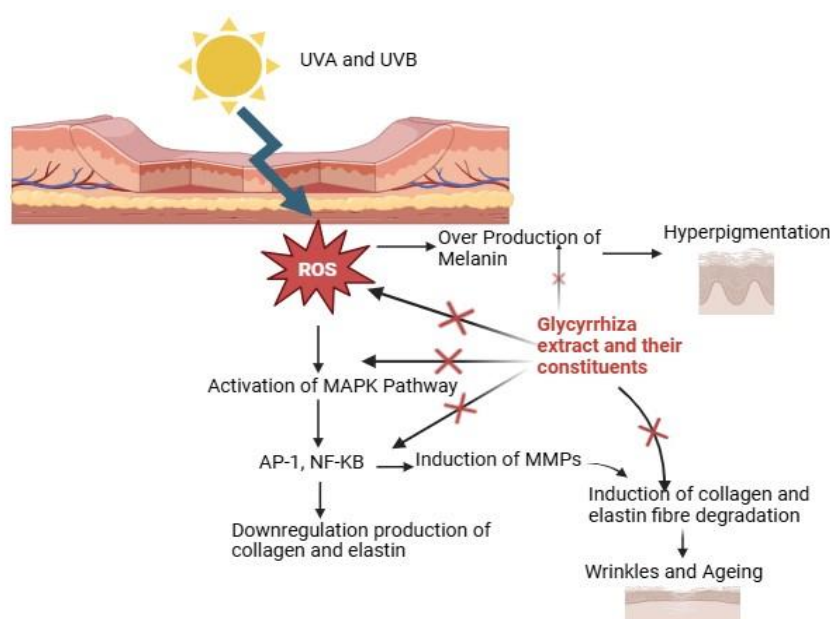


Figure 3: Schematic illustration of the multidirectional effects of Licorice counteracting sensitive skin ageing processes.

Matricaria chamomilla (Chamomile)

Matricaria chamomilla, a popular therapeutic plant which belongs to family Asteraceae. The medicinal and fragrant excellence this plant earned own nickname “the star of the medicinal plants.” Its also known as the name of chamomile due to its apple like scent, in the Greek word “chamaimlon” means “earth-apple. (Wasim et al. 2024)

Matricaria chamomilla includes various therapeutically valuable active chemical constituents. These include sesquiterpenes, flavonoids, coumarins, and polyacetylenes. The main constituents of the oil include mainly terpenoids, sesquiterpenes and α -bisabolol and another active component are chamazulene, apigenin, quercetin, patuletine and luteolin present. (Sah et al. 2022)

Mechanistic Approaches of Matricaria chamomilla (Chamomile) on sensitive ageing skin

Some researcher already discussed the biological activity of chamomile have anti- inflammatory activity,

antioxidant activity, anti-allergic activity, anti-microbial activity, analgesic, anticancer activity, hepatoprotective properties. But when it comes what is the mechanism of chamomile on sensitive ageing skin this can understand on the behalf of property of antioxidant activity.

Antioxidant and anti-inflammatory activities are linked to each other. Sensitive skin easily affected by the extrinsic and intrinsic factors. Normally free radicals produced in cell/tissue during normal physiology and proper functioning but excessive exposure induces excessive production of free radicals which is dreadful and causes the oxidative stress and damage cell, lipids and protein. Oxidative stress induces the expression of cyclooxygenase (COX) and Lipoxygenase (LOX) which further trigger the secretion of inflammatory mediators. Several studied proven to chamomile have antioxidant property and its chemical constituent apigenin strongly inhibited free radicals and damage H_2O_2 induction which also leads to oxidative stress. (Wanget al. 2020)

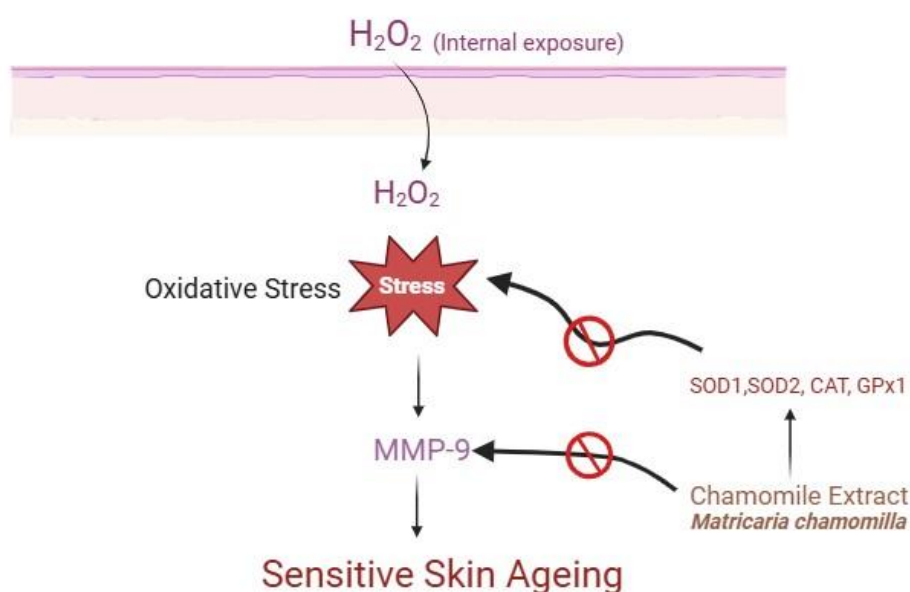


Figure 4: Schematic illustration of the multidirectional effects of Chamomile counteracting sensitive skin ageing processes.

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