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Review Article

Herbal products as skincare therapeutic agents against ultraviolet radiation-induced skin disorders

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ABSTRACT

This paper aims to highlight the pharmacological aspects of listed herbal skincare products used for the treatment of various disorders caused due to ultraviolet radiation. The pharmacological aspects include safety and efficacy validation as per regulatory guidelines following internationally accepted scientific principles for their development of skincare products. Herbal products have always been used traditionally for the treatment of various skin ailments and have become more prevalent because of their safety and high efficacy benefits. The incorporation of synthetic molecules and chemical substances in the different medicinal and pharmaceutical formulations is the leading cause of the dermal toxicity. Therefore, the developments of herbal skincare products containing scientifically validated herbal ingredients have better acceptance, respect, and belief in the society. The listed herbal products in this review can help take forward the commercial development of skincare products for therapeutic as well as beauty care purposes from such plants.

1. Introduction

The human skin plays a significant role in physiological functions of sensation, protection, thermoregulation, defense system, and metabolic mechanisms to help in maintaining homeostasis [1,2]. It is mostly exposed to different environmental factors such as harmful radiation, toxic chemicals, and pathogens [3]. The ultraviolet (UV) portion of sunlight is responsible for various skin disorders [4]. Continuous exposure to UVB leads to various adverse effects on the skin [5]. The increase in awareness about the photoaging and carcinogenic effects of UV radiation (UVR) resulted in tremendous increase in the demand for herbal skincare products. The most frequently used inorganic filters in the market possess titanium dioxide (TiO_2) and zinc oxide (ZnO). These UV filters are suggested to be the most frequent cause of dermal toxicity and contact allergy, which is caused by a wide range of chemicals present in sunscreens [6]. The herbal products exhibit various therapeutic properties and have always been used for centuries in the treatment of many skin disorders [7]. Several herbal products have been uncovered for their therapeutic potential and are gaining considerable attention in the market as skincare products [8]. Internationally, numerous studies have been conducted on many herbal products to reveal their therapeutic potential via various *in vivo* and *in vitro* models. However, future long-term studies and new approaches are required in this area [9].

2. Methodology

The literature published between 2003 and 2018 was searched on Pubmed and Google Scholar databases and as included in this review. The main keywords used were “skin”, “ultraviolet radiation”, “UVB”, “skin disorders”, “photodamage”, “photoaging”, “skin cancer”, “natural products”, “herbal products”, “photo-protection”, “sunscreens” and “skincare products”. The present review summarizes the published data over a hundred scientifically validated herbal products that include their biological and

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pharmacological information and various experimental models used to study skin photodamage.

3. Ultraviolet radiation (UVR)

Ultraviolet radiation is divided into three subtypes as UVA, UVB, and UVC as based on wavelengths and biological effects which are accountable for various skin disorders [4]. UVA has wavelengths between 320 and 400 nm and termed as long-wave radiation is absorbed by the deep dermis. UVB, also known as mid-UV, has wavelengths between 290 and 320 nm and is mostly consumed or dissipated within the epidermis and is significantly responsible for skin photodamage. UVB is a complete mutagen and more efficient than UVA in contributing most of the hazardous effects associated with sun exposure [10,11]. UVC, known as shorter UV, has wavelengths between 200 and 290 nm and is also absorbed within the epidermis and has germicidal property [12]. UVR can be both beneficial and harmful to human skin. The extent of UVR reaching into the earth's surface depends on latitude, altitude, season, daytime, cloudiness, and the ozone layer. The beneficial effects include Vitamin D production, killing different pathogens, and treating certain skin diseases like Psoriasis vulgaris and vitiligo. The damaging effects mostly include degradation of the extracellular matrix and all the significant risk factors associated with sunlight include sunburn, tanning, photoaging, and skin cancer development [13–15] (Fig. 1).

4. Environmental skin disorders

Photodamage is a type of skin disorder thatarises from the exposure of the skin to solar light or UVR which includes erythema, edema, hypermelanogenesis, oxidative stress, inflammation, immunosuppression, and further development of cutaneous malignancies.

4.1. Erythema (sunburn)

Erythema is an acute inflammatory response to continuous UVR exposure. The severity of erythema depends upon the rate and extent of skin exposure to UVR [16].

4.2. Hypermelanogenesis

UVR exposure to the skin may result in immediate pigmentation or delayed pigmentation response. UVR exposure to the skin elevates melanin synthesis, which increases number and activity of melanocytes, leading to the deposition of melanin granules in the upper layers of the epidermis [16].

