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MEDICINAL PLANTS IN ANTI-AGING THERAPY: CURRENT PERSPECTIVES AND FUTURE PROSPECTS

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ABSTRACT

The universal process of aging affects all living organisms, leading to reduced physiological function and a heightened risk of age-related diseases. With global life expectancy on the rise, addressing aging concerns has become essential, as underscored by the World Health Organization's Global Strategy for healthy aging. The skin, the body's largest organ, plays crucial roles in immune defense, hydration, and environmental protection, while also being a key factor in individual identity. Consequently, the demand for effective anti-aging solutions, including supplements and skincare applications, continues to grow.

This article examines various aging theories, including DNA, free radical, neuroendocrine, and telomerase theories, while exploring the molecular foundations of skin aging. Key mechanisms, such as telomere shortening, oxidative stress, and inflammation, drive the aging process, with external factors like UV exposure accelerating skin deterioration. Certain bioactive phytochemicals, notably polyphenols and carotenoids, demonstrate potential in counteracting aging effects; for example, resveratrol and epigallocatechin gallate (EGCG) help preserve collagen and maintain skin elasticity, while beta-carotene supports cellular repair and UV defense.

Additionally, medicinal plants like Aloe vera, amla, turmeric, and ginseng, along with their active constituents—such as aloin, curcumin, and ginsenosides—exhibit antioxidant, anti-inflammatory, and collagen-supportive properties. These findings suggest that phytochemical-based approaches could play a valuable role in anti-aging skincare, with promising implications for health and wellness industries.

KEY WORDS: Aging,Aging theories,bioactive phytochemicals.

1.0 INTRODUCTION

All living things experience the spontaneous and unavoidable process of aging. The steady loss of homeostasis and physiological functioning is the basis for the complex natural phenomena of aging, which inevitably leads to age-related illnesses, injuries, and death[1].The issues related to aging are becoming increasingly pressing as a result of the significant increase in human longevity. Countries have been urged to take action so that people everywhere might enjoy happy, fulfilling lives in their latter-years. through the Global Strategy of the World Health Organization. By 2060, it is predicted that the burden of severe illnesses would have doubled due to the enormous growth in the aging population. As a result, the anti-aging industry and companies, such as those that manufacture anti-aging medications and food additives, are seeing an increase in popularity [2].The skin is the biggest organ in the human body, as is well known. Because it carries out and regulates several vital physiological processes, such as immunological defence and hydration, the skin is classified as an organ. management, the synthesis of vitamin D, environmental and mechanical protection, and the perception of stimuli. The social barrier that divides an individual from other members of society is also represented by the skin. Since one's skin greatly influences who they are, many individuals are now searching for methods to slow down the aging process of their skin, which has resulted in a resurgence of interest in so-called "anti-aging" products[3]. Several hypotheses have been proposed to explain aging, including the DNA or genetic theory, free radical theory, neuroendocrine theory, membrane theory, Hay-Flick limit theory, telomerase theory, and mitochondrial decline theory.Numerous phytochemicals that come from different species have been shown to have life-extending and anti-aging properties. Since calorie restriction (CR) can improve health and quality of life, it appears to be the anti-aging strategy that has garnered the mostsupport.Growingolder is accelerated by a number of factors[4].

2.0 PATHOPHYSIOLOGY OF SKIN AGEING

The scientific literature proposes a number of molecular bases that provide complete justification for the pathophysiology of skin aging. Cellular senescence or the loss of telomeres, point mutations in extranuclear mitochondrial DNA, oxidative stress, chromosome abnormalities, single-gene mutations, reduced sugar, chronic inflammation, and many other factors could all be explained by this process. According to research, just 3% of the elements that contribute to skin aging are intrinsic, with external causes typically being the primary reason[5].

2.1. MECHANISM OF AGEING AT THE CELLULAR AND MOLECUAR LEVEL

The Two contemporary analytical methods are molecular biology and cell culture. In 1920, Careel conducted an experiment using chick heart fibroblasts, which allowed cells to reproduce endlessly, to analyse aging at the molecular level of cell culture [6].They were rendered immortal when taken out of the in vivo process and put in a vitro setting. Normal human fibroblasts have a limited capacity to proliferate in vitro, as Hayflick showed in 1960 [7].He demonstrated how normal cells might double indefinitely before stopping to divide following the exponential growth phase, a phenomenon known as the Hayflick limit. Two overlapping processes that lead to mortality are linked to aging: loss of regenerative capacityandgradual cell degradation.

Changes in satellite cells result in a decrease in muscle regenerative capacity, which in turn causes a reduction in proliferative and myogenic capacities. The slow reduction of satellite cells and muscle stem cells, which experience age-related declines in proliferative and myogenic capacities, causes the regenerative capacity of skin muscles to diminish as the skin aging phenomena begins. In fact, as people age, the number of satellite cells in mammalian muscles gradually decreases [8].

At every stage of life, proliferative degradation and regeneration of cells occur continuously under normal circumstances. But in mitotic equilibrium, damaged cells are replaced and the functional integrity of both cells and tissues is maintained. Degeneration occurs as a result of the production of reactive oxygen species (ROS), non-enzymatic protein glycosylation, loss of proliferative and regenerative telomerase shortening, and apoptosis. This makes the roles of endogenous and exogenous elements in the aging process simpler [9].

2.2. GLYCATION IN AGEING

The Advanced Glycation End-products (AGE), or advanced glycosylation end products, build up as a result of age-related cell deterioration [21]. Collagen cross-linking, including increased molecular packing, anomalies in the extracellular matrix, and compromised cell-matrix interaction, is caused by the production of AGEs on collagen. Additionally, AGEs attach to particular receptors on immune cells, causing the release of inflammatory mediators and the creation of ROS, which increases the amount of AGE damage [10].

2.3. FREE RADICAL IN AGENING

The Free radical participation in endogenous metabolic reactions was first hypothesized in 1954 as part of the Free Radical Theory of Ageing (FRTA) [11].According to the FRTA, the start of free radical reactions (RRs) is the typical aging process. Following that, various recommendations were made, including (a) the mitochondria launched the majority of free radical reactions at a pace that increased with age, and (b) the rate at which free radical damage to the mitochondria determines life duration [12].

By reducing the free radical reactions linked to suboptimal living conditions or by reducing (a) the chain lengths of free radical reactions, for example, with antioxidants like vitamin E (b) their rates of initiation may be depressed by minimizing copper, iron, and other oxidant catalysts, which can lower the rate of formation of ageing changes, and by reducing the rate of disease pathogenesis, it became evident that improvements in general living conditions increased Average Life Expectancies at Birth (ALE-B) [13].

"Free radical" refers to any extremely reactive chemical with a free electron. the reduced elements of the prehistoric oxygen-less atmosphere through free radical reactions, which were mostly brought on by solar ionizing radiation. The atoms and molecules' inherent chemical characteristics were represented in the byproducts of these interactions, which included basic self-replicating DNA progenitors. In addition to producing more or less random changes throughout the cells, the free radical reactions also supply the environment with chemicals required for the survival and development of the initial protocells.While some modifications were age-related and resulted in cell death, others were inheritable and enhanced the offspring's capacity to live and function, or to evolve. the natural aging process brought on by age-causing free radical reactions that occur constantly in cells and tissues. Nearly all of the reactions today originate endogenously from enzymatic and non-enzymatic free radical reactions, whereas in the past they were mostly triggered by UV radiation from the sun and, to a lesser extent, by volcanic activity [14].

2.4. CELL CYCLE AND AGEING

Atrophy of organs or tissue is a well-known aspect of aging that can lead to the destruction of genes that build up organs because of poor circulation, a lack of hormone support, a decrease in physical activity, and a less active lifestyle. Reduced regenerative capacity, which involves two cell cycle control processes—regulation of cell proliferation and stimulation of proliferation and programmed cell death—has occurred in recent years as the mechanism of aging [15].

3.0 MEDICINAL PLANTS PREVENTS SKIN AGEING

3.1 Aloe vera

The plant Aloe barbadensis, which belongs to the Liliaceae family, is used to make aloes. Among the many consumer products that contain it are drinks, skin care lotions, cosmetics, and ointments for severe burns and sunburns. It is commonly recognized to have substantial medical and therapeutic benefits, and the leaves are commonly used in anti-aging and moisturizer products. Naturally, all living things age, leading to slow and detrimental changes in the organisms. UV rays cause photodamage to the skin, which eventually destroys the dermal extracellular matrix and changes the skin's structure over time. The formation of wrinkles on the skin is associated with the expression of matrix metalloproteinases and collagen synthesis.Aloin A and B, two aloe vera constituents that have been shown to be useful in the management of wrinkles and aging, have the capacity to inhibit the activity of collagenase, the enzyme that degrades collagen fibers and initiates matrix metalloproteinase (MMP) synthesis. A study found that when it comes to healing skin that has been exposed to UV radiation, baby aloe shoot extract (BAE) has more potential than adult aloe shot extract (AE). The plant also possesses a number of other pharmacological characteristics, including as wound-healing antioxidant action, immunological stimulation, antibacterial, anticancer, and therapeutic properties. Additional traditional uses include treating burns, wounds, swelling, fever, and cosmetics. A member of the Liliaceae family, aloe vera (Aloe barbadensis) offers a great deal of potential for healing skin disorders[16][17].

Aloe vera leaves are used. It is commonly drunk as a health beverage and can be applied topically or taken orally. Stretch marks, wrinkles, dark or white spots, and acne are all commonly treated with it. Moreover, aloe vera has immunomodulatory, antiviral, and anti-inflammatory qualities.Aloe vera is found in desert areas, Africa, and India. Most forms of aloe include anthraquinone glycosides. Barbaloin is the primary constituent of aloin, a mixture of glycosides and the primary active ingredient in Aloe. Barbaloin is one of the constituents in the medication, along with aloe-emodin and resins. Moisturizers and anti-aging products often contain aloe vera leaves. To treat wrinkles and aging, aloe vera's constituents, including aloin A and B, have shown promise in inhibiting the action of collagenase, the enzyme that breaks down collagen fibers [18,19].

3.2 Amla

Amla is mostly made up of fresh and dried fruits from the plant Emblica officinalis, which belongs to the Euphorbiaceae family. In addition to being a natural source of vitamin C (ascorbic acid), amla fruit also contains fat, phyllembelin, and tannins. The memory-boosting and cholesterol-reducing The amla churn's qualities are widely known. In particular, amla fruit has a very high mineral content in calcium, iron, and phosphorus. It is believed that foods high in vitamin C, such as amla, can slow down the aging process. It gives the skin a healthy appearance. Age is brought on by damage to many cells and tissues throughout time, which is mostly brought on by oxygen free radicals. The scavenging action of vitamin C eliminates free radicals [18].

The accumulation of free radicals in various tissues is connected to a range of stress-related circumstances, which hasten the aging process. Tannins from E. officinalis also provide protection in a rat model of tardive dyskinesia because of their antioxidant qualities. Moreover, in animals Through lowering the activity of gamma amino butyric acid (GABA) and monoamine oxidase-A (MAO-A), as well as antioxidant activity, the E. officinalis extract exhibits antidepressant properties in models [20,21]

3.3 Turmeric

The plant Curcuma longa, a species of the Zingiberaceae family, produces both fresh and dried rhizomes that are used to make turmeric [18].Turmeric is commonly used as a spice in curries. Strong antioxidants found in turmeric have been shown in studies to combat free radicals and stave off cancer, Alzheimer's disease, and other degenerative brain conditions. One It is recommended to take 500 mg of standardized turmeric extract every day. Turmeric contains a yellow-colored substance called curcuminoids. Curcuminoids' primary component is curcumin (50–60%). Additionally, it contains camphor, camphene, volatile oil, resin, etc [22,23].

3.4 Honey

The dried rhizomes that are used to make turmeric Bees (Apis mellifera and other Apis species) belonging to the Apidae family deposit honey, a sweet secretion, in honey combs. Honey is composed of aqueous solutions of sucrose (2%), fructose (45%), and glucose (35%). Polyphenols, gum, maltose, and flavonoids.There are also proteins, vitamins, etc. Honey's phenolic components, which include flavonoids and benzoic and cinnamic acids, provide it an antioxidant effect that helps keep our skin from getting wrinkled [18,19]

3.5 Ginseng

Ginseng is the dried root of a number of Panax species, which belong to the Araliaceae family and include P. ginseng (Korean ginseng), P. japonica (Japanese ginseng), and P. notoginseng (China ginseng) [18].Ginseng has a range of triterpenoid group saponin glycosides. Ginsenosides, panaxosides, and chikusetsusaponin are the three substances that give ginseng its diverse physiological effects.This plant's roots are where the

Ginsenoside is a bioactive compound [19].This bioactive ingredient modulates immunological response and fortifies the body's defenses against stress, fatigue, anxiety, and trauma. Additionally, it enhances learning performance and exhibits anti-stressqualities. As well as memory. One study found that young mice with leukemia lived longer when given ginseng. Another study on Panax ginseng found that it can increase antioxidant capacity and reduce lipid peroxidation by reducing oxidative stress [22].

3.6 Apple

Apples are made from the fresh fruit of the Malus domestica plant, which is a member of the Rosaceae family. Along with other nutrients and intriguing compounds (such as triterpenoids and anthocyanins), apples (sp. Malus domestica) contain notable amounts of polyphenols [24]. Oligomeric proanthocyanidins are the primary source of the antioxidant activity of apple extract. Numerous polyphenolic compounds, such as rutin, epicatechin, catechin, and phloretin, are found in apples.Proanthocyanidin B2 and chlorogenic acid. Catechin is responsible for the apple's capacity to postpone aging. It influences cellular lifespan through the survival and viability of HFL-1 primary human fibroblasts [25].

3.7 Ashwagandha

Ashwagandha, a herbal medication used in Indian medicine, is mostly made from the dried root of Withania somnifera (Fam. Solanaceae). Additionally, stem roots and leaves are present in these preparations. It's commonly referred to as Indian ginseng. Reportedly, it has properties that include anti-aging, anti-tumor, anti-stress, anti-infective, antioxidant, and mind-boosting. There are flavonoids and withanolides. [22].

Table. 01: Medicinal plants and their active constituents.

S.no.	Plant name	Botanical name	Part used	Active constituent
1.	Aleo vera	Aleo barbadensis	leaves	aloin
2.	Amla	Emblica officinalis	fruits	Emblicanin A & B
3.	Turmeric	Curcuma longa	Rhizomes	Curcumin
4.	Honey	Apis mellifera	Sugar secretion	Flavonoids
5.	ginseng	Pana ginseng	Root	Ginsenosides
6.	Apple	Malus domestica	Fruits	Polyphenols
7.	Ashwagandha	Withania somnifera	Leaves and stem	withanolides

4.PHYTOCHEMICAL WITH ANTI AGING POTENTIAL

Plants contain bioactive substances called phytochemicals, which offer a wealth of anti-aging benefits. They are useful for enhancing longevity and skin health because they shield skin and bodily tissues from oxidative stress, inflammation, and other age-related cellular damage.

4.1. Polyphenols

Many different types of plants, such as fruits, vegetables, tea, and wine, are rich in polyphenols. They are separated into lignans, stilbenes, phenolic acids, and flavonoids, all of which have been demonstrated to have anti-aging properties:

4.1.1Resveratrol:

Resveratrol is a well-researched polyphenol having antioxidant and anti-inflammatory qualities that can be found in berries, wine, and grapes. It triggers the activation of sirtuins, particularly SIRT1, a protein that controls cellular health, improves DNA repair, and extends life. Additionally, resveratrol helps to preserve the suppleness of the skin by blocking matrix metalloproteinases (MMPs), which are enzymes that break down collagen [26].

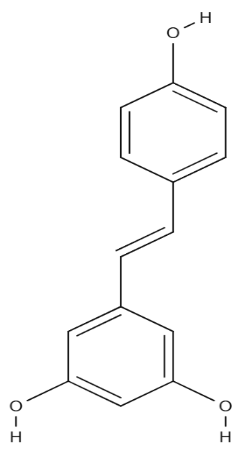

Fig no. 1. Resveratrol

4.1.2 Epigallocatechin gallate (EGCG):

Green tea contains EGCG, which is well-known for its potent antioxidant properties that lessen oxidative stress. In order to prevent wrinkles and preserve the firmness of the skin, EGCG scavenges free radicals and prevents the breakdown of collagen fibers. EGCG is also helpful at preventing photoaging because it lessens UV-induced skin damage, according to studies [27].

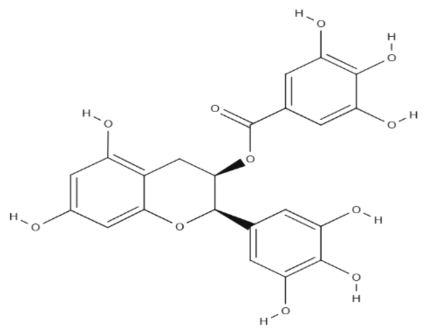

Fig no. 2. Epigallocatechin gallate (EGCG)

4.2 Carotenoids

Carotenoids are pigments that are present in vegetables and fruits with vibrant colors, such spinach, tomatoes, and carrots. Their ability to protectthe skin is well-known:

4.2.1 Beta-Carotene:

The sweet potatoes and carrots contain this substance, which is a precursor to vitamin A. Because of its antioxidant properties, beta-carotene lessens the oxidative damage caused by UV radiation. Additionally, by controlling the proliferation and differentiation of skin cells, it facilitates skin renewal and healing [28].

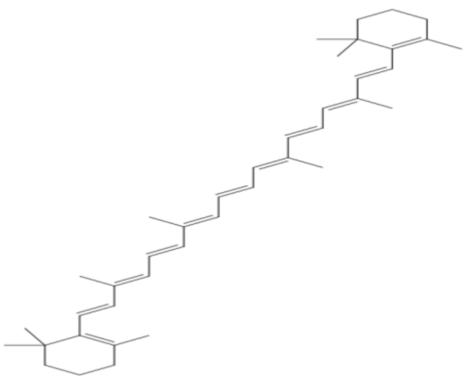

Fig no. 3. Beta-Carotene

4.2.2 Lycopene:

Lycopene, which is present in tomatoes and other red fruits, has strong antioxidant properties, especially when it comes to UV-induced oxidative damage. According to studies, taking lycopene supplements thickens and boosts the density of the skin, improving its suppleness and minimizing fine wrinkles [29].

Fig no. 4. Lycopene.

4.3 Flavonoids

The class of polyphenolic chemicals known as flavonoids comprises anthocyanins, flavonols, flavones, and isoflavones. They preserve collagen and have anti-inflammatory and antioxidant qualities.

4.3.1 Quercetin:

Quercetin, an anti-inflammatory compound, is present in green tea, onions, and apples. Elastase, an enzyme that breaks down elastin, which is essential for skin suppleness, is inhibited, and skin inflammation is decreased. Additionally, quercetin protects skin cells from oxidative damage and stabilizes cell membranes [30].

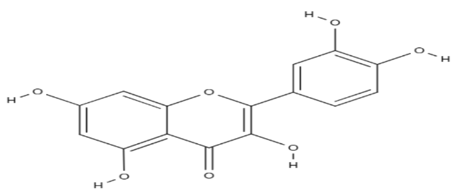

Fig no. 5. Quercetin.

4.3.2 Isoflavones

Isoflavones like genistein, which are found in soy and other legumes, have estrogenic properties that may help with postmenopausal skin aging. By interacting with the skin's estrogen receptors, isoflavones increase the production of collagen, lessen dryness, and increase suppleness [31].

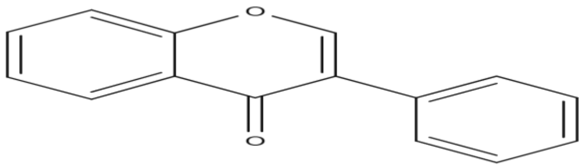

Fig no. 6. Isoflavones.

4.4 Saponins

Glycosides called saponins are present in many different plants, including quinoa, licorice, and ginseng. They have anti-inflammatory and skin-conditioning properties.

4.4.1 Ginsenosides

The ginseng plant contains saponins that have been shown to have anti-aging effects. Ginsenosides shield the skin from UV-induced collagen degradation and encourage the production of new collagen. They also help the skin's hyaluronic acid levels, which makes the skin appear firm and full [32].

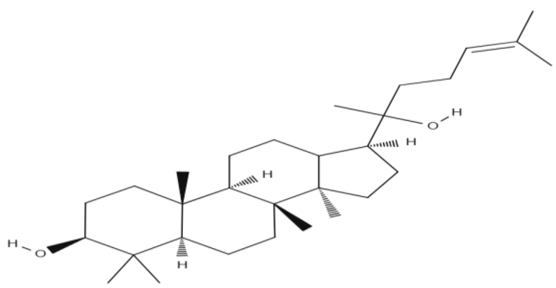

Fig no. 7. Ginsenosides

4.5 Alkaloids

Alkaloids, like caffeine, are frequently present in tea, coffee, and cocoa. Through lowering skin irritation and enhancing circulation, they have anti-aging benefits.

4.5.1 Caffeine

Caffeine is well-known for its antioxidant and vasoconstrictive qualities, which help to reduce puffiness by narrowing blood vessels, especially around the eyes. In addition to reducing the visibility of wrinkles and dark spots, caffeine may shield skin cells from oxidative damage caused by UVB rays [33].

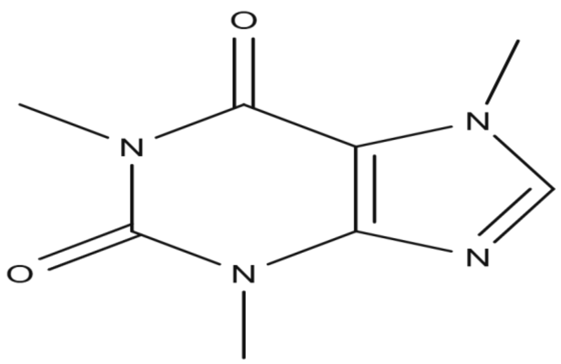

Fig no. 8. Caffeine.

4.6 Vitamin C (Ascorbic Acid)

Vitamin C is an important antioxidant that comes from plants, even though it isn't exactly a phytochemical in the same sense as polyphenols. Both photoprotection and collagen formation depend on it.

4.6.1 Ascorbic Acid

Vitamin C aids in the stabilization of collagen molecules and shields them from oxidative damage. Additionally, it scavenges ROS and reduces oxidative stress by acting as a strong antioxidant. Vitamin C can be used in skincare products to minimize pigmentation and enhance skin texture, making the skin look younger [34].

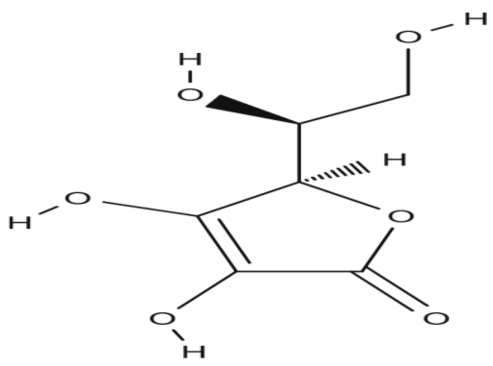

Fig no. 9 Ascorbic Acid

5.MECHANISM OF ANTI AGING ACTIONS

Phytochemicals provide anti-aging benefits through various cellular and molecular pathways, primarily by defending against oxidative stress, minimizing inflammation, enhancing collagen production, and promoting cellular longevity.

5.1 Antioxidant Activity

The antioxidant qualities of phytochemicals are one of the main ways they provide anti-aging benefits. The buildup of oxidative damage brought on by reactive oxygen species (ROS), which harm lipids, proteins, and DNA in cells, is closely associated with aging. By neutralizing ROS, phytochemicals can stop cellular damage and slow down the aging process.

Mechanism: Phenolic hydroxyl groups found in phytochemicals such as polyphenols (resveratrol, EGCG) transfer electrons to counteract free radicals. This function aids in preventing oxidative stress on proteins, DNA, and cell membranes [35].

5.2 Anti-Inflammatory Effects

Chronic low-grade inflammation, commonly known as "inflammaging," plays a major role in the aging process. By inhibiting pro-inflammatory pathways, phytochemicals can lessen inflammation associated with aging.

Mechanism: Pro-inflammatory cytokines (like interleukin-6, IL-6) and enzymes (like cyclooxygenase-2, COX-2) are inhibited by a variety of phytochemicals. For instance, green tea's catechins and flavonoids like quercetin lower inflammatory marker levels, reducing aging and tissue damage [36].

5.3 Collagen Synthesis and Protection

The primary structural protein in skin is collagen, and when it degrades, wrinkles and a lack of suppleness result. By encouraging the manufacture of collagen and blocking the enzymes that degrade collagen and elastin, phytochemicals aid in the maintenance of skin structure.

Mechanism: Fibroblasts, the cells that synthesize collagen, are activated by specific phytochemicals, which in turn promote the formation of collagen. The ginsenosides in ginseng, for example, encourage the production of collagen, whereas substances such as resveratrol prevent the breakdown of collagen by matrix metalloproteinases (MMPs) [37].

5.4 Cellular Longevity and DNA Repair

Activating certain pathways linked to longevity, such those involving sirtuins, which control cell repair and death, is one way that phytochemicals can enhance cellular lifespan.

Mechanism: Sirtuins, especially SIRT1, are activated by polyphenols like resveratrol and are essential for DNA repair and cellular stress tolerance. The protective telomeres of chromosomes, which shorten with age, are likewise stabilized by sirtuins. Cellular senescence is slowed down as a result [38].

CONCLUSION

Aging is an inevitable biological process affecting all living organisms, characterized by a gradual decline in physiological functions and homeostasis, leading to age-related diseases. This article delves into the multifaceted nature of aging, particularly focusing on skin, the body's largest organ, and its susceptibility to intrinsic and extrinsic aging factors. Intrinsic factors, such as telomere shortening, oxidative stress, and cellular senescence, account for a minimal percentage of skin aging. In contrast, external factors like UV exposure accelerate skin aging by promoting reactive oxygen species (ROS) production and other degenerative changes.

The article explores anti-aging mechanisms at cellular and molecular levels, including theories like free radical, mitochondrial, and telomerase theories. It emphasizes the significant role of phytochemicals from medicinal plants, which offer promising anti-aging effects. Notable examples include Aloe vera, known for its moisturizing and collagen-preserving properties, and antioxidant-rich compounds like resveratrol, beta-carotene, and epigallocatechin gallate (EGCG), found in various plants. These compounds mitigate oxidative stress, reduce collagen degradation, and support cellular repair processes. Furthermore, the study highlights the anti-aging properties of widely used medicinal plants—Amla, Turmeric, Honey, and Ginseng—each contributing to skin resilience and longevity.

Through an understanding of the biochemical mechanisms underlying skin aging, the research presents phytochemical-based strategies for preventing premature aging and enhancing skin health. Given the growing elderly population and increased demand for anti-aging solutions, the findings underscore the potential of phytochemicals in promoting healthier, youthful skin and enhancing the quality of life among aging individuals.

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