Herbal Based in-situ Gel Formulation for under Eye Applications a Recent Innovation

Trakshi Gaur
Swami Vivekanand Subharti University
Charu Saxena
charusaxena18@gmail.com

Swami Vivekanand Subharti University

Short Report

Keywords: In-situ gel, calendula officinalis, Psoraleacorylifolia, antioxidant, bioadhesion, AI-assisted formulation

Posted Date: August 11th, 2026

DOI: https://doi.org/10.21203/rs.3.rs-10546845/v1

Additional Declarations: No competing interests reported.

Herbal Based *in-situ* Gel Formulation for under Eye Applications a Recent Innovation

Trakshi Gaur[1], Charu Saxena*[1],

[1]Research Scholar Faculty of Pharmacy, Swami Vivekanand Subharti University Meerut Uttar Pradesh INDIA 250005

*[*1]Associate Professor, Faculty of Pharmacy, Swami Vivekanand Subharti University Meerut Uttar Pradesh INDIA 250005*

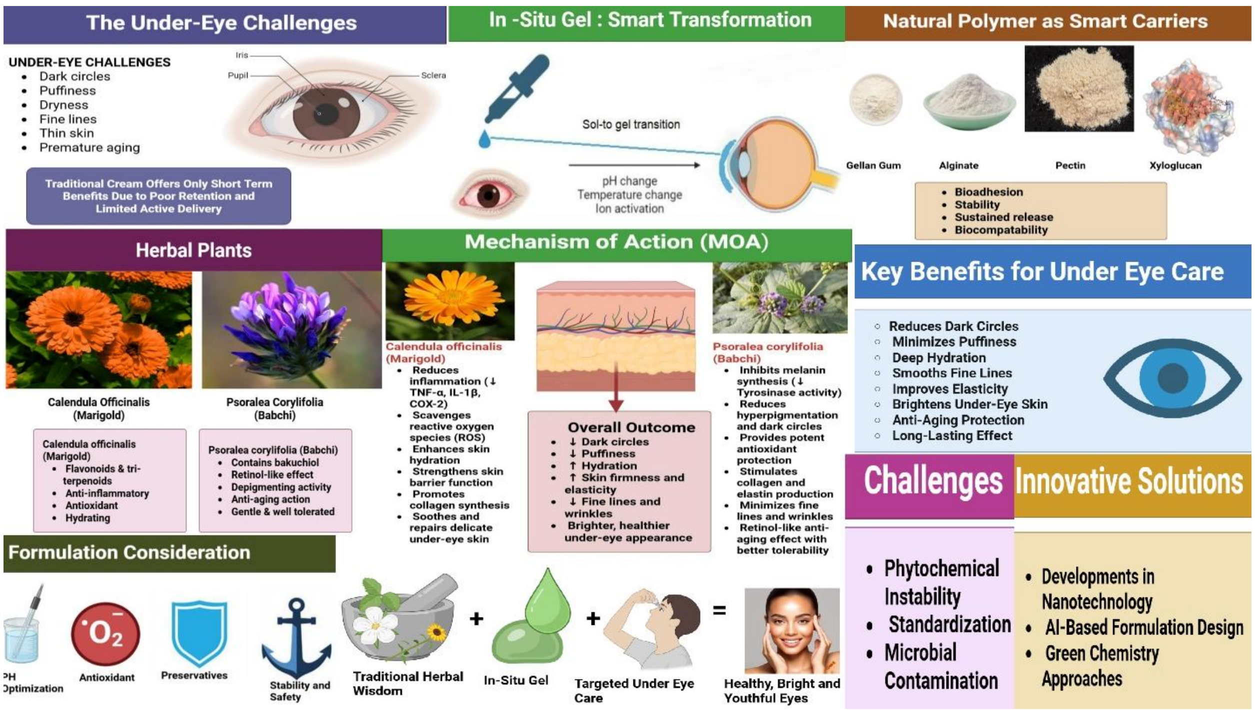
Corresponding Author
Dr.Charu Saxena
Associate Professor
Faculty of Pharmacy
Swami Vivekanand Subharti University Meerut
Email:charusaxena18@gmail.com