4.3. UVR -induced epigenetic alterations

Epigenetics is the modification in gene expression, function, and generation of a heritable phenotype irrespective of change in DNA sequence. UVR-induced histone acetylation contributes to the UVR transcriptional response [17]. Epigenetic alterations are reversible, and therefore dietary food or bioactive compounds may have the ability to reverse, inhibit or delay the epigenetic modifications for the prevention of the disease [18].

4.4. UVR—induced microRNAs regulationec

MicroRNAs (miRNAs) are small non-coding RNAs which act as a regulator in post-transcriptional modifications. Recent studies show that miRNAs have been explored as a therapeutic target against UVR-induced cellular responses [19]. The diversity of miRNA targets determines their involvement in various cellular networks. miRNAs have shown to regulate many biological processes such as cell differentiation, proliferation, and apoptosis [20].

4.5. UVR-induced DNA damage and repair

Reactive oxygen species (ROS) generated by UVR irradiation can indirectly damage DNA bases which lead to dimerization and is considered as the biomarker of oxidative DNA damage [21]. The injury persists beyond repair leading to cell death by induction of the apoptosis pathway. If the DNA damage continues in the S-phase of the cell cycle, there is an increase in proliferation, which ultimately leads to skin carcinogenesis [22].

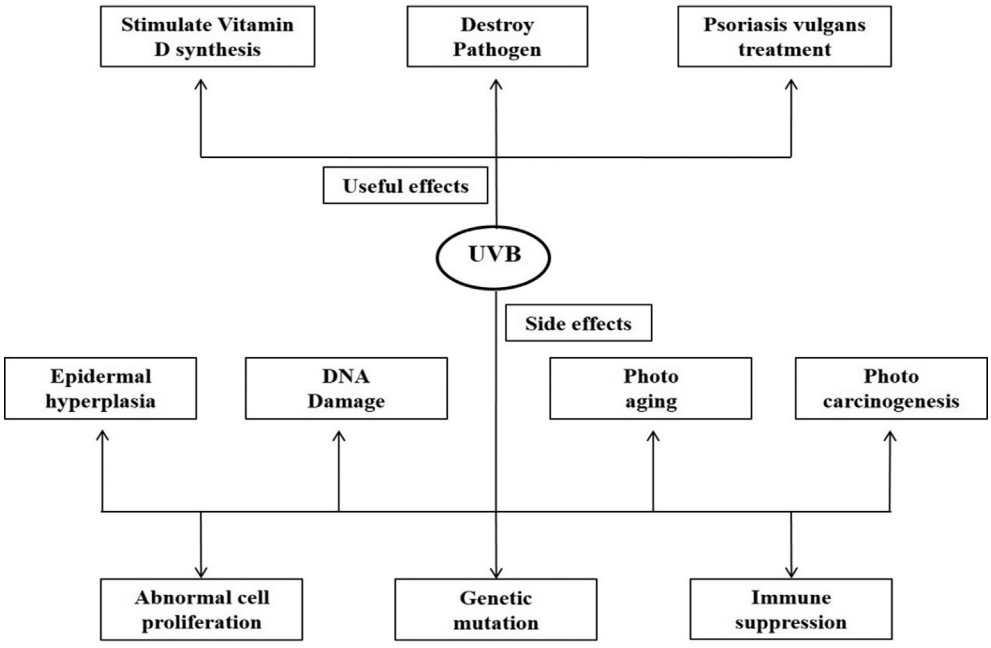

Fig. 1. Effects of UVR on the skin [12].

4.6. Immunological responses

UV radiation also affects the immune system and its exposure results in the generation of T-suppressor cells. UVR passes on suppressive effects on many immune parameters. The decrease in cellular immunity is responsible for various pathogens and loss of immune surveillance against tumors [23].

4.7. Photoaging

Aging is a natural and complicated process of progressive deterioration in the functioning of all organs in the body, including the skin. Intrinsic aging is a genetic phenomenon that occurs with time [24,25]. The onset of aging and its severity is exacerbated by exposure of skin to environmental factors. UVR is the most harmful factor which induces aging-like skin changes termed photoaging. Intrinsic photoaging is a time-dependent phenomenon that mainly depends on the extent of sun exposure and skin color [26,27]. Photoaging has more profound effects than an intrinsic one, accounting for about 90% of all the visible aging changes [28].

4.8. Photocarcinogenesis

Photocarcinogenesis is the unlimited growth of cells in the skin and is categorized into basal cell carcinomas (BCC), squamous cells carcinoma (SCC) (both specifically called non-melanocytic carcinomas), and cutaneous malignant melanomas. Cancer prevailing in basal layers of the epidermis is called basal cell carcinoma. It grows slowly and rarely spreads to other parts. SCC occurs in the middle layer of the epidermis and is considered more aggressive than BCC. Melanomas arise in the melanocytes; the cells are involved in melanin production and are responsible for 75% of all skin-related deaths. The survey from the past several years has found that there has been an increase in the prevalence of skin cancer. It has been assessed that approximately 1 in 5 Americans will develop skin cancer. It has been surveyed that over 2–3 million new cases of non-melanoma skin cancer (NMSC) appear per year globally, the highest rate among the Caucasian population [29–31].

Various natural products with their detailed molecular mechanism have been explored for their cellular photoprotective effects against UVR by utilizing different experimental models. Various studies revealed that topical application of almond oil has been found capable of preventing the structural damage caused by UV irradiation [32]. The inhibitory effect of encapsulated curcumin on UV-induced photoaging in mice has been examined [33]. *Amla* (*Emblica officinalis*) has been studied for its protective effect against UVB-induced photoaging [34]. Curcumin prevented UVR-induced transcriptional response in human keratinocytes [17]. A recent study showed the decreased expression of miRNAs in epigallocatechin gallate-mediated UVB protection in human dermal fibroblasts [35]. Glycyrrhizic acid prevented the oxidative stress-mediated DNA damage response through modulation of autophagy in UVB-irradiated human primary dermal fibroblasts [36].

5. Molecular signaling pathways induced by UVR

UVR exposure stimulates the production of ROS which overwhelms the defense mechanism of the skin, making endogenous cytoprotectants insufficient and causes alterations in inflammatory mediators, vascularity, and infiltration of inflammatory cells [7]. ROS stimulates various intracellular signaling pathways including mitogen-activated protein kinases (MAPK) and alters primarily the mitochondrial pathway, leading to cell death [37,38]. The generation of ROS by UVR acts as a mediator to activate several signaling cascades for various cellular responses. Therefore, the inhibition of ROS-induced signaling pathways can help to protect skin cells from UVR [39,40]. Moreover, the altered expression of various components (MMPs, cytokines) leads to various pathophysiological conditions. This will provide an ideal framework for more specific targets for the assessment of risk factors, diagnostic biomarkers, and effective therapeutic alternatives for studying various molecular signalling pathways induced by UVR [41] (Fig. 2).

6. Traditionally used plants for skin disorders

Plant-derived products have been used for medicinal purposes for centuries and the earliest records from 2900–2600 BC document the use of approximately 1000 plants, such as oil of *Cedrus species* (cedar), *Commiphora myrrha* (myrrh), *Cupressus sempervirens* (cypress), *Glycyrrhiza glabra* (Liquorice), and *Papaver somniferum* (opium) [42]. Various natural phytoingredients (curcumin, silymarin, ginkgo biloba) have been exploited for their cellular protective effects with the detailed mechanisms in different experimental models [41]. Herbal products from the plant's sources for cosmetic or skin pathological states have always been popular because of several advantages such as fewer side-effects, better patient tolerance, being cheaper and acceptable due to the long history of use. These include aloe vera, grapevine, ginseng, green tea, tea tree oil, rosemary, lemon, soybean, papaya, garlic, ginkgo, olive oil, and Ocimum [43] (Table 1).

7. Pros and cons of commercially available sunscreens

Currently, cosmaceutics, wherein biocative ingredients are used, are more preferred over synthetic molecules or chemical substances mainly due to safety issues in long-term treatment, which leads to dermal toxicity. The increase in awareness about the carcinogenic and photoaging effects of UVR and socio-economic upliftment of the society has resulted in a tremendous increase in the demand of herbal skincare products, especially sunscreen products by the society. The sunscreens mostly employ inorganic UV filters and show protection against solar radiation, which involves physical phenomena, i.e., scattering and reflection of UVR. The most frequently used inorganic filters are titanium dioxide (TiO_2) and zinc oxide (ZnO) which reflects the UV light, and tend to be opaque and white on the skin, and consequently is unacceptable for cosmetic use. The other oxides used are alumina, ceria, and zirconia. These oxides are formulated as nanoparticles, which decreases the reflection of visible radiation and, thereby, produces less white coloration when applied to the skin, and confers additional beneficial and efficacious photoprotection. According to Balogh et al., although sunscreens report several advantages, they also have numerous safety challenges that need to be overcome [53,54].

These inorganic UV filters are suggested to be the most frequent cause of dermal toxicity, such as photo-contact allergy which is caused by a wide range of synthetic molecules or chemical substances present in sunscreens [6]. The photo-toxicity of TiO_2 nanoparticles has been a severe concern [55]. Benzophenone-3 is one of the major causes of allergic reactions, especially contact dermatitis. The research on the use of herbal products is steadily increasing to overcome the occurrence of harmful effects associated with sunscreen products [56].

The use of safe cosmetic agents is essential for the prevention and treatment of UVR-induced skin disorders. There is a need to develop new herbal formulations that are safe and efficient. The history of the use of herbal products for the treatment of various dermatological agents for skincare purposes is as old as human civilization. Therefore, there is a wide scope for the development of new herbal formulations based on herbal ingredients which are efficient and scientifically validated in various *in vivo* and *in vitro* systemss.

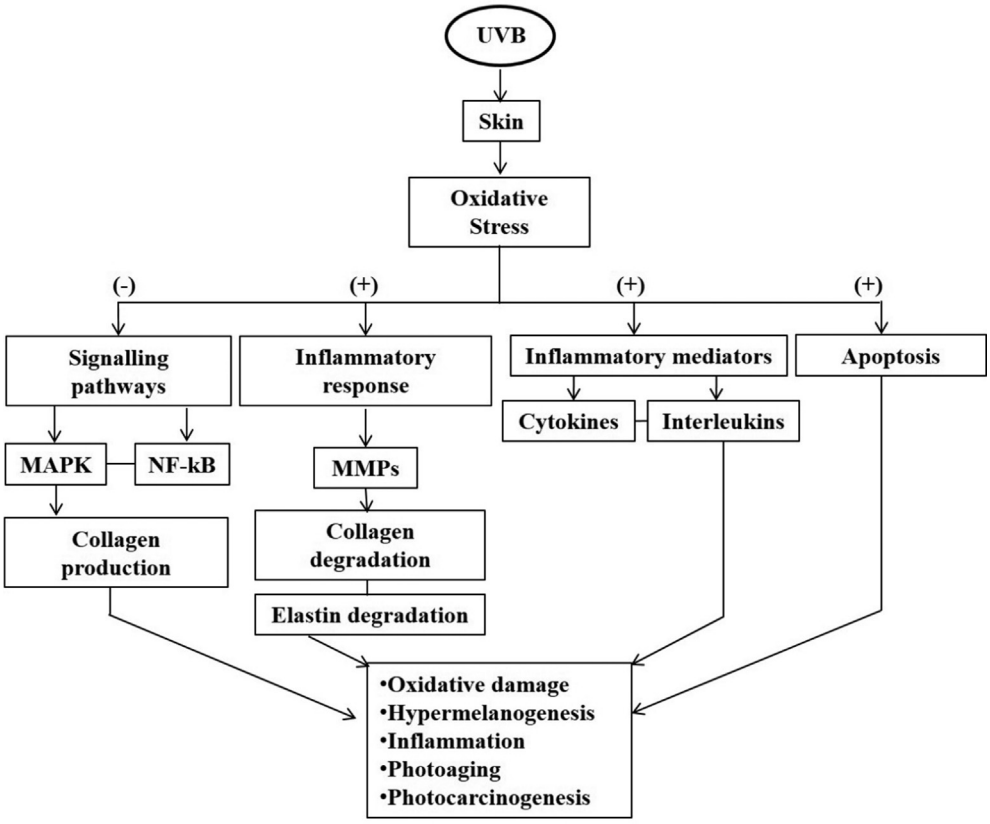

Fig. 2. Mechanism of UVB induced skin photodamage and central pathways affected by chronic exposure of the skin to UVB radiation [40].

8. Herbal skincare products as a therapeutic alternative

Herbal skincare products are now-a-days more preferred and chosen by people because of their fewer side-effects and cost-effectiveness [57]. Traditionally, herbal products are applied to a particular area or a part of the skin for the treatment of various skin ailments. The topical formulations can be classified into creams, gels, ointments, lotions, and foams [58,59].

The herbal products exhibit various therapeutic properties such as anti-oxidant, anti-inflammatory, anti-viral, cardio-protective, neuroprotective, and hepato-protective properties [7]. Many plants-derived natural molecules such as alkaloids, flavonoids, isoflavones, proanthocyanidins, phenolic compounds, and essential oils are associated with the treatment of many dermatological disorders. Several herbal products have been uncovered for their therapeutic potential against UV irradiation and are gaining considerable attention [8]. The photoprotective properties of such herbal products regarding safety and efficacy need to be validated as per the regulatory guidelines which follows internationally accepted scientific principles. It is requisite for the development of such herbal skincare products possessing strong therapeutic potential for the treatment of UVB-induced skin disorders and a better quality of life [60]. The combination of different herbal products may result in their synergistic effect. This will further help in pre-clinical and clinical investigations in the area of dermatology.

Table 1
Represents traditionally used plants for various skin disorders.

S. No.	Plant binomial name	Common name	Family	Therapeutic use	Reference
1.	*Aloe barbadensis*	*Aloe vera*	Asphodelaceae	Cuts, burns and eczema	[44]
2.	*Azadirachta indica*	Neem	Meliaceae	Immuno-modulator, anti-inflammatory, anti-malarial, anti-fungal, anti-bacterial, anti-viral, anti-oxidant, anti-mutagenic and anti-carcinogenic.	[45]
3.	*Carica papaya* L.	Papaya	Caricaceae	Eczema, dermatitis and psoriasis	[46]
4.	*Curcuma longa*	Turmeric	Zingiberaceae	Scleroderma and anti-inflammatory	[47]
5.	*Emblica officinalis*	Amla	Phyllanthaceae	Anti-aging and skin disorders	[48]
6.	*Gingko biloba*	Gingko	Ginkgoaceae	Wound healing	[49]
7.	*Glycyrrhiza glabra*	Liquorice	Fabaceae	Anti-inflammatory, anti-microbial, anti-oxidative, anti-cancer and immune-modulator	[50]
8.	*Ocimum sanctum*	Tulsi	Labiatae	Anti-microbial, immune-modulator, anti-stress and anti-inflammatory	[51]
9.	*Psoralea corylifolia*	Babchi	Leguminosae	Psoriasis, leukoderma, and leprosy	[52]
10.	*Santalum album* L.	Sandalwood	Santalaceae	Acne, eczema, atopic dermatitis, psoriasis, anti-inflammatory, anti-microbial and anti-proliferative	[41]

9. Scientific investigation of herbal products against UVR-induced skin disorders

UVR has many deleterious effects on human skin. Among these results, photoaging and skin cancer are of great concern [56]. Due to changes in lifestyle and awareness about the dangers of the UVR, there has been a significant upsurge in research in the area of the use of herbal products for the prevention and treatment of UVR-induced skin disorders. There is a need to understand novel therapeutic targets which are involved in the progression of UVR−induced skin disorders [61]. These herbal products are mostly rich in polyphenols, flavonoids, and have a noticeable activity that can impede the skin from the deleterious effects of UVR. These herbal products should be incorporated for the development of herbal skincare products [62]. Internationally, many herbal products have been studied which had shown novel therapeutic potential for the prevention and treatment of UVR-induced skin disorders (Refer to supplementary table 2).

However, scanty reports are available on the skin beneficial effects of herbal products on skin photodamage, photoaging, and photo-carcinogenesis. These findings help in understanding the fact that there is a tremendous need to study various herbal products for their skin beneficial effects. There is a need for the development of herbal formulation based on scientifically validated herbal products for therapeutic as well as beautification purposes.

10. Discussion

Skin is the largest organ and continuous exposure to UVR leads to different pathological and dermatological conditions. UVR acts as a mediator to activate several signaling cascades for various cellular responses. The increase in consciousness about the carcinogenic and photoaging effects of UVR and socio-economic improvement of the society has resulted in the increased demand for herbal skincare products, especially sunscreen products. Currently, cosmaceutics, are more preferred over synthetic molecule or chemical substances due to safety issues related to dermal toxicity. The research on the use of herbal products is steadily increasing to overcome the occurrence of harmful effects associated with sunscreen products using inorganic filters. Herbal products have always been used traditionally for the treatment of various skin ailments. There is a need to develop new herbal formulations that are safe and efficient. The listed herbal products in this paper have shown skin beneficial effects against UVR-induced skin disorders in various experimental models which recapitulate the same in humans. It is requisite for the development of such herbal skincare products possessing strong therapeutic potential for the treatment of UVB-induced skin disorders and a better quality of life. A lot has been done in the last decade for the safety and efficacy of herbal products for discussing more active natural products for skincare.

11. Conclusion

This review provides the summarized information of listed herbal skincare products used for the treatment of various disorders caused due to UVR. These products were scientifically validated as per the regulatory guidelines which follow internationally accepted scientific principles. The data of these listed herbal products including biological, pharmacological information, and experimental models have been summarized and transformed into tabular forms. These herbal products can be taken forward for formulation and development purposes as skincare products for therapeutic as well as beauty care uses.

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Conflict of interest

None.

Author contributions

RRS: Contributed to the literature review, writing of MS, and its formatting.

AD: Contributed to the writing of MS.

STA: Contributed to the design of MS, Literature review, Writing, Editing, and Formatting of the MS.

Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.jaim.2021.07.016.

References

[1] Lai-Cheong JE, McGrath JA. Structure and function of skin, hair and nails. Medicine 2009;37(5):223−6.
[2] Wysocki A, Mustoe T, Schultz G. Molecular cell biology of skin. Rev Cell Biol Mol Med 2006:217−50.
[3] Celleno L, Tamburi F. Structure and function of the skin. Nutr Cosmetics: Beauty from Within 2009:3−45.
[4] Venus M, Waterman J, McNab I. Basic physiology of the skin. Surgery 2010;29(10):471−4.
[5] Im AR, Song JH, Lee MY, Chae S. Magnolol reduces UVB-induced photodamage by regulating matrix metalloproteinase activity. Environ Toxicol Pharmacol 2015;39(1):417−23.
[6] Karlsson I, Hillerström L, Stenfeldt A-L, Mårtensson J, Börje A. Photodegradation of dibenzoylmethanes: potential cause of photocontact allergy to sunscreens. Chem Res Toxicol 2009;22(11):1881−92.
[7] Afnan Q, Kaiser PJ, Rafiq RA, Nazir LA, Bhushan S, Bhardwaj SC, et al. Glycyrrhizic acid prevents ultraviolet-B-induced photodamage: a role for mitogen-activated protein kinases, nuclear factor kappa B and mitochondrial apoptotic pathway. Exp Dermatol 2016;25(6):440−6.
[8] Afaq F, K Katiyar S. Polyphenols: skin photoprotection and inhibition of photocarcinogenesis. Mini Rev Med Chem 2011;11(14):1200−15.
[9] Katiyar SK, Matsui MS, Elmets CA, Mukhtar H. Polyphenolic antioxidant (-)-Epigallocatechin-3-Gallate from green tea reduces UVB-induced inflammatory responses and infiltration of leukocytes in human skin. Photochem Photobiol 1999;69(2):148−53.
[10] Ramachandran S, Prasad NR, Karthikeyan S. Sesamol inhibits UVB-induced ROS generation and subsequent oxidative damage in cultured human skin dermal fibroblasts. Arch Dermatol Res 2010;302(10):733−44.
[11] Johnson S, Frogley J. Brighter than sunshine. 2010. p. 2010.
[12] Kaidbey KH, Kligman AM. The acute effects of long-wave ultraviolet radiation on human skin. J Invest Dermatol 1979;72(5):253−6.
[13] Korać RR, Khambholja KM. Potential of herbs in skin protection from ultraviolet radiation. Phcog Rev 2011;5(10):164.
[14] Nghiem DX, Kazimi N, Clydesdale G, Ananthaswamy HN, Kripke ML, Ullrich SE. Ultraviolet A radiation suppresses an established immune response: implications for sunscreen design. J Invest Dermatol 2001;117(5):1193−9.
[15] Matsumura Y, Ananthaswamy HN. Short-term and long-term cellular and molecular events following UV irradiation of skin: implications for molecular medicine. Expet Rev Mol Med 2002;4(26):1−22.
[16] Hönigsmann H. Erythema and pigmentation. Photodermatol Photoimmunol Photomed 2002;18(2):75−81.
[17] Pollack BP, Sapkota B, Boss JM. Ultraviolet radiation-induced transcription is associated with gene-specific histone acetylation. Photochem Photobiol 2009;85(3):652−62.
[18] Katiyar SK, Singh T, Prasad R, Sun Q, Vaid M. Epigenetic alterations in ultraviolet radiation-induced skin carcinogenesis: interaction of bioactive dietary components on epigenetic targets. Photochem Photobiol 2012;88(5):1066−74.
[19] N Syed D, Imran Khan M, Shabbir M, Mukhtar H. MicroRNAs in skin response to UV radiation. Curr Drug Targets 2013;14(10):1128−34.

[20] Lee D, Shin C. MicroRNA–target interactions: new insights from genome-wide approaches. Ann N Y Acad Sci 2012;1271(1):118.
[21] Cadet J, Douki T, Pouget J-P, Ravanat J-L. Singlet oxygen DNA damage products: formation and measurement. Methods Enzymol 1999;319:143–53.
[22] Trautinger F. Mechanisms of photodamage of the skin and its functional consequences for skin ageing. Clin Exp Dermatol 2001;26(7):573–7.
[23] Simon J, Tigelaar R, Bergstresser P, Edelbaum D, Cruz P. Ultraviolet B radiation converts Langerhans cells from immunogenic to tolerogenic antigen-presenting cells. Induction of specific clonal anergy in CD4+ T helper 1 cells. J Immunol 1991;146(2):485–91.
[24] Gilchrest BA. Skin and aging processes. CRC Press; 1984.
[25] Langton A, Sherratt M, Griffiths C, Watson R. Review Article: a new wrinkle on old skin: the role of elastic fibres in skin ageing. Int J Cosmet Sci 2010;32(5):330–9.
[26] Thurstan SA, Gibbs NK, Langton AK, Griffiths CE, Watson RE, Sherratt MJ. Chemical consequences of cutaneous photoageing. Chem Cent J 2012;6(34):273–4.
[27] Pandel R, Poljšak B, Godic A, Dahmane R. Skin photoaging and the role of antioxidants in its prevention. ISRN Dermatol 2013;2013.
[28] Herschthal J, Kaufman J. Cutaneous aging: a review of the process and topical therapies. 2007.
[29] Diepgen T, Mahler V. The epidemiology of skin cancer. Br J Dermatol 2002;146(s61):1–6.
[30] Simões M, Sousa J, Pais A. Skin cancer and new treatment perspectives: a review. Cancer Lett 2015;357(1):8–42.
[31] De Gruijl F. Skin cancer and solar UV radiation. Eur J Cancer 1999;35(14):2003–9.
[32] Sultana Y, Kohli K, Athar M, Khar R, Aqil M. Effect of pre-treatment of almond oil on ultraviolet B–induced cutaneous photoaging in mice. J Cosmet Dermatol 2007;6(1):14–9.
[33] Agrawal R, Kaur IP. Inhibitory effect of encapsulated curcumin on ultraviolet-induced photoaging in mice. Rejuvenation Res 2010;13(4):397–410.
[34] Adil MD, Kaiser P, Satti NK, Zargar AM, Vishwakarma RA, Tasduq SA. Effect of Emblica officinalis (fruit) against UVB-induced photo-aging in human skin fibroblasts. J Ethnopharmacol 2010;132(1):109–14.
[35] An I-S, An S, Park S, Lee SN, Bae S. Involvement of microRNAs in epigallocatechin gallate-mediated UVB protection in human dermal fibroblasts. Oncol Rep 2013;29(1):253–9.
[36] Umar SA, Tanveer MA, Nazir LA, Divya G, Vishwakarma RA, Tasduq SA. Glycyrrhizic acid prevents oxidative stress mediated DNA damage response through modulation of autophagy in ultraviolet-B-irradiated human primary dermal fibroblasts. Cell Physiol Biochem 2019;53(1):242–57.
[37] Afaq F, Ahmad N, Mukhtar H. Suppression of UVB-induced phosphorylation of mitogen-activated protein kinases and nuclear factor kappa B by green tea polyphenol in SKH-1 hairless mice. Oncogene 2003;22(58):9254–64.
[38] Assefa Z, Van Laethem A, Garmyn M, Agostinis P. Ultraviolet radiation-induced apoptosis in keratinocytes: on the role of cytosolic factors. Biochim Biophys Acta Rev Cancer 2005;1755(2):90–106.
[39] Kang S, Chung JH, Lee JH, Fisher GJ, Wan YS, Duell EA, et al. Topical N-acetyl cysteine and genistein prevent ultraviolet-light-induced signaling that leads to photoaging in human skin in vivo. J Invest Dermatol 2003;120(5):835–41.
[40] Cooper S, Bowden G. Ultraviolet B regulation of transcription factor families: roles of nuclear factor-kappa B (NF-κB) and activator protein-1 (AP-1) in UVB-induced skin carcinogenesis. Curr Cancer Drug Targets 2007;7(4):325.
[41] Ahmad A, Ahmad R. Understanding the mechanism of hepatic fibrosis and potential therapeutic approaches. Saudi J Gastroenterol: Off J Saudi Gastroenterol Assoc 2012;18(3):155.
[42] Borchardt JK. The beginnings of drug therapy: ancient mesopotamian medicine. Drug News Perspect 2002;15(3):187–92.
[43] Pazyar N, Yaghoobi R, Rafiee E, Mehrabian A, Feily A. Skin wound healing and phytomedicine: a review. Skin Pharmacol Physiol 2014;27(6):303–10.
[44] Rajeswari R, Umadevi M, Rahale CS, Pushpa R, Selvavenkadesh S, Kumar KS, et al. Aloe vera: the miracle plant its medicinal and traditional uses in India. J Pharmacogn Phytochem 2012;1(4):118–24.
[45] Subapriya R, Nagini S. Medicinal properties of neem leaves: a review. Curr Med Chem Anti Cancer Agents 2005;5(2):149–56.
[46] Nguyen TT, Shaw PN, Parat MO, Hewavitharana AK. Anticancer activity of C arica papaya: a review. Mol Nutr Food Res 2013;57(1):153–64.
[47] Thangapazham RL, Sharma A, Maheshwari RK. Beneficial role of curcumin in skin diseases. In: The molecular targets and therapeutic uses of curcumin in health and disease. Springer; 2007. p. 343–57.
[48] Kumar KS, Bhowmik D, Dutta A, Yadav AP, Paswan S, Srivastava S, et al. Recent trends in potential traditional Indian herbs Emblica officinalis and its medicinal importance. J Pharmacogn Phytochem 2012;1(1):18–28.
[49] Bairy K, Rao C. Wound healing profiles of Ginkgo biloba. J Nat Remedies 2001;1(1):25–7.
[50] Anilkumar D, Joshi H, Nishteswar K. Review of glycyrrhiza glabra (yastimadhu)-a broad spectrum herbal drug. Pharma Sci Monit 2012;3(4).
[51] Mondal S, Mirdha BR, Mahapatra SC. The science behind sacredness of Tulsi (Ocimum sanctum Linn.). Indian J Physiol Pharmacol 2009;53(4):291–306.
[52] Khushboo P, Jadhav V, Kadam V, Sathe N. Psoralea corylifolia Linn.—"Kushtanashini". Phcog Rev 2010;4(7):69.
[53] Manaia EB, Kaminski RCK, Corrêa MA, Chiavacci LA. Inorganic UV filters. Braz J Pharmaceut Sci 2013;49(2):201–9.
[54] Afaq F, Adhami VM, Mukhtar H. Photochemoprevention of ultraviolet B signaling and photocarcinogenesis. Mutat Res Fund Mol Mech Mutagen 2005;571(1–2):153–73.
[55] Horie M, Sugino S, Kato H, Tabei Y, Nakamura A, Yoshida Y. Does photocatalytic activity of TiO2 nanoparticles correspond to photo-cytotoxicity? Cellular uptake of TiO2 nanoparticles is important in their photo-cytotoxicity. Toxicol Mech Methods 2016;26(4):284–94.
[56] Lautenschlager S, Wulf HC, Pittelkow MR. Photoprotection. Lancet 2007;370(9586):528–37.
[57] Mukherjee PK, Maity N, Nema NK, Sarkar BK. Bioactive compounds from natural resources against skin aging. Phytomedicine 2011;19(1):64–73.
[58] Jamadar MJ, Shaikh RH. Preparation and evaluation of herbal gel formulation. J Pharmaceut Edu Res 2017;1(2):201–24.
[59] Mishra U, Murthy PN, Pasa G, Nayak RK. Formulation and evaluation of herbal gel containing methanolic extract of ziziphus xylopyrus. Asian J Biochem Pharmaceut Res 2011;4(1).
[60] Kraft JN, Lynde CW. Moisturizers: what they are and a practical approach to product selection. Skin Therapy Lett 2005;10(5):1–8.
[61] Datta HS, Paramesh R. Trends in aging and skin care: ayurvedic concepts. J Ayurveda Integr Med 2010;1(2):110.
[62] Pinnell SR. Cutaneous photodamage, oxidative stress, and topical antioxidant protection. J Am Acad Dermatol 2003;48(1):1–22.