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PHYTOESTROGENS AS PLANT BIOACTIVES FOR SKIN AGING MANAGEMENT: A NARRATIVE REVIEW OF MECHANISMS, FORMULATION CHALLENGES, EFFICACY, AND SAFETY

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Abstract: The use of phytoestrogens in anti-aging cosmetics has generated growing interest, as they have the potential to mimic the effects of estrogens on aging skin without the risks associated with systemic hormone therapy. This narrative review aims to summarize the mechanisms of action of the main classes of phytoestrogens and to evaluate their efficacy for the intended purpose. The existing data, although limited in number, suggest moderate benefits, particularly in cases of photoaging or in postmenopausal women, where estrogen deficiency is a significant factor. However, efficacy is limited by the instability of cutaneous bioavailability, the stability of cosmetic formulations, and the lack of clinical studies conducted over a longer period of time. From a practical standpoint, the inclusion of phytoestrogens in cosmetic products may represent a complementary option for mature skin care; however, at this time, their use should be supplemented with specialized therapeutic interventions. Future research should focus on optimizing delivery systems, standardizing extracts, and conducting well-controlled clinical studies to accurately determine their efficacy and safety for short-, medium-, and long-term use.

Keywords: phytoestrogens, phytohormones, isoflavones, skin aging, topical cosmetics

1. Introduction

Skin aging is a complex process influenced by both external factors—such as exposure to pollution, UV rays, and dietary habits—and internal factors, including genetic and hormonal influences.

Skin aging is characterized by progressive structural and functional alterations affecting both the epidermis and dermis. At the molecular level, aging is associated with reduced fibroblast activity, fragmentation of collagen fibers, degradation of elastin, impaired extracellular matrix turnover, and increased oxidative stress. Furthermore, chronic exposure to ultraviolet radiation promotes the formation of reactive oxygen species (ROS), which activate matrix metalloproteinases (MMPs) responsible for collagen degradation and wrinkle formation. As a result, aged skin exhibits reduced elasticity, increased dryness, thinning, and impaired wound-healing capacity (Verdier-Sévrain et al., 2006; Thornton, 2013).

Hormone levels decline with age, serving as a major endogenous contributor to skin deterioration, particularly in women during the menopausal transition. These age-related changes are primarily driven by the decline of testosterone and estrogen secretion, which directly impacts collagen synthesis, dermal thickness, hydration, and elasticity. Estrogen, in particular, exerts vital trophic effects on the skin by stimulating the secretion of collagen and hyaluronic acid, improving microcirculation, and reducing oxidative stress. The extensive regulatory role of estrogens in skin physiology is underscored by the expression of estrogen receptors (ERα and ERβ) across keratinocytes, fibroblasts, melanocytes, sebaceous glands, and hair follicles. Consequently, declining estrogen levels lead to decreased collagen content, impaired barrier function, reduced hydration, and diminished antioxidant defenses. Ultimately, clinical observations suggest that this post-menopausal loss of estrogen accelerates cutaneous aging far beyond the expectations of chronological aging alone (Lephart, 2018; Thornton, 2013; Rzepecki et al., 2019).

Phytoestrogens are of interest in anti-aging cosmetics due to their ability to interact with estrogen receptors that are predominant in the skin. Through mechanisms similar to those of estrogen (Lephart, 2018), these compounds can help maintain skin structure and function, with beneficial effects on elasticity, hydration, and the skin aging process. It is assumed that topical application allows for relevant local effects with a reduced potential for systemic reactions.

Medical evidence indicates that systemic and topical estrogen interventions effectively increase dermal collagen density while optimizing skin thickness, elasticity, and moisture retention (Sauerbronn et al., 2000; Son et al., 2005; Troxel et al., 2026). Although topical delivery minimizes localized adverse reactions, systemic absorption remains a documented effect (Troxel et al., 2026). Due to the established correlation between estrogen therapy and increased risks for endometrial and breast malignancies, phytoestrogens have emerged as a highly sought-after substitute in both dermatology and hormone replacement therapy (Patra et al., 2023; Intharuksa et al., 2025).

Despite growing commercial interest and an increasing number of cosmetic products containing phytoestrogen-rich extracts, the available evidence remains heterogeneous. Differences in plant sources, extraction methods, formulation strategies, concentrations, and study designs make it difficult to draw definitive conclusions regarding efficacy and safety. Furthermore, while several *in vitro* and small-scale clinical studies have reported favorable outcomes, larger controlled trials are still needed to establish the long-term benefits and risks associated with topical phytoestrogen use (Farkas, 2026; Lephart, 2021).

In this context, the present narrative review examines plant-derived phytoestrogens used in anti-aging cosmetics, focusing on their plant sources, cutaneous mechanisms of action and the strength of available experimental and clinical evidence. Additionally, the review seeks to highlight existing formulation-related limitations and potential safety concerns.

2. Review Methodology

To conduct this narrative review, experimental, clinical, and review studies were selected that examined the effects of phytoestrogens (particularly isoflavones) on the skin and the mechanisms through which they interact with biological processes relevant to skin aging.

Searches were conducted in PubMed, Scopus, Web of Science databases, using terms such as „phytoestrogen”, „isoflavones”, „skin aging”, „topical phytoestrogens”, „anti-aging”, „estrogen receptors”, as well as combinations thereof, with no time limit. Last search was performed on April 1, 2026.

Studies published in English with original data (*in vitro, ex vivo, in vivo*) and clinical studies or critical reviews on the efficacy of phytoestrogens on the skin were included. Studies in which dietary supplements or hormonal drug interventions were administered internally were excluded. We prioritized papers presenting clear mechanistic evidence to explain biological plausibility and controlled clinical trials to assess efficacy.

In accordance with the hypothesis presented above, scientific interest in cosmetology has focused primarily on phytoestrogens, particularly isoflavones, as evidenced by the results obtained from the keyword combinations used in searches. A search in the Web of Science database for the combination “topical phytoestrogens” and “anti-aging” yielded 10 results; searching for “phytoestrogens” and “anti-aging” yielded 58 results, while the terms “topical isoflavones” and “anti-aging” yielded 21 results (**Figure 1**).

At the same time, various areas of interest in which the studies were conducted are emerging. A review of recent literature indicates that phytoestrogens, particularly isoflavones, have the potential to significantly modulate skin aging processes associated with declining estrogen levels (Amini et al., 2025; Lephart, 2021; Lephart, 2025).

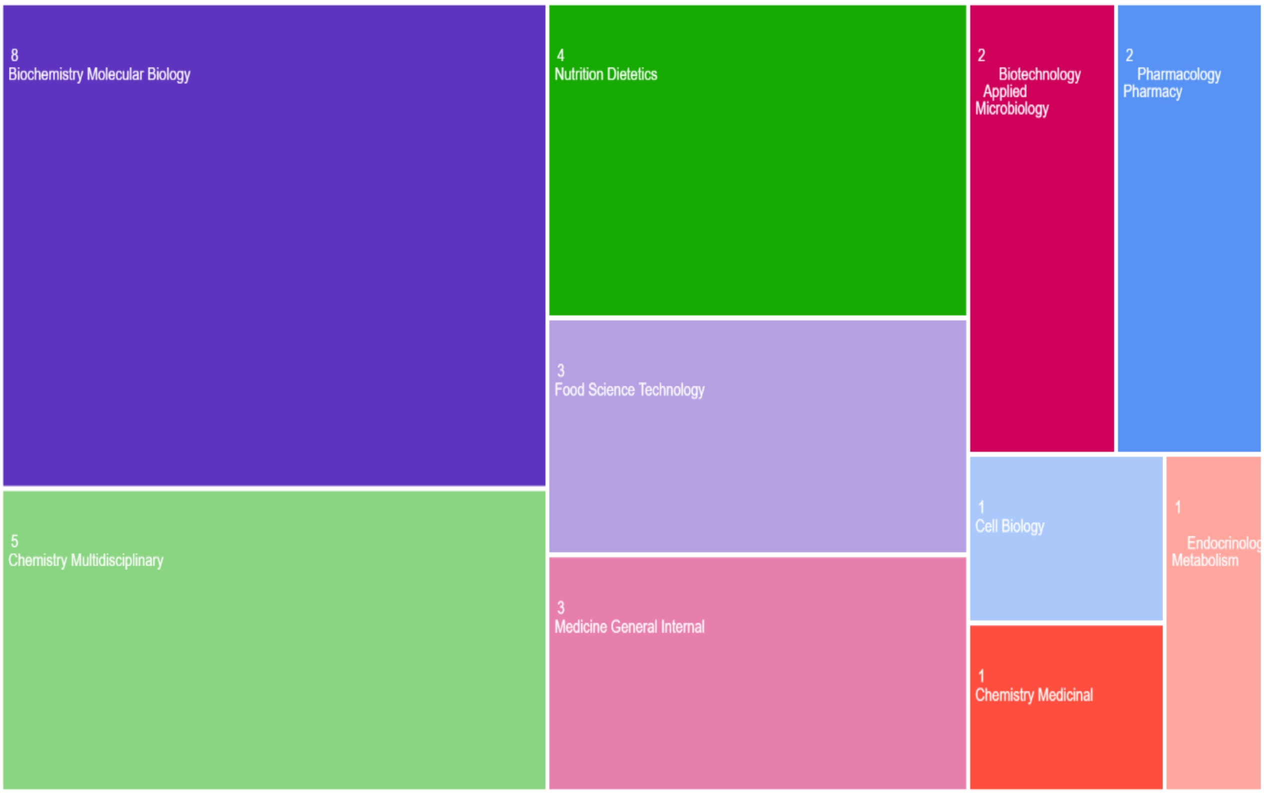
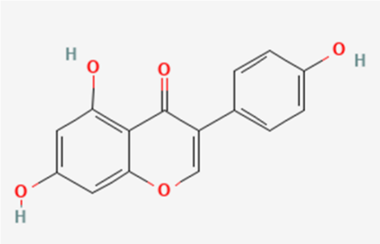
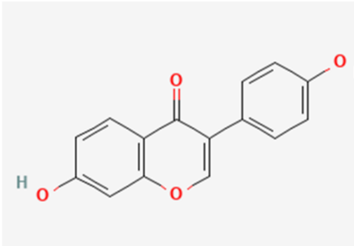


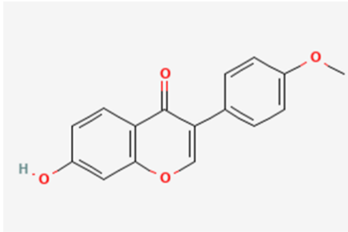
Fig. 1. Number of publications found on Web of Science using the terms “topical isoflavones” and “anti-aging,” grouped by field (n=21) (image generated by Web of Science)



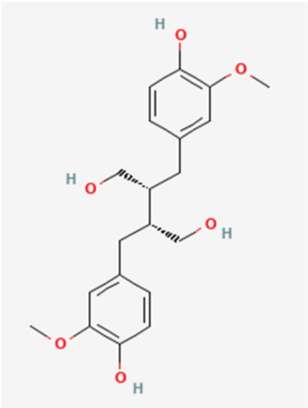
Genistein



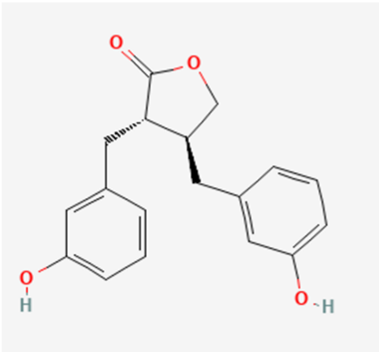
Daidzein



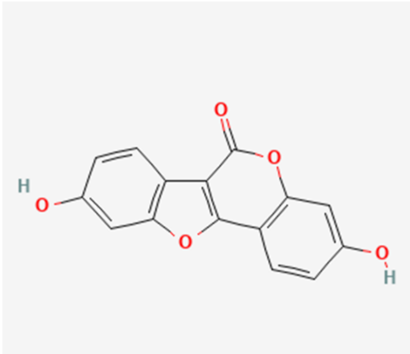
Formononetin



Secoisolariciresinol



Enterolactone



Coumestrol

Fig. 2. Chemical structures of the most relevant isoflavones, lignans and coumestans used in cosmetics (structures generated by PubChem)

3. Definition and Classification of Phytoestrogens Relevant to Skin Aging

While phytohormones and phytoestrogens belong to the same botanical semantic sphere, they are not equivalent and serve entirely different functions. Phytohormones represent the totality of hormones produced by plants – such as auxins, gibberellins, and cytokinins – and their role is strictly linked to regulating plant growth, development and physiology. In contrast, phytoestrogens do not play a hormonal role within the plant itself; instead, they are plant-derived compounds that share structural similarities with mammalian estrogens, allowing them to exert estrogen-like effects specifically within animal or human organisms. Thus, phytohormones act exclusively within plant systems, whereas the external biological action of phytoestrogens makes them the relevant focus for the study of this topic.

Phytoestrogens can be grouped by chemical structure into isoflavones (genistein, daidzein), lignans (secoisolariciresinol, enterolactone), and other phytoestrogens with weak estrogenic activity—cumestans (coumestrol), and stilbenes (resveratrol) (Lephart, 2021). Isoflavones, due to their ability to bind to estrogen receptors and influence intracellular processes of collagen synthesis and other anti-aging mechanisms (Amini et al., 2025), continue to dominate research (**Figure 2**).

4. Major Plant Sources and Phytochemical Profiles

The Fabaceae family is the primary source of phytoestrogens studied for their anti-aging effects. The primary focus is on isoflavones from soy (*Glycine max*), but other species are also being investigated for their efficacy in stimulating collagen synthesis and protecting the extracellular matrix, such as Chinese liquorice (*Glycyrrhiza uralensis*). Recent studies note the presence of phytoestrogens primarily in seeds and underground parts, as extracts obtained from these parts tend to be the most effective in cosmetic applications (Amini et al., 2025).

4.1. Soybean - *Glycine max* (L.) Merr.

A recent study shows that an isoflavone-rich extract from soybean leaves can counteract the loss of collagen fibers in the skin of an animal model exposed to estrogen deficiency, suggesting antioxidant and collagen-modulating potential. The study focused on soybean leaves enriched with isoflavones, a product obtained by treating soybean plants with ethylene, with the aim of achieving a final isoflavone content of 11 mg/g. Thus, the enriched leaves reached an isoflavone content approximately fifty times higher than that of typical leaves. The identified isoflavones were daidzein and genistein (Yoo et al., 2024).

4.2. Red Clover - *Trifolium pratense* L

In the cosmetics industry, red clover is used as a complementary ingredient in formulations designed for mature or sensitive skin. Recent studies suggest that the isoflavones in red clover help maintain skin homeostasis, interacting primarily with β-type estrogen receptors (ER-β) in the skin (Amini et al., 2025). Red clover has long been an ingredient of interest due to its phytoestrogen content, as demonstrated by a study from 2006. This study examines the potential of a standardized red clover extract containing 11% isoflavones. From a biological standpoint, red clover extracts have demonstrated the ability to reduce oxidative stress and inhibit collagen degradation (Circosta et al., 2006), mechanisms relevant to combating skin aging.

4.3. Chinese Liquorice - *Glycyrrhiza uralensis* Fisch. ex DC.

Recent research highlights the presence of compounds such as glycyrrhizin, isoliquiritigenin, liquiritigenin, liquiritin, and glabrol in the roots of Chinese liquorice (Amini et al., 2025; Jiang et al., 2021). The main compounds quantified in extract evaluated on healthy volunteers were liquiritin-apioside, liquiritin, and liquiritigenin. Thus, the potential of Chinese liquorice extracts, rich in flavonoids, to inhibit the production of matrix metalloproteinase 1 (MMP-1) - an enzyme responsible for collagen degradation - is emerging, both in *in vitro* and *in vivo* models (Amini et al., 2025), suggesting significant benefits in anti-aging cosmetic products.

5. Mechanisms of Action at the Skin Level

Recent studies show that phytoestrogens can influence certain skin characteristics through various actions. Among these, the following stand out: collagen production via β-estrogen receptor-dependent signaling, skin hydration through the regulation of hyaluronic acid synthesis, and the reduction of extracellular matrix degradation through the inhibition of MMPs (Amini et al., 2025). These mechanisms are significant in managing skin aging.

5.1. Interaction with Cutaneous Estrogen Receptors

Compared to endogenous estrogens, phytoestrogens have a lower affinity for estrogen receptors (Amini et al., 2025), resulting in milder, dose-dependent effects, but also a superior safety profile.

Soy isoflavones are considered compounds with increased selectivity for β-estrogen receptors. This explains their beneficial effects on skin homeostasis without excessive systemic estrogenic stimulation. The reviewed studies highlight that the activation of these receptors in dermal fibroblasts is associated with the stimulation of the synthesis of structural skin components and with the improvement of changes induced by estrogen deficiency (Yoo et al., 2024).

Similarly, the isoflavones in red clover, particularly biochanin A and formononetin, act through estrogen-like mechanisms, exhibiting a higher affinity for β-estrogen receptors. This interaction reduces the impact of estrogen deficiency on dermal structure and fibroblast metabolism (Circosta et al., 2006).

Licorice extracts contain phytoestrogenic compounds such as liquiritigenin, which is known for its selective activity on β-estrogen receptors. The study in question demonstrated that the activation of these signaling pathways is associated with increased expression of genes involved in collagen synthesis and with improved dermal density (Amini et al., 2025).

5.2. Action on the Extracellular Matrix

The influence on the extracellular matrix is one of the most important anti-aging mechanisms attributed to phytoestrogens.

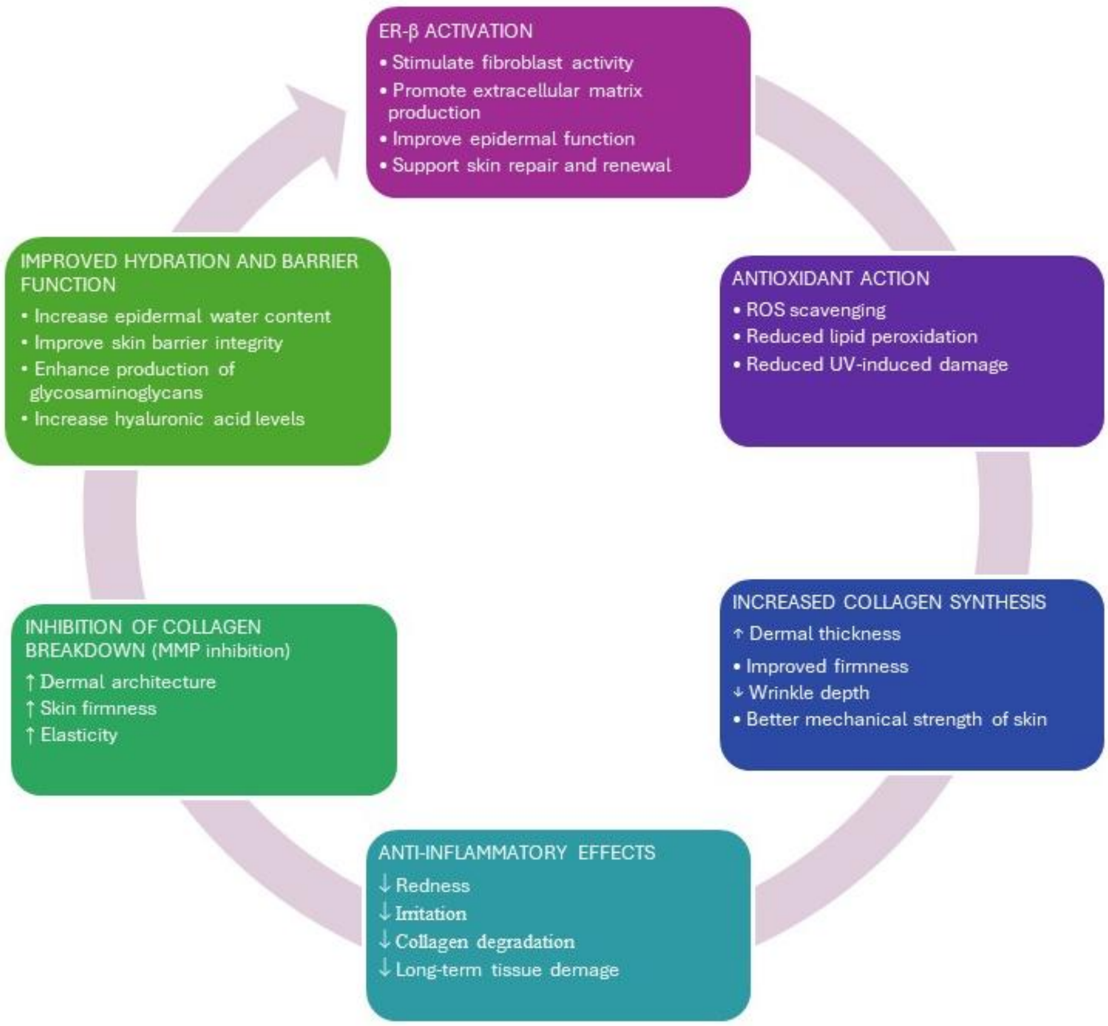


Fig. 3. Potential mechanisms through which phytoestrogens influence skin aging and their consequences

At the dermal level, fibroblasts are the primary cellular target of these compounds (Amini et al., 2025), with the activation of estrogen receptors leading to increased synthesis of type I and III collagen and the maintenance of skin elasticity.

According to the studies reviewed, administration of isoflavone-enriched soybean leaf extract led to the restoration of dermal collagen fibers in ovariectomized rats, suggesting a direct effect on extracellular matrix remodeling and fibroblast activity (Yoo et al., 2024).

A recent study shows that isoflavonoids from soy increased collagen and hyaluronic acid, but were less effective than the control, estradiol (Farkas E et al., 2026).

In the case of red clover, administration of isoflavones reduced skin changes induced by ovariectomy, preventing a decrease in dermal thickness and a reduction in collagen content. These results suggest a protective effect on the extracellular matrix through the stimulation of fibroblasts and the limitation of structural degradation. Chinese liquorice extract has been shown to affect the COL1A1 and COL3A1 genes—which are essential for collagen production—in human dermal fibroblasts, thereby increasing procollagen I production. In addition, the study highlighted the inhibition of MPP-1 induced by UVB rays and pollution (Circosta et al., 2006), which contributes to reducing collagen degradation and preserving dermal structure (**Figure 3**).

5.3. Protection Against Photoaging

Photoaging results from chronic exposure to ultraviolet radiation and the associated oxidative stress. These processes lead to collagen degradation, impairment of the skin barrier, and hyperpigmentation. Phytoestrogens possess significant antioxidant properties, helping to limit the oxidative degradation of proteins and membrane lipids. Isoflavones and flavonoids from soy, red clover, and Chinese liquorice have demonstrated the ability to reduce oxidative stress caused by UV rays and to diminish the inflammatory processes associated with photoaging. Liquorice extract prevents dermal collagen breakdown by blocking the MMP-1 production triggered by UVB rays and pollutant particles. Furthermore, active compounds in licorice, such as glabridin and liquiritigenin, possess antioxidant and photoprotective activity (Amini et al., 2025), reducing the oxidative effects associated with UV radiation exposure.

Numerous studies have suggested that phytoestrogens could reduce UV-induced erythema by decreasing inflammation and lipid peroxidation (Lin, 2008; Widyarini, 2001). At the same time, the flavonoid compounds in licorice produce depigmenting effects by inhibiting tyrosinase, thereby limiting inflammatory hyperpigmentation and skin pigmentation irregularities (Amini et al., 2025). These mechanisms support the use of phytoestrogens in the prevention and management of the clinical signs of photoaging.

5.4. Anti-inflammatory Effect and Other Relevant Mechanisms

Inflammation drives skin aging by progressively degrading the extracellular matrix and impairing skin barrier function. Phytoestrogens can reduce inflammation-induced tissue degradation through their antioxidant and estrogen-like activity (Amini et al., 2025).

Isoflavones from soy and red clover help maintain dermal homeostasis by supporting fibroblast activity and reducing changes associated with estrogen deficiency (Yoo et al., 2024; Circosta et al., 2006), including loss of elasticity and thinning of the dermis.

In the case of Chinese liquorice extract, the anti-inflammatory effects are associated with both a reduction in oxidative stress and a limitation of extracellular matrix degradation through the inhibition of MMP-1. At the same time, the improvement in dermal density observed in the clinical study (Amini et al., 2025) suggests beneficial effects on the microstructure of the dermis and on the maintenance of vascular and skin tissue support (**Table 1**).

Table 1. Preclinical and clinical evidence for topical phytoestrogens in skin aging

Plant source, active compounds	**Study outcome and mechanisms of action in the skin**	**Study design**	**Bibliographic reference**
Human studies			
Genistein	Protection against peroxidation by modulating oxidant/antioxidant system and mitochondria membrane potential; mechanisms related to ERs and GPER30 and kinases activation	*In vitro*, human fibroblasts/keratinocytes	Savoia et al., 2018
Glycyrrhiza uralensis extract, with liquiritigenin as a quantitative chemical marker	Induces Collagen I and III Gene Expression Induces Pro Collagen I Protein Expression Inhibits UVB Induced MMP1 Inhibits Pollution Induced MMP1	*In vitro*, human epidermal keratinocytes and dermal fibroblasts	Amini et al., 2025
Gel with isoflavones (genistein 4%)	Estrogens have a stronger effect on histomorphometrical parameters than isoflavones	DB-RCT, postmenopausal women (n=46); 24 weeks; control group: gel with 17-beta-estradiol 0.01%	Moraes et al., 2009
Active formulation containing 1% *Glycyrrhiza uralensis* extract, with liquiritigenin as a quantitative chemical marker	Improvements in dermal density for sub-group above 50 years old	*In vivo*, healthy female volunteers (n=46, mean age=58 years); 8 weeks, twice daily	Amini et al., 2025
Genistein (99% purity), vitamin E, vitamin B3, and ceramide	Skin wrinkling parameters showed a significant reduction	DB-RCT, postmenopausal women (n=50, mean age=55,8 years), 6 weeks	Na Takuathung et. al., 2023
Resveratrol, 2% emulsion	Reduces the appearance of skin wrinkles; increases skin firmness; decreases skin redness	*In vivo*, observation study female subjects (n=20, average age=44.6 years); 8 weeks	Brinke et al., 2021
Trans-resveratrol: one capsule of 75 mg/day and apply 1 g of cream (1.5% trans-resveratrol) twice daily	When taken orally and applied topically, trans-resveratrol was effective at wrinkle reduction, and when applied topically, it increased sebum levels.	DB-RCT, Females aged 40 years and above (n=122); 8 weeks	Rao et al., 2025
Animal studies			
Genistein, solution 0.5% Daidzein, solution 0.5%	Provide effective photoprotection (measured by sunburn cell formation and/or erythema)	White Yorkshire pigs, 4 days	Lin et al, 2008

Biochanin A, solution 0.5%			
Isoflavones from *Trifolium pratense,* red clover: genistein, daidzein, biochanin A, formononetin; the metabolites equol and isoequol and the derivative dehydroequol.	Protect from inflammation and immune suppression induced by UV radiation	Hairless albino mice	Widyarini et al., 2001

6. The Efficacy of Phytoestrogens in Anti-Aging Products and Evaluation Methods

6.1. Parameters Used in Evaluating the Efficacy of Anti-Aging Products

The efficacy of anti-aging cosmetic products is determined through a series of clinical tests that monitor structural and functional changes in the skin. Among the most important parameters analyzed are the degree of hydration, skin elasticity and firmness, wrinkle reduction, transepidermal water loss (TEWL), pigmentation levels, and skin tone uniformity (Fluhr et al., 2006; Lodén and Maibach, 2000).

Hydration of the stratum corneum is one of the main indicators of the skin's barrier function. It is measured by corneometry, using a device called a corneometer, which determines moisture levels by measuring the skin's electrical conductivity (Rogiers, 2001). Thus, the drier the skin, the lower its electrical conductivity, and increased hydration and an increased dielectric constant are associated with the reduction of fine wrinkles and improved skin elasticity.

TEWL (Transepidermal Water Loss) reflects the integrity of the skin barrier and is measured using a TEWL meter. Elevated TEWL values are associated with skin aging (Pinnagoda et al., 1990). When testing cosmetic products, a decrease in TEWL following product use suggests an improvement in the skin's barrier function attributable to the product.

Skin elasticity is assessed via cutometry using a cutometer. This measures the skin's ability to return to its original shape after the application of controlled negative pressure.

The R2 and R7 parameters are considered relevant indicators of biological elasticity and skin firmness (Dobrev, 2000). Reduced skin elasticity and firmness are associated with the degradation of collagen and elastin fibers, which are among the main causes of skin aging.

Wrinkle evaluation involves analyzing parameters such as depth, surface area, roughness, and skin texture. Assessments are conducted both clinically and instrumentally, utilizing standardized photography, 3D imaging analysis (Luebberding et al., 2013), or specialized systems such as Visioscan, PRIMOS, and Antera 3D.

Hyperpigmentation and skin color unevenness are assessed via colorimetry or mexametry. These methods allow for the measurement of melanin levels and erythema using the mexameter, a narrow-band reflectance spectrophotometer (Fullerton et al., 1996).

Reducing pigmentation spots and evening out skin tone are considered key factors in determining the effectiveness of anti-aging products.

Beyond traditional approaches, we must consider how phytoestrogens can influence the body. For cosmetic products containing phytoestrogens, a detailed analysis should also be conducted on how they act throughout the entire body. Thus, we should determine the extent to which they are absorbed—both at the skin level and whether they are taken up into the bloodstream—how these substances are eliminated from the body, and how these parameters vary depending on concentration and frequency of use.

6.2. Clinical Evidence on the Efficacy of Phytoestrogens in Anti-Aging

Genistein is one of the most studied phytoestrogens used in anti-aging products due to its ability to bind to β-estrogen receptors present in the skin. Activation of these receptors can stimulate collagen synthesis, increase hyaluronic acid secretion, and reduce oxidative stress (Patra et al., 2023; Intharuksa et al., 2025) involved in skin aging.

A randomized, double-blind, placebo-controlled clinical trial evaluated the efficacy of a topical product containing genistein, combined with vitamin E, vitamin B3, and ceramides, in postmenopausal women. The study included 50 participants who applied the product over a 6-week period. The authors reported an increase in skin hydration, a reduction in fine pores, and an improvement in certain wrinkle parameters, particularly in participants over the age of 56. These results must, however, be interpreted with caution, as the tested product contained several ingredients with proven anti-aging effects (vitamin E, ceramides, and niacinamide) (Na et al., 2023), making it difficult to attribute the results exclusively to genistein. Additionally, the study duration was short, and the sample size was small.

7. The Cosmetic Formulation of Anti-Aging Products Containing Phytoestrogens

The phytoestrogens from the targeted plant sources are isoflavones and polyphenolic flavonoids with fairly weak estrogenic activity. Structurally, most isoflavones have relatively low molecular weights, which promotes diffusion through the *stratum corneum* and skin permeability. However, the chemical form strongly influences absorption. Thus, aglycones are more easily absorbed through membranes due to their increased lipophilicity, unlike glycosides, which are more hydrophilic (Setchell et al., 2001).

In the case of red clover, biochanin A and formononetin are more lipophilic than genistein and daidzein, which may limit their dispersion in aqueous vehicles. Thus, solubilization systems are often necessary for efficient absorption (Del Rio et al., 2013).

Similarly, glabridin from licorice is lipophilic and highly sensitive to oxidation and light, which makes it difficult to formulate into stable aqueous systems (Ao et al., 2010).

In general, isoflavones are relatively stable in a slightly acidic to neutral range (approximately pH 4–7), a range comparable to the natural pH of the skin. However, under alkaline conditions, accelerated oxidation, isomerization, and phenolic degradation may occur, and sensitivity to light and oxygen increases (Hu, 2007). In the case of glabridin, instability is accentuated both in an alkaline environment and under conditions of light exposure, where oxidative degradation occurs more rapidly (Ao et al., 2010).

Polyphenols are more susceptible to photooxidative processes because they absorb UV radiation and can lead to changes in chemical structure and photoinduced oxidation. These processes can lead to reduced biological activity, color changes in the formulation, precipitation, and diminished efficacy of the cosmetic product (Fernandes et al., 2023; Savic et al., 2026). To promote stability, specific packaging (opaque and airless), antioxidants such as vitamin E, chelating agents, and lipid encapsulation systems are used.

The compatibility of phytoestrogens with excipients is a key consideration in the development of dermo-cosmetic formulations. Common issues include complexation with metal ions, precipitation in the presence of electrolytes, incompatibility with ionic surfactants, and oxidative degradation in insufficiently stabilized emulsions (Savic et al., 2026). Thus, isoflavones exhibit superior stability in anhydrous systems, W/O (water-in-oil) emulsions, phospholipid carriers, and nanoencapsulated systems.

Finally, phytoestrogens are also compatible with other active ingredients: antioxidants (vitamins C and E), peptides, or other moisturizing ingredients, which results in a synergistic anti-aging effect without significantly increasing the risk of skin irritation (Tomas et al., 2025).

To improve solubility, stability, and skin permeability, modern delivery systems for phytoestrogens, such as liposomes and nanoemulsions, have been developed. Liposomes and nanoemulsions are advanced, small-sized colloidal systems designed to facilitate dispersion. Liposomes are phospholipid vesicles frequently used in cosmetic formulations to protect active compounds from oxidation and to improve skin penetration. These systems allow for the controlled release of active substances and reduce the irritation potential of formulations (Akombaetwa et al., 2023).

Nanoemulsions increase the contact surface area and facilitate the solubilization of lipophilic compounds, improving distribution and skin permeability. Among their advantages are superior stability compared to other types of delivery systems, as they increase dermal penetrability and facilitate the development of an improved cosmetic formulation (Woo et al., 2025).

Solid lipid nanoparticles and nanostructured lipid carriers reduce oxidative degradation and facilitate the incorporation of highly lipophilic compounds into stable lipid bases (Eroğlu et al., 2023). These systems prolong contact time with the skin surface and improve the permeability of the stratum corneum. They are considered promising for active ingredients such as glabridin and biochanin A.

Self-emulsifying systems allow for the spontaneous formation of fine dispersions upon contact with the aqueous phase of the formulation, increasing the dispersion and solubilization of lipophilic compounds (Eid et al., 2023). In cosmetic products, these systems can contribute to the uniform distribution of phytoestrogens and increased skin penetration.

The use of standardized extracts encourages a potential synergistic effect between bioactive compounds and complex antioxidant and anti-inflammatory activity (Stallings and Lupo, 2009). However, these extracts have disadvantages such as lower stability and difficulty in standardization within cosmetic formulations.

Currently, modern trends in cosmetic formulation aim for the rigorous standardization of plant extracts and their combination with nano-encapsulated systems to optimize stability and skin bioavailability (Woo et al., 2025; Eroğlu et al., 2023).

Standardization of extracts (Stallings and Lupo, 2009) is essential because phytoestrogen content varies depending on species, cultivation methods, harvesting, processing, and extraction.

8. Safety and Controversies

The benefits of using phytoestrogens to combat the skin aging process have been mentioned previously, highlighting their antioxidant and moisturizing actions and their influence on collagen synthesis; however, studies also outline other important benefits for the skin.

One benefit is the improvement of the skin's barrier function. The combination of phytoestrogens and phytosterols can stimulate the production of ceramides and hyaluronic acid in the epidermis, reducing transepidermal water loss (Carneiro et al., 2023), thus highlighting, from a distinct perspective, a previously noted benefit.

The cosmetics industry also relies heavily on product presentation. Thus, consumer acceptance will be much higher for products—even hormonal ones—derived from natural sources.

Despite their promising potential, the use of phytoestrogens in anti-aging cosmetics poses certain significant limitations.

First, their hormonal activity is weak and fluctuating. The efficacy of phytoestrogens depends on their concentration, chemical composition, and ability to bind to estrogen receptors. This may limit their anti-aging effect compared to other types of hormonal therapies (Baber, 2010).

Another drawback is their limited ability to penetrate the skin. Phytoestrogens vary in terms of lipophilicity, which can reduce their bioavailability in the dermis unless delivery systems such as nanovectors or advanced lipid formulations are used (Cheng et al., 2025).

Furthermore, from a regulatory standpoint, there is a lack of standardization for these extracts. Concentrations of active ingredients can vary between products, and some formulations may contain insufficient amounts to produce significant effects (Tomas et al., 2025), which highlights the discrepancy between marketing claims and scientific reality.

Clinical data are still limited, particularly regarding long-term topical treatments, and although the risk is considered low, there are potential safety precautions for individuals with a history of hormone-dependent diseases (Lephart, 2025), where systemic absorption could interfere, even minimally, with hormonal therapies.

Furthermore, some phytoestrogens can negatively affect skin health if not used in appropriate amounts or formulations. They can cause increased sensitivity or even skin irritation, particularly in formulations containing irritating ingredients (alcohol, fragrances).

9. Research Gaps and Future Directions

Phytoestrogens found in soy, red clover, and Chinese liquorice are promising compounds due to their estrogen-like, antioxidant, and anti-inflammatory properties. Among these, the isoflavones in soy and red clover have the strongest scientific support, particularly regarding their interaction with estrogen receptors and their effects on skin elasticity and hydration.

The best-supported mechanisms are antioxidant activity and the reduction of inflammation. Although some anti-aging or regenerative effects remain insufficiently demonstrated clinically, the available clinical evidence suggests favorable effects on skin parameters; however, these are limited by small sample sizes, the short duration of the studies, and the lack of standardization in formulations.

Major obstacles in interpreting the results include variations in the concentrations used, extraction methods, and the characteristics of the populations studied. Furthermore, the lack of uniform evaluation methods and data on long-term safety limits the credibility of current results.

At the same time, the report highlights gaps that can provide a clear and useful perspective for further exploration of the topic and the development of the industry. Although most recommendations for further development are based on the assessment of safety and stability over time, it is also important to investigate how these phytoestrogens are assimilated by the body and how they are subsequently eliminated to avoid potential adverse reactions in the glands or other organs.

In this context, the future development of products containing phytoestrogens should aim for the standardization of plant extracts, clear reporting of concentrations, and the use of objective, reproducible testing methods. More extensive clinical studies, conducted on well-defined populations and with longer follow-up periods, are needed to clarify the efficacy and safety of these compounds.

Conclusions

This paper has highlighted the significant potential of phytoestrogens, as plant-based active ingredients in anti-aging cosmetic formulations, by analyzing scientific studies that demonstrate their beneficial effects.

Overall, plant phytoestrogens show considerable potential as alternatives or adjuvants in skin care, but full validation of their efficacy and safety requires a much broader approach.

Conflict of Interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

Author Contributions

MA. P: Conceptualization, Investigation, Visualization, Writing – original draft. E. LZ: Conceptualization, Supervision, Writing – review & editing.

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Generative AI Statement:

The authors declare that the research was conducted in the absence of any Artificial Intelligence (AI) Tools.

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