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DEVELOPMENT AND EVALUATION OF ANTI-AGING CREAM WITH ANTIOXIDANT RICH HERBAL EXTRACTS

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Abstract:

Skin aging is a gradual biological process influenced by both intrinsic and extrinsic factors, with oxidative stress playing a major role. This review emphasizes the formulation and evaluation of herbal antioxidant-rich anti-aging creams utilizing natural extracts such as Aloe vera, green tea, turmeric, grape seed, pomegranate, and licorice. These botanicals contain polyphenols, flavonoids, and vitamins that neutralize free radicals, protect collagen and elastin fibers, and enhance skin elasticity. The review also highlights formulation techniques, evaluation parameters, and stability aspects, presenting herbal antioxidants as safe, effective, and sustainable alternatives to synthetic anti-aging agents.

Abbreviations :*ROS – Reactive Oxygen Species,UV – Ultraviolet,DPPH – 2,2-Diphenyl-1-picrylhydrazyl,EGCG – Epigallocatechin Gallate,O/W – Oil-in-Water,pH – Potential of Hydrogen,MMP – Matrix Metalloproteinase*

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INTRODUCTION:

The skin, the largest organ of the human body, acts as a vital protective barrier against environmental aggressors, mechanical injury, microorganisms, and ultraviolet radiation. It not only protects internal organs but also performs several physiological functions, including thermoregulation, sensory perception, and synthesis of vitamin D upon exposure to sunlight. Skin aging, both intrinsic and extrinsic, is a multifactorial process influenced by genetic, metabolic, and environmental factors. Over time, the skin undergoes visible and structural changes such as fine lines, wrinkles, pigmentation, and loss of elasticity. The increasing awareness of skin health has encouraged scientific exploration of natural bioactive compounds and herbal formulations to delay or reverse signs of aging.[1]

Structure of the Skin

The human skin comprises three main layers: the epidermis, dermis, and hypodermis. Each layer performs distinct functions essential for maintaining skin health, texture, and appearance. The epidermis serves as the outermost protective barrier composed primarily of keratinocytes arranged in several layers. It contains melanocytes responsible for pigmentation, Langerhans cells for immune defense, and Merkel cells for sensory perception. The dermis, located beneath the epidermis, is a connective tissue layer composed of collagen and elastin fibers embedded in a matrix of proteoglycans and glycosaminoglycans. It provides mechanical strength, elasticity, and support for skin appendages such as sweat glands, sebaceous glands, and hair follicles. The hypodermis, or subcutaneous layer, mainly consists of adipose tissue that insulates the body, cushions internal organs, and maintains skin contour.[2]

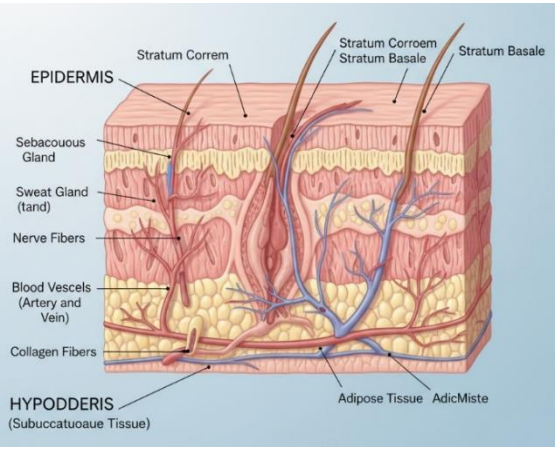

Fig. 1: Structure of Human Skin showing Epidermis, Dermis, and Hypodermis.

Process of Skin Aging

Skin aging is an inevitable process influenced by both **intrinsic** and **extrinsic** mechanisms. Intrinsic or chronological aging occurs naturally over time, primarily due to genetic and metabolic changes. It leads to thinning of the epidermis, decreased fibroblast activity, reduced collagen synthesis, and diminished elasticity. Extrinsic aging, often termed **photoaging**, results from external factors such as ultraviolet (UV) radiation, air pollution, smoking, poor nutrition, and stress. Among these, UV radiation is the most significant contributor, responsible for approximately 80% of visible facial aging. UV exposure induces the production of reactive oxygen species (ROS), which trigger oxidative stress, inflammation, and the activation of matrix metalloproteinases (MMPs) that degrade collagen and elastin fibers.[3]

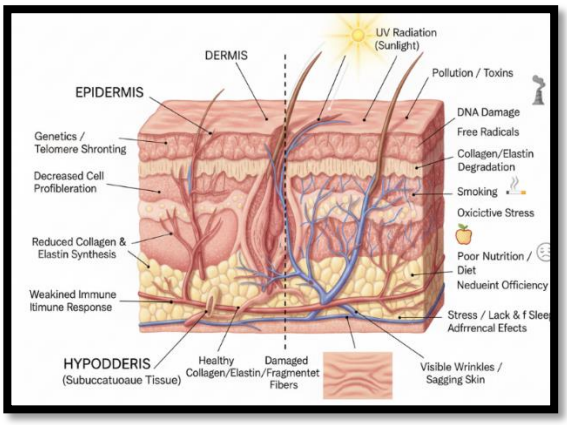

Fig. 2: Mechanism of Skin Aging illustrating Intrinsic and Extrinsic Factors.

Role of Oxidative Stress in Skin Aging

Oxidative stress arises when the balance between free radical generation and antioxidant defense is disrupted. Free radicals such as superoxide anion (O_2^-), hydroxyl radicals (•OH), and hydrogen peroxide (H_2O_2) are highly reactive molecules that damage lipids, proteins, and DNA within skin cells. This oxidative damage accelerates the breakdown of collagen and elastin fibers in the dermis, leading to wrinkle formation and loss of elasticity. Furthermore, ROS alter signaling pathways that control cell growth and repair, resulting in premature aging. Antioxidants play a crucial role in maintaining the redox balance by neutralizing these reactive species and protecting the skin from oxidative deterioration.[4]

Role of Antioxidants in Skin Protection

Antioxidants can be either endogenous, produced naturally within the body, or exogenous, obtained through diet or topical application. Enzymatic antioxidants such as superoxide dismutase (SOD), catalase, and glutathione peroxidase neutralize free radicals through biochemical reactions. Non-enzymatic antioxidants, including vitamins C and E, carotenoids, polyphenols, and flavonoids, provide additional defense by donating electrons to stabilize free radicals. The continuous use of topical formulations containing antioxidants replenishes the

skin's defense system, restores elasticity, and reduces visible signs of aging. Herbal extracts, rich in bioactive phytoconstituents, have shown promising antioxidant and rejuvenating properties, making them suitable alternatives to synthetic agents that often cause irritation or hypersensitivity.[5]

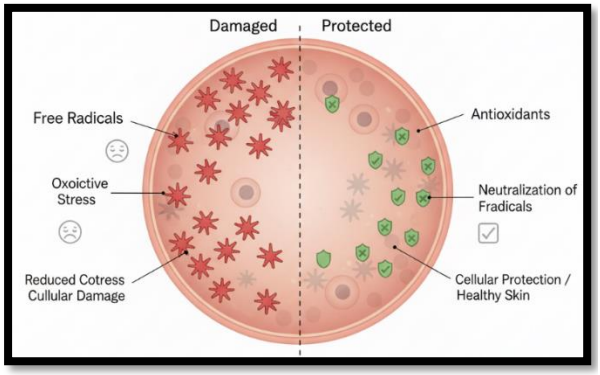

Fig. 3: Role of Antioxidants in Preventing Oxidative Stress in Skin Cells.

Herbal Approach to Anti-Aging Therapy

In recent years, there has been a significant shift toward herbal and natural skincare products. Consumers prefer plant-based ingredients due to their safety, biodegradability, and synergistic therapeutic effects. Various herbal extracts such as Aloe vera, green tea, turmeric, grape seed, pomegranate, and licorice are widely studied for their anti-aging efficacy. These botanicals contain polyphenols, flavonoids, tannins, and vitamins that exhibit strong antioxidant, anti-inflammatory, and collagen-stimulating properties.[6]

Aloe vera contains polysaccharides, amino acids, and vitamins that enhance hydration, soothe irritation, and promote wound healing. Green tea, rich in epigallocatechin gallate (EGCG), exhibits photoprotective and antioxidant effects by scavenging ROS and inhibiting collagen degradation. Turmeric (Curcuma longa) contains curcumin, a bioactive compound that prevents pigmentation, reduces inflammation, and neutralizes oxidative stress. Grape seed extract, abundant in proanthocyanidins, strengthens collagen fibers, improves elasticity, and brightens the skin. Pomegranate extract, rich in ellagic acid and polyphenols, stimulates fibroblast proliferation and protects against UV-induced damage. Licorice extract, containing glabridin, acts as a skin-brightening agent and provides anti-inflammatory benefits.[7]

Mechanism of Herbal Antioxidants in Anti-Aging Creams

Herbal antioxidants act through multiple mechanisms. They neutralize free radicals, chelate metal ions that catalyze oxidation, and inhibit lipid peroxidation in cellular membranes. Additionally, they suppress the expression of inflammatory cytokines and MMP enzymes responsible for collagen breakdown. By enhancing fibroblast activity and promoting collagen and elastin synthesis, these compounds restore dermal structure and reduce wrinkle depth. The synergistic action of combined herbal extracts offers enhanced protection compared to single-ingredient formulations, ensuring greater efficacy and stability in cosmetic applications.[8]

Need for Herbal-Based Anti-Aging Formulations

Conventional anti-aging creams often rely on synthetic components such as retinoids, hydroxy acids, and peptides, which may cause irritation, dryness, and long-term sensitization. In contrast, herbal-based formulations are biocompatible and safe for prolonged use. Moreover, the global cosmetic industry is increasingly adopting eco-friendly and sustainable ingredients derived from renewable botanical sources. The integration of herbal antioxidants in topical formulations aligns with consumer demand for natural, cruelty-free, and effective skincare solutions.[9]

Scientific and Industrial Relevance

The development of herbal antioxidant creams is not only of academic interest but also of industrial and commercial importance. With increasing pollution and UV exposure, the demand for anti-aging products with natural ingredients is rising globally. The cosmetic industry is continuously exploring novel herbal extracts and advanced formulation techniques, such as nanoemulsions, liposomes, and hydrogels, to enhance skin penetration and efficacy. Research and development in this area contribute to safer, more sustainable, and scientifically validated alternatives to synthetic formulations.[10]

Pathophysiology of Skin Aging

Skin aging is a complex, gradual process influenced by both intrinsic and extrinsic factors, resulting in structural and functional deterioration of the skin. It manifests as wrinkles, sagging, dryness, and pigmentation due to biochemical, cellular, and molecular alterations in skin tissue. Understanding these mechanisms helps in designing effective anti-aging formulations, particularly those based on antioxidant-rich herbal extracts.[11]

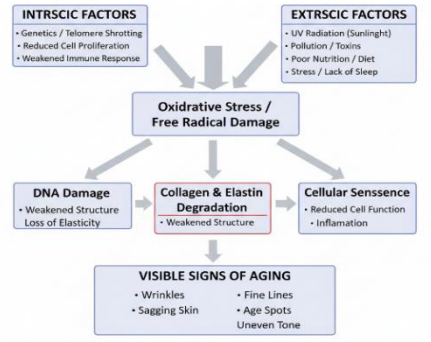

Figure 1: Pathophysiology of Skin Aging – Mechanism Showing Intrinsic and Extrinsic

Factors Leading to Oxidative Stress, Collagen Degradation, and Cellular Senescence

Intrinsic Aging

Intrinsic aging, also known as chronological aging, is genetically programmed and occurs naturally over time. It involves a decline in the regenerative capacity of skin cells and reduced synthesis of collagen and elastin. Fibroblasts in the dermis become less active, leading to thinning of the skin and loss of elasticity. The turnover rate of keratinocytes in the epidermis slows, causing dullness and rough texture. Decreased activity of sebaceous and sweat glands results in dryness, while hormonal changes, particularly the decline of estrogen in aging women, further affect skin firmness and hydration. At the molecular level, telomere shortening and mitochondrial dysfunction contribute to cellular senescence and reduced energy metabolism, accelerating the aging process.[12]

Extrinsic Aging

Extrinsic aging, or photoaging, results from environmental exposures such as ultraviolet (UV) radiation, air pollution, smoking, and poor nutrition. Among these, UV radiation is the most damaging factor, accounting for the majority of premature aging signs. Ultraviolet rays penetrate the skin and stimulate the formation of reactive oxygen species (ROS), which initiate oxidative stress. This leads to DNA damage, lipid peroxidation, and activation of transcription factors like nuclear factor-kappa B (NF-κB) and activator protein-1 (AP-1). These pathways increase the expression of matrix metalloproteinases (MMPs), enzymes that degrade collagen and elastin fibers in the dermis, resulting in wrinkles and sagging. UV exposure also triggers melanocyte activity, causing hyperpigmentation and uneven skin tone.[13]

Oxidative Stress and Cellular Senescence

Oxidative stress plays a central role in both intrinsic and extrinsic aging. ROS such as superoxide anions and hydroxyl radicals are produced as by-products of normal metabolism and environmental stressors. When antioxidant defenses become insufficient, these radicals attack cellular lipids, proteins, and DNA. Mitochondrial DNA is particularly vulnerable, and its damage leads to reduced energy production and impaired cell repair. Accumulated oxidative damage promotes the release of inflammatory cytokines and contributes to cellular senescence—where skin cells lose their ability to divide and regenerate. Senescent fibroblasts secrete inflammatory mediators and degradative enzymes, amplifying tissue damage and accelerating the aging process.[14]

Extracellular Matrix Degradation

The extracellular matrix (ECM) provides mechanical strength and elasticity to the skin. In aging skin, increased MMP activity and oxidative stress lead to fragmentation of collagen and elastin fibers, disrupting the ECM's structure. Reduced synthesis of new collagen, along with loss of glycosaminoglycans, diminishes skin hydration and firmness. As a result, the skin becomes thinner, less elastic, and more prone to wrinkle formation.

Role of Antioxidants in Skin Protection

Antioxidants play a crucial role in protecting the skin from oxidative stress caused by free radicals generated through UV exposure, pollution, and aging. These free radicals damage collagen and elastin fibers, leading to wrinkles, pigmentation, and loss of elasticity. Herbal antioxidants such as polyphenols, flavonoids, and vitamins from natural extracts effectively neutralize these reactive oxygen species (ROS).[15]

According to the synopsis data, extracts like *Aloe vera*, green tea, turmeric, grape seed, pomegranate, and licorice are rich in natural antioxidants. Aloe vera contains vitamins and polysaccharides that enhance hydration and protect collagen. Green tea polyphenols, especially EGCG, prevent UV-induced oxidative damage. Turmeric's curcumin reduces inflammation and neutralizes ROS. Grape seed extract, rich in proanthocyanidins, strengthens collagen, while pomegranate polyphenols protect against photoaging. Licorice extract with glabridin acts as a natural antioxidant and skin-brightening agent.[16]

Materials and Methods

The formulation and evaluation of an antioxidant-rich herbal anti-aging cream were carried out using selected herbal extracts known for their potent antioxidant, anti-inflammatory, and skin-rejuvenating properties. The methodology involved the systematic procurement of raw materials, formulation of an oil-in-water (O/W) emulsion-based cream, and evaluation of its physicochemical and antioxidant characteristics to ensure its stability and effectiveness.

Materials

The materials used in the formulation included standardized herbal extracts, cosmetic-grade excipients, and laboratory-grade reagents. All extracts and excipients were selected based on their safety, biocompatibility, and functional roles in the formulation.[174]

Table 1: List of Materials Used in Formulation

Material	Source	Function in Formulation
Aloe vera extract	Local herbal supplier	Acts as a moisturizer, antioxidant, and healing agent
Green tea extract	Standardized herbal supplier	Provides antioxidant and UV protection
Turmeric extract	Local herbal supplier	Antioxidant, anti-inflammatory, and anti-pigmentation activity
Grape seed extract	Herbal extract manufacturer	Stimulates collagen production, prevents wrinkles
Pomegranate extract	Standardized herbal supplier	Improves elasticity, hydration, and photoprotection
Licorice extract	Local herbal supplier	Skin-brightening and anti-inflammatory properties
Almond/Coconut oil	Laboratory grade	Forms the oil phase, emollient and moisturizer
Stearic acid	Laboratory grade	Acts as an emulsifying agent and thickener
Glycerin	Laboratory grade	Serves as a humectant, maintains skin hydration
Distilled water	Laboratory supply	Used as the aqueous phase for the emulsion

Each selected extract was screened for its antioxidant potential and compatibility with other ingredients before formulation.

Equipment

The equipment used in the study was essential for ensuring precision and reproducibility of results.[18]

Table 2: List of Equipment Used

Equipment	Purpose
Homogenizer	To ensure uniform emulsion formation during cream preparation
Water bath	To heat and maintain both oil and aqueous phases
pH meter	For accurate determination of the cream's pH
Brookfield viscometer	To measure the viscosity and consistency of the cream
Glass slides and weights	For spreadability testing
Stability chamber	For conducting accelerated stability studies
UV spectrophotometer	For evaluating antioxidant activity using DPPH assay

Preparation of Herbal Anti-Aging Cream

The herbal cream was prepared by the oil-in-water (O/W) emulsion method, a standard approach for cosmetic emulsions. The formulation involved two separate phases—an oil phase and an aqueous phase—that were combined under controlled temperature and homogenization conditions.[19,20]

Preparation of Oil Phase:

The oil phase consisted of stearic acid and selected oils (almond or coconut oil). These components were accurately weighed and heated to approximately **70°C** in a water bath until completely melted and homogeneous.

Preparation of Aqueous Phase:

The aqueous phase included distilled water and glycerin. This mixture was heated separately to the same temperature (70°C) to ensure phase compatibility during emulsification.[21]

Emulsification:

The hot aqueous phase was slowly added to the oil phase with continuous stirring using a homogenizer at a constant speed. This resulted in the formation of a smooth, uniform emulsion.

Incorporation of Herbal Extracts:

After the emulsion cooled to around 40°C, pre-weighed herbal extracts—*Aloe vera*, *Green tea*, *Turmeric*, *Grape seed*, *Pomegranate*, and *Licorice*—were incorporated with continuous homogenization to ensure even distribution.[22]

Cooling and Packaging:

The cream was stirred continuously until it reached room temperature and attained the desired consistency. The final product was then transferred into clean, airtight containers for evaluation and storage.

Evaluation Parameters

The formulated herbal cream was subjected to various evaluation tests to determine its physicochemical stability, aesthetic quality, and antioxidant potential.

Organoleptic Evaluation:
Physical characteristics such as color, odor, texture, and appearance were visually inspected. The cream was expected to be smooth, homogeneous, and free from lumps or phase separation.[23]

pH Determination:
The pH of the cream was measured by dispersing 1 g of sample in 100 mL of distilled water using a calibrated digital pH meter. The acceptable range for topical applications is between 5.0–6.5, matching the skin's natural pH.

Viscosity Measurement:
The viscosity was determined using a Brookfield Viscometer at room temperature. A moderate viscosity ensures good consistency, stability, and spreadability of the cream.[24]

Spreadability Test:
Spreadability was measured using the glass slide method. A known quantity of cream was placed between two glass slides, and the upper slide was allowed to slip off under a fixed weight. The time taken for this movement was recorded; less time indicates better spreadability.

Homogeneity Test:
Homogeneity was visually checked to ensure the absence of lumps, coarse particles, or phase separation. Uniform distribution of herbal extracts was confirmed through microscopic observation.

Washability Test:
A small amount of cream was applied to the skin and rinsed with water to assess washability. The cream should be easily washable without leaving a greasy residue.

Antioxidant Activity (DPPH Assay):
The antioxidant potential of the cream was evaluated using the DPPH radical scavenging assay. A sample extract of the cream was mixed with DPPH solution and incubated in the dark for 30 minutes. The absorbance was measured at **517 nm** using a UV spectrophotometer.
The percentage inhibition of free radicals was calculated using the formula:
% Inhibition = $[(A_0 - A_1) / A_0] \times 100$

where A_0 = absorbance of control (DPPH only) and A_1 = absorbance of sample.[25]

Stability Studies:

The optimized formulation was subjected to accelerated stability testing at 40 ± 2°C and 75 ± 5% RH in a stability chamber for 3 months. Samples were withdrawn periodically to assess changes in appearance, viscosity, pH, and antioxidant activity. Stable formulations were identified by minimal variation in these parameters.

Future Prospects
Future advancements in herbal anti-aging formulations will focus on integrating modern technologies such as nanocarriers, liposomes, and phytosomes to enhance the penetration and stability of herbal antioxidants. Standardization of extracts and clinical validation will ensure consistent efficacy and safety. Combining artificial intelligence and molecular modeling may help identify novel antioxidant compounds from plants. Sustainable sourcing and green extraction techniques will also gain importance to support eco-friendly production. Thus, the future of anti-aging skincare lies in scientifically optimized, naturally derived formulations that combine traditional herbal wisdom with modern pharmaceutical innovation

SUMMARY AND CONCLUSION:

Skin aging is a natural yet complex biological process influenced by intrinsic factors such as genetics and hormonal changes, and extrinsic factors such as ultraviolet (UV) radiation, pollution, and oxidative stress. These factors lead to structural degradation of collagen and elastin fibers, resulting in wrinkles, sagging, and uneven pigmentation. The central role of oxidative stress in accelerating skin aging has been well established, highlighting the importance of antioxidants in maintaining skin health and vitality.

Herbal antioxidants have emerged as promising agents in the formulation of anti-aging skincare products due to their safety, efficacy, and multifaceted pharmacological actions. Extracts of *Aloe vera*, *Green tea*, *Turmeric*, *Grape seed*, *Pomegranate*, and *Licorice* are rich in polyphenols, flavonoids, and vitamins that neutralize reactive oxygen species (ROS), reduce inflammation, and protect dermal components from oxidative degradation. Unlike synthetic compounds, these plant-based antioxidants are biocompatible, eco-friendly, and provide long-term benefits without adverse effects.

The formulation of herbal anti-aging cream using an oil-in-water emulsion base ensures good spreadability, stability, and aesthetic acceptability. Evaluation parameters such as pH, viscosity, homogeneity, and DPPH antioxidant activity confirm the formulation's quality and effectiveness.

The synergistic action of multiple herbal extracts enhances free radical scavenging and collagen preservation, contributing to improved skin firmness and elasticity.

In conclusion, the integration of antioxidant-rich herbal extracts in cosmetic formulations offers a safe and effective approach for combating premature skin aging. Such formulations not only repair and rejuvenate the skin but also align with the global trend toward natural and sustainable skincare. Continued research focusing on formulation optimization, advanced delivery systems, and clinical validation will further strengthen the scientific foundation and commercial potential of herbal-based anti-aging creams.

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