Abstract-

The under-eye area is one of the most fragile parts of the face, with thin skin, few sebaceous glands, high muscle activity, and thick vasculature. Because of these unique characteristics, it is sensitive to frequent problems such as dark circles, puffiness, dryness, and fine lines. Traditional creams frequently provide only short-term advantages due to ineffective retention and active delivery. *In-situ* gel technology provides a possible alternative since it exists as a liquid during application and transforms into a gel in response to physiological stimuli such as temperature, pH, or ionic concentration.This transition allows for longer contact times, controlled active release, and increased user comfort. Calendula officinalis (marigold) and Psoralea corylifolia (Babchi) have tremendous potential for under-eye care due to their relaxing, antioxidant, depigmenting, and anti-aging characteristics. Calendula's flavonoids and triterpenoids reduce inflammation and increase hydration, whereas bakuchiol from Babchi has retinol-like properties but is more acceptable. Natural polymers such as gellan gum, alginate, pectin, and xyloglucan offer bioadhesion, stability, and sustained release, making them good carriers for these sensitive actives. To maintain stability and safety, important formulation considerations include pH optimization, antioxidant addition, and preservative selection. Although difficulties such as phytochemical instability, standardization, and microbial contamination exist, developments in nanotechnology, AI-based formulation design, and green chemistry approaches provide unique solutions. Overall, herbal in-situ gels provide an advanced, sustainable, and patient-friendly technique for effective under-eye treatment by combining traditional herbal therapy with modern medication delivery.

Key words: *In-situ* gel, calendula officinalis, Psoraleacorylifolia, antioxidant, bioadhesion, AI-assisted formulation

Graphical Representation

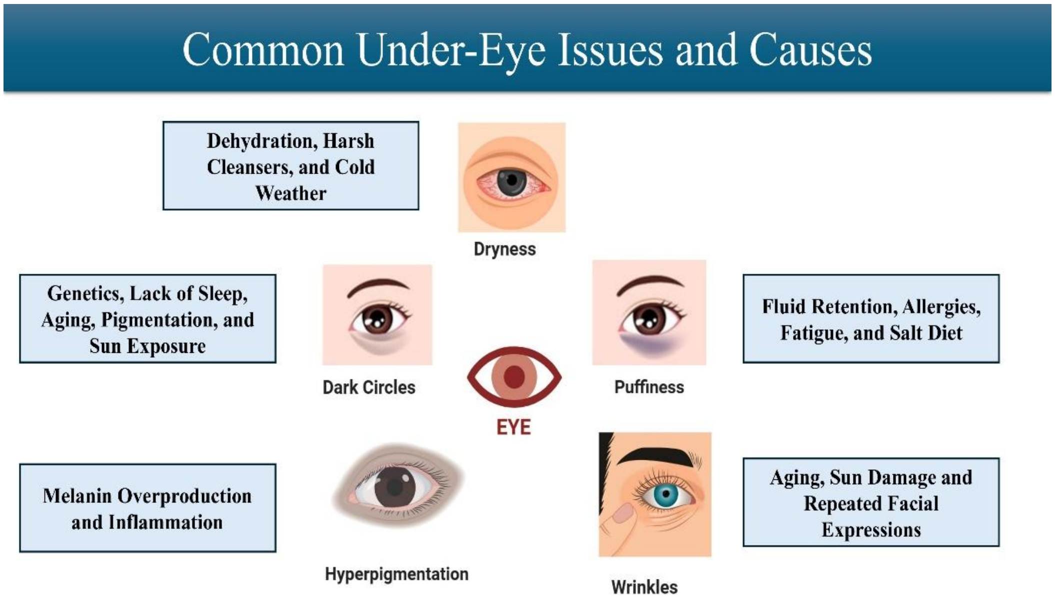


Introduction:

Anatomical and physiological feature of under eye area:

The under-eye area is a highly sensitive and specialized portion of facial anatomy. The skin here is substantially thinner—about 0.3 to 0.5 mm—than the rest of the face, with fewer oil glands and less fat, making it more fragile and susceptible to dryness, fine wrinkles, and injury. The orbicularis oculi, a circular muscle responsible for facial expressions such as blinking, squinting, and smiling, is located just beneath this thin layer. This muscle provides some structure but is always active, which contributes to early wrinkle formation. The area is highly vascular because it has a network of microscopic blood arteries and capillaries beneath the muscle. Sluggish blood flow or pooling around the eyes can cause dark circles or bluish discolouration[1][2]. The infraorbital fat pads, which produce a smooth contour and cushion the eyeball, add to the complexity. These fat pads can migrate, shrink, or protrude outward over time, resulting in puffiness or hollowness under the eyes. The area also contains lymphatic vessels, which are in charge of removing fluids and metabolic waste. When drainage becomes poor, fluid accumulates, resulting in puffiness or eye bags[3]. The septum orbital the under-eye region serves a variety of physiological functions. It supports and cushions the eyeball, allowing for smoother movement and protection during facial movements. Although the skin regulates temperature and moisture, its lack of sebaceous (oil) glands renders it susceptible to dryness, irritation, and small wrinkles, a thin sheet of connective tissue that maintains the fat in place, provides support for all of these layers[4]. As we become older, this structure weakens, allowing fat or fluid to protrude and contribute to sagging. The area is also densely covered in nerve endings, making it extremely sensitive—this is why itching, stinging, and swelling are felt more strongly here. Microcirculation through the fine capillaries guarantees the transport of oxygen and nutrients to the skin, yet even minor disturbances in circulation can cause discolouration or puffiness. Finally, because of its thin skin, regular muscle activity, and minimal collagen support, the under-eye area is one of the first to display apparent indications of aging, such as wrinkles, sagging, and dark circles[5][6] The common under-eye issues, their causes, and symptoms are summarized in Table 1 and illustrated in Figure 1."

Common under-eye issues:



Issues	Causes	Symptoms	Reference
Dark Circles	Genetics, lack of sleep, aging, pigmentation, sun exposure	Brown, purple, or bluish shadows under the eyes	[7][8]
Dryness	Dehydration, harsh cleansers, cold weather	Rough texture, tightness, itching	[9][10]
Hyperpigmentation	Melanin overproduction, inflammation	Uneven tone or dark patches under eyes	[11][12]
Wrinkles	Aging, sun damage, repeated facial expressions	Small creases, "crow’s feet"	[13][14]
Puffiness	Fluid retention, allergies, fatigue, salty diet	Swollen or baggy appearance	[15][16]

Table:1 Common Under Eye Issue

Limitations of synthetic medicines in under eye causes:

Since the skin under the eyes is so sensitive, synthetic medications commonly fail to provide safe and effective remedies that last. Strong active components, such as hydroquinone or retinoid, might induce rebound pigmentation, peeling, or irritation, while others quickly lose their potency because of stability when subjected to air or light. Also, while though under-eye problems are usually caused by a number of causes, including poor circulation, oxidative stress, and genetics, their effects are usually temporary and only target one aspect, such as pigmentation or collagen. The side effects and poor textures usually prevent regular use, which reduces their total effectiveness. For this reason, a lot of researchers are currently considering more sustainable options in the form of softer, multi-targeted herbal formulations[17].

Limitations of synthetic medicines in under eye causes with scientific proof

Despite their widespread use, synthetic medications clearly have limitations when it comes to treating under-eye issues, and scientific research supports this. The corneal epithelium, tear film, and blood–ocular barrier are the eye's inherent defence mechanisms. significantly reduce drug penetration, so that just a small portion of the active ingredient reaches the target location. Low bioavailability and briefly therapeutic duration result, requiring frequent doses or more potent formulations. Additionally, clinical research reveals that annoying synthetic methods, such intravitreal injections, are not appropriate for normal under-eye therapy due to the dangers of retinal toxicity, endophthalmitis, and intraocular inflammation, even though they are effective in delivering medications to deeper tissues. In addition, because topical synthetic drugs are absorbed through the thin periocular skin, they may cause skin irritation, allergic reactions, or systemic adverse effects. Essentially, synthetic medications may provide tailored action, but their limitations—poor absorption, annoying administration, and safety risks—make them impractical for sensitive under-eye treatment. Because of this, scientists are looking more closely at complex natural delivery methods and herbal Phytoconstituents as safer, wider options[18].

Role of natural Phytoconstituents in under eye cause

As they combine with the body's natural functions, natural Phytoconstituents have a sensitive yet effective role in treating under-eye issues. One of the main causes of dark circles and early age is oxidative stress, which can be reduced by substances derived from plants such flavonoids, polyphenols, and alkaloids. While chamomile and green tea Catechins reduce puffiness by enhancing microcirculation and decreasing fluid retention, ingredients like aloe vera reduce irritation and hydrate the thin skin under the eyes. The liquorice root and turmeric curcuminoids are examples of natural brightening agents that help lighten pigmentation without the negative side effects of pharmaceutical medications. These Phytoconstituents work in a complex way, protecting collagen, enhancing flexibility, reducing inflammation, and re-establishing normal balance, which makes them particularly appropriate for the sensitive area beneath the eyes. Natural Phytoconstituents, which function as nature's own gentle treatments for sensitive skin, are essential in the management of under-eye issues. They attack dryness, puffiness, dark circles, and fine wrinkles in a number of ways thanks to their concentration of bioactive ingredients. Flavonoids from green tea and calendula, which have antioxidant qualities, shield the thin skin around the eyes from oxidative stress, which speeds up ageing and pigmentation. In addition, their anti-inflammatory properties, including curcumin in turmeric or chamazulene in chamomile, reduce micro-inflammation and reduce swelling or redness. Some Phytoconstituents also have a natural brightening effect; for example, bakuchiol from babchi or Glabridin from liquorice root helps control melanin synthesis, gradually lightening dark circles without the harshness of artificial bleaching treatments. Beyond this, substances like green tea Catechins and aloe vera polysaccharides increase the synthesis of collagen, increasing flexibility and reducing fine wrinkles. Lastly, their calming and moisturizing ingredients—like calendula polysaccharides or aloe mucilage—bind in moisture and maintain the suppleness of the area beneath the eyes, avoiding dryness and creasing. Phytoconstituents are a great option for comprehensive, basic under-eye care because these natural molecules act in conjunction to protect, relax, brighten, and nourish[19][20].

Since the sensitive skin in this area is extremely at risk for stress, vascular changes, and pigmentation defects, natural phytoconstituents play a major and full role in preventing under-eye issues. These plant-based substances have several advantages at once and function as organic healers and protectors. Their antioxidant defence reduces oxidative stress, which causes dark circles, fine wrinkles, and early ageing, by neutralising free radicals. In addition, their ability to hydrate and soothe—using substances like liquorice polysaccharides or aloe vera mucilage—ensures that the skin stays calm and supple, avoiding dryness that accentuates wrinkles. Numerous phytoconstituents also improve microcirculation; for example, horse chestnut saponins and green tea catechins improve blood flow and lessen puffiness or bluish discolouration. Their function in pigmentation balance, where substances like bakuchiol from babchi or glabridin from liquorice control melanin synthesis to slowly reduce hyperpigmentation and level out skin tone, is equally significant. Also, gotu kola's phytoconstituents, like curcumin and triterpenoids, increase the creation of collagen, supporting the skin beneath the eyes and minimising drooping. Their anti-inflammatory properties, such as those of calendula's flavonoids or chamomile's apigenin, reduce swelling and redness, giving the look of freshness and reduced tiredness. Together, these natural substances perform a range of functions, including protecting, healing, moisturising, and brightening, which makes them perfect for modern formulations like gels, serums, and in-situ delivery systems meant for sensitive under-eye care[21][22].

Various medicinal herbs have been reported for the management of under-eye disorders. Their active constituents and therapeutic uses are summarized in Table 2

Name	Scientific name	Active ingredient	Uses	Reference
Aloe vera	Polysaccharides, glycoproteins	Excellent for hydration and soothing, supports skin healing	Reduces mild inflammation and puffiness	[23][24]
Ashwagandha	Withania somnifera (L.) Dunal	Alkaloids (withanine, somniferine), sitoindosides, and withanolides (triterpene lactones)	reduces oxidative stress, reduces inflammation, and maintains proper balance of collagen	[25]
Basil	Ocimum sanctum L. (Holy Basil / Tulsi)	Rosmarinic acid, ursolic acid, flavonoids, and essential oils (eugenol, linalool)	Anti-inflammatory action decreases swelling and puffiness Brightening effect helps in naturally lightening dark circles and pigmentation	[26]
Carrot	Daucus carota L.	Polyphenols, vitamin C, carotenoids, and beta-carotene (provitamin A)	softens and nourishes the skin under the eyes. Anti-aging action increases skin renewal, which inhibits wrinkles and fine	[27]

			lines.	
Chamomile	Matricaria chamomilla	Apigenin, bisabolol, azulene	Calms irritation, brightens skin, reduces redness	[28]
Coffee	Coffeea arabica L. Coffea canephora (Robusta)	Diterpenes, polyphenols, caffeine, and chlorogenic acids	Caffeine renews tired eyes, reduces swelling and puffiness, and lightens pigmentation by tightening blood vessels.	[29]
Coriander	Coriandrum sativum L.	Flavonoids, phenolic acids, essential oils (camphor, borneol, and linalool), and vitamin C	reduces fine lines and wrinkles, nourishes and softens thin under-eye skin, reduces swelling and puffiness, and protects sensitive under-eye skin from oxidative stress.	[30]
Cucumber	Cucumis sativus L.	Polyphenols, vitamin C, silica, flavonoids, and cucurbitacins	immediately refreshes sleepy eyes, reduces inflammation, and nourishes and softens the sensitive area under the eyes.	[31]
Fenugreek	Trigonella foenum-graecum L.	Vitamin C, alkaloids, flavonoids, and saponins (diosgenin)	Brightening effect naturally lightens dark circles and reduces dark circles. Anti-inflammatory action: reduces oedema and puffiness under the eyes	[32]
Gotu kola	Centella asiatica (L.) Urban	Triterpenoid saponins, flavonoids, madecassoside, and asiaticoside	Collagen support reduces fine wrinkles by tightening and strengthening the sensitive skin under the eyes. Anti-inflammatory action reduces swelling and discomfort	[33]
Grape seed	Vitis vinifera L.	Linoleic acid, vitamin E, flavonoids, and proanthocyanidins	Antioxidant shield protects against oxidative stress and free radical damage to the sensitive skin under the eyes. Collagen support improves firmness, reduces fine wrinkles, and strengthens	[34]

			the structure of the skin.	
Green Tea	Camellia sinensis	EGCG (Epigallocatechin gallate), tannins	Fights free radicals, reduces dark circles, improves circulation	[35]
Lemon	Citrus limon	Vitamin C, citric acid, flavonoids, antioxidants	Vitamin C may help reduce dark pigmentation	[36]
Licorice	Glycyrrhiza glabra	Glabridin, flavonoids	Lightens dark circles, anti-inflammatory, antioxidant	[37]
Marigold	Calendula officinalis	Calendula oil	Reduces swelling and puffiness under the eyes	[38]
Neem	Azadirachtaindica	Azadirachtin, nimbin, quercetin, vitamin E, fatty acids	Reduces mild inflammation and puffiness	[39][40]
Peppermint	Mentha × piperita L.	Rosmarinic acid, flavonoids, menthol, and menthone	decreases oedema and fluid retention under the eyes, quickly refreshes tired eyes, and soothes irritation.	[41]
Pomegranate	Punica granatum L.	Punicalagins, anthocyanins, and ellagic acid	Antioxidant barrier against oxidative damage brightening impact to reduce wrinkles	[42]
Rose	Rosa damascena	Vitamin C, phenolics, anthocyanins	Hydrates, tones skin, reduce redness	[43]
Saffron	Crocus sativus L.	Flavonoids, crocin, and safranal	Controlling pigmentation to lighten dark circles anti-inflammatory properties to reduce swelling	[44]
Sea buckthorn	Hippophae rhamnoides L.	Omega fatty acids, carotenoids, vitamin C, flavonoids	Collagen provides firmness support. Hydration boost to help soothe sensitive skin	[45]
Shatavari	Asparagus racemosus Willd.	Flavonoids, alkaloids, and saponins (shatavarins)	Enhancing elasticity for rejuvenating skin Calm action to reduce discomfort	[46]
Strawberry	Fragaria × ananassa Duchesne	Anthocyanins, vitamin C, and ellagic acid	Brightening effect to fade pigmentation - Antioxidant protection for delicate skinn	[46]
Turmeric	Curcuma longa	Curcumin	Reduces dark pigmentation, improves	[28]

			circulation	
Witch hazel	Hamamelis virginiana L.	Volatile oils, flavonoids, and tannins	de-puffing effect through skin tightening and oedema reduction calming impact to reduce irritation	[47]

Table:2 Herbs used for under eye treatment

Limitations conventional formulation for under eye causes with scientific proofs

Conventional ointments, gels, and creams targeted for the sensitive under-eye region often fail to produce consistent, long-lasting results. Although they might offer short-term relief or cosmetic coverage, research reveals a number of disadvantages:

Large or poorly soluble molecules find it challenging to get through the skin under the eyes because it is so thin (around 0.5 mm). Because of this, many active substances simply provide surface hydration, failing to penetrate deeper layers where pigmentation or vascular issues actually start. The instability of natural active ingredients like vitamin C or herbal antioxidants is another problem; they quickly degrade in the presence of light, oxygen, or heat, losing most of their effectiveness before they can address oxidative stress or melanin development. Another factor is texture; oil-based carriers in traditional ointments frequently feel oily, clog pores, or irritate the delicate periocular area, all of which lower patient compliance. Beyond that, under-eye problems like dark circles, puffiness, and wrinkles are caused by a variety of causes, including pigmentation, poor circulation, fluid retention, and collagen loss; these formulations often address a single reason, such as dryness. Single-target techniques usually result in significant improvement, according to scientific evaluations. Moreover, their effects are short-term: traditional products only offer temporary hydration or relaxation in the absence of advanced delivery mechanisms. Comparative research reveals that although conventional creams provide rapid but surface-level relief, modern nanocarrier-based systems maintain release, work more effectively, and penetrate deeper. Conventional formulations are essentially limited by one-dimensional targeting, unstable actives, and shallow action, which explains why their effects frequently seem temporary[48][49].

List of conventional formulation with their limitations for under eye causes given in table 3

Formulation	**limitations**	**Reference**
Creams	Hydrate mostly the surface; limited penetration through the thin skin behind the eyes (~0.5 mm). Actives frequently stay on the surface and don't address vascular problems or deeper pigmentation.	[50]
Ointments	Oil-based carriers can irritate the sensitive periocular area, feel heavy and oily, and clog pores. Discomfort and unacceptable appearance cause a decrease in patient compliance.	[51]
Lotions	Lighter than creams, but they still	[52]

	don't have advanced delivery mechanisms. The effects are temporary, providing nothing deeper therapeutic activity nor more than temporary hydration or relaxation.	
Traditional gels	Unstable for tiny substances like vitamin C or herbal antioxidants, but non-greasy and attractive. This decrease effectiveness when exposed to heat, light, or oxygen because they break down quickly.	[53]
Conventional serums	Contain concentrated active ingredients, but their penetration remains limited in the absence of nanocarrier systems. frequently focus on just one mechanism (such as hydration or brightness), which is inadequate for complicated under-eye issues.	[54]

Table:3 List of conventional formulation with their limitations for under eye causes

Role and scope of herbal formulations in under eye causes

The use of herbal remedies to treat under-eye issues like wrinkles, puffiness, dark circles, and fine lines has come to be seen as a safer and more complete option. Their strength is in using plant-based bioactive substances that have calming, depigmenting, antioxidant, and anti-inflammatory properties. They also offer multifunctional, patient-friendly solutions. By reducing free radicals, extracts such as Psoralea corylifolia (Babchi) and Calendula officinalis (Marigold) provide antioxidant protection and reduce oxidative stress associated with pigmentation and early ageing. Aloe vera, chamomile, and calendula are examples of ingredients that reduce discomfort and puffiness brought on by fluid retention or vascular congestion. While flavonoid-rich herbal compounds promote collagen development, enhancing elasticity and minimising fine wrinkles, active ingredients including liquorice root, turmeric, and Babchi regulate melanin synthesis, helping to brighten brownish under-eye circles. Importantly, compared to synthetic chemicals, herbal formulations are typically safer and kinder to the sensitive periocular skin, reducing the possibility of allergic reactions or discomfort. Herbal formulations can treat several mechanisms at once, including pigmentation, circulation, moisture, and collagen loss. This allows them to provide more comprehensive care than traditional single-target creams. By enhancing stability and penetration through their integration with cutting-edge delivery technologies like liposomes, hydrogels, and nanoemulsions, they become scientifically proven treatments rather than only cosmetic aids. Herbal gels that are calming and non-greasy enhance patient comfort, making them appropriate for long-term use. Herbal formulations meet customer preferences while upholding scientific credibility in response to the increased demand for natural and eco-friendly skincare products. Furthermore, new plant extracts and combinations are being investigated in ongoing research, increasing the possibility of creative, safe, and effective under-eye treatments[55][56].

List of herbal formulation with their advantages in under eye cause is shown in table 4

Herbal formulation	Bioactive compounds	Advantages	Reference
Psoralea corylifolia (babchi)	Psoralen, flavonoids	Minimizes brownish dark circles, balances pigmentation, controls melanin synthesis, and stimulates skin repair.	[57]
Calendula officinalis (marigold)	Flavonoids, triterpenoids	Strong reducing and anti-inflammatory properties; reduces puffiness, reduces irritation, improves skin healing, and improves hydration.	[57]
Aloe vera gel	Polysaccharides, vitamins, enzymes	Minimizes swelling and puffiness, increases comfort, soothes sensitive skin beneath the eyes, and offers cooling and hydration.	[57]
Chamomile extract	Apigenin, bisabolol	Provides small antioxidant protection against fine wrinkles, reduces inflammation, reduces vascular congestion, and decreases puffiness.	[57]
Licorice root extract	Glycyrrhizin, Glabridin	Reduces melanin formation, brightens the area under the eyes, and lightens dark circles caused by pigmentation. It also inhibits Tyrosinase activity.	[57]
Turmeric extract	Curcumin	Strong anti-inflammatory and antioxidant; lowers oxidative stress, promotes collagen production, and minimizes wrinkles and fine lines.	[57]

Green tea extract	Catechins (EGCG)	Eliminates free radicals, lowers oxidative stress, enhances microcirculation, reduces puffiness, and delays the onset of ageing symptoms.	[57]

Table: 4 list of herbal formulation with their advantages in under eye cause

***In-situ* gel:**

An *in-situ* gel is a clever composition that remains liquid while being applied but transforms into a gel once within the body due to changes in temperature, pH, or the presence of specific ions. This permits the treatment to remain at the site for extended periods of time, boosting its effectiveness and lowering the number of times it must be administered. *In-situ* gel formulations are a type of drug delivery method that is supplied in liquid form but undergoes into a gel at the point of application. Physiological stimuli such as changes in pH, temperature, or the presence of particular ions initiate this transition. These systems are widely employed in a variety of applications, such as the eye, nasal cavity, buccal region, vaginal and rectal channels, skin, and even injection[58]. One of the most significant advantages of *in-situ* gels is their capacity to deliver sustained and regulated drug release at the target region, which improves therapeutic efficacy. In addition, they promote patient compliance by reducing dose frequency and providing a more comfortable mode of administration. Based on their gelation mechanisms, in situ gels can be divided into three categories: pH-sensitive, thermo-sensitive, and ion-sensitive systems. pH-sensitive *in-situ* gels gel in reaction to variations in pH at the application location, such as the eye or stomach. Polymers like Carbopol and Polyacrylic acid are often utilized in these systems—for example, eye drops that remain liquid in the container but form a gel upon contact with the neutral pH of the eye (~7.4). Temperature fluctuations are used by thermo-sensitive *in-situ* gels to initiate gelation. Polymers like Poloxamers (Pluronic F127) and methylcellulose are commonly used in these formulations. They are liquid at ambient temperature but form gels at body temperature (~37°C), making them suitable for nasal or injection delivery. Finally, ion-sensitive in situ gels react to certain ions found in physiological fluids, such as calcium or sodium. Gellan gum and sodium alginate are often utilized in such systems, which include ocular and oral medication administration where gelation occurs when in contact with tear fluid or saliva[59][60][61].

Recent studies investigating herbal phytoconstituents in in-situ gel formulations for under-eye care are summarized in Table 5

Study / Year	Herbal Phyto-Constituent(s)	Focus / Findings
Singhal et al., IJABR 2025	Neem, Panch Tulsi, Aloe vera	Polyherbal under-eye gel is safe, irritation-free, and increased hydration while reducing puffiness and lightening dark circles.
Jokubaite et al., *Gels* 2024	Propolis, Balsam Poplar Buds, p-Coumaric acid	In situ gels based on poloxamer showed prolonged release of phenolic chemicals, improved SPF, and antioxidant protection.

Verma & Kumar, IJSRED 2025	*Strychnos potatorum* seeds	Antimicrobial, anti-inflammatory, and antioxidant ion-activated in situ gel shows promise for ocular and under-eye administration.
Clinical Cosmetology Review 2024	Calendula officinalis	In situ gels increased periocular skin hydration and had better soothing anti-inflammatory effects.
Herbal Ophthalmic Research 2023	*Psoralea corylifolia* (Babchi)	Psoralen molecules were stabilised using nano-gel systems, which also demonstrated depigmenting and collagen-supporting properties.
Asian Journal of Pharmaceutics 2023	*Camellia sinensis* (Green Tea)	Thermo-responsive gels enhanced microcirculation while reducing oxidative stress and puffiness.
Phytomedicine Reports 2022	Centella asiatica	In situ gels decreased fine wrinkles and increased collagen formation; they are safe for delicate skin beneath the eyes.
Int. J. PharmTech Research 2022	*Cucumis sativus* (Cucumber)	Cooling gel decreased puffiness and vascular congestion while increasing softness.
J. Herbal Medicine 2021	*Glycyrrhiza glabra* (Licorice root)	Tyrosinase-inhibiting gel decreased dark circles and pigmentation.
Pharmacognosy Journal 2021	*Curcuma longa* (Turmeric)	Antioxidant gel enhanced the skin tone beneath the eyes and decreased oxidative stress.
Cosmetic Dermatology Trials 2020	Aloe vera + Chamomile	Combination gel demonstrated complementary hydrating and calming properties.
Ophthalmic Herbal Delivery 2020	*Eclipta alba* (Bhringraj)	In situ gel decreased under-eye dullness and enhanced circulation.

Table: 5 recent studies used various herbal Phytoconstituents to examine in situ gel formulations for under-eye care

The relevance of herbs:

Herbs have been utilized as natural treatments for millennia and still play an important part in modern healthcare and wellness. Their value stems from their high concentration of bioactive substances like as alkaloids, flavonoids, tannins, glycosides, and essential oils, which have a variety of medicinal effects. Herbs possess anti-inflammatory, antioxidant, antibacterial, antidiabetic, and anticancer effects. Herbs are commonly utilized in Ayurveda, traditional Chinese medicine, and modern phytotherapy since they are natural and have fewer negative effects than manufactured medications[62]. Herbs are very useful in pharmaceuticals and cosmetics for producing herbal formulations such as creams, gels, in-situ gels, and serums. Herbs such as aloe vera, turmeric, neem, and marigold, for example, are widely used in skincare because of their healing, relaxing, and anti-aging characteristics. Furthermore, herbs enhance overall health by addressing not just physical symptoms but also promoting mental and emotional well-being. Because of their accessibility, affordability, and sustainability, they are becoming a significant component of customized and preventative medicine[63][64].(Shown in Figure No. 2 and 3)

Marigold (calendula officinalis)

Figure:2 Calendula officinalis[65]

Marigold, also known as pot marigold or calendula (Calendula officinalis), is a member of the Asteraceae (Compositae) family with well-known therapeutic and cosmetic properties. The flowers, especially the petals and extracts, are the most commonly used parts because they are high in flavonoids (such as quercetin and isorhamnetin), triterpenoids (such as faradiol esters), carotenoids (such as lutein, zeaxanthin, and calendulin), essential oils, polysaccharides, and saponins[65]. Marigold has various pharmacological benefits: it is anti-inflammatory, which makes it great for decreasing puffiness; it is a strong antioxidant, which aids in the fight against oxidative stress and aging; and it helps wound healing by speeding up cell regeneration. It also possesses antibacterial, hydrating, and depigmenting properties, making it an excellent choice for skincare. Marigold extract is prized in under-eye treatments for its calming, brightening, and anti-aging properties, and it is frequently added into in-situ gel formulations to provide sustained and targeted delivery. It is available in a variety of forms, including aqueous or ethanolic extracts, infused oils, dry powders, and diluted essential oils. Recent research (2023-2025) highlights its use in in-situ ocular and under-eye gels, nanoemulsion systems for improved skin penetration,and biopolymer-based wound healing gels, demonstrating its versatility and efficacy in modern dermatological and pharmaceutical formulations[66][67].

The major phytoconstituents of Calendula officinalis and their biological activities are presented in Table 6

Plant part	**Phytoconstituents**	**Biologicalactives**	**Reference**
Flowers	Flavonoids (quercetin, isorhamnetin, and rutin), triterpenoids (faradiol esters), Carotenoids: lutein, zeaxanthin, and β-carotene. Essential oils: α-cadinol and γ-cadinene. Saponins	Anti-inflammatory, Wound healing Antioxidant, antimicrobial, and UV protection	[68][69]
Petals	Carotenoids (lutein and zeaxanthin), flavonoid glycosides, and triterpenoids	Antioxidant, eye health (macular protection), and anti-aging	[70]
Leaves	Phenolic acids (caffeic acid, chlorogenic acid), flavonoids, and coumarins.	Antimicrobial, Anti-inflammatory, and Diuretic	[71]
Seeds	Tocopherols, fixed oils (linoleic, oleic, and palmitic acids)	Emollient, skin-protective, and anti-inflammatory.	[72]
Roots	Triterpenoid saponins, steroids	Antifungal and Immunomodulatory	[73]
Complete extract of plants	A mixture of flavonoids, triterpenoids, phenolics, and essential oils	Broad-spectrum antibacterial, antioxidant, and anti-cancer properties	[74]

Table: 6 Phytoconstituents and Biological Activities

Babchi (*Psoralea corylifolia* L.)

Figure:3Psoralea corylifolia L.[75]

Babchi (Psoralea corylifolia L.), also known as Bakuchi in Ayurveda, is a well-known medicinal plant prized for its therapeutic potential in both traditional and modern medicine. This herb comes from the Fabaceae family and has been used for millennia in India, China, and other Asian countries. The plant is tiny and erect, with distinctive flat seeds that have substantial therapeutic potential. Babchi has traditionally been described as a powerful treatment for a variety of skin ailments, including vitiligo, psoriasis, and leprosy. Its seeds and seed oil are high in bioactive substances such as psoralen, bakuchiol, and isopsoralen, which aid in its antibacterial, antioxidant, anti-inflammatory, and anticancer activities. Recent pharmacological studies have highlighted its role in modifying immunological responses and enhancing skin pigmentation, confirming many of the assertions stated in Ayurveda and Chinese medicine[76][77].

Because of its diverse phytochemical profile and wide range of biological activities, Babchi is now attracting global research interest. Scientists are working not just on medicinal uses but also on developing innovative formulations such as gels, nanoemulsion, and topical treatments to increase efficacy and reduce toxicity. Psoralea corylifolia is thus a valuable plant for both traditional healing methods and current pharmaceutical research[78][79][80].

Psoralea corylifolia L.: Phytoconstituents and Biological Activities: shown in table 7

Phytoconstituents	Chemical nature	Biological actives	References
Psoralen, isopsoralen, angelicin	Furanocoumarins	Photosensitizing, skin pigmentation, anti-cancer, antimicrobial, antioxidant	[81]
Neobavaisoflavone, Bavachin, Bavachalcone, corylifolin	Flavonoids/isoflavonoids	Antioxidant, anti-inflammatory, estrogenic, antimicrobial	[82]
Bakuchiol	Meroterpene(phenolic	Antiaging, anti-acne,	[83]

	monoterpene)	hepatoprotective, antioxidant, antimicrobial, anti-inflammatory	
Isobavachalcone, psoralidin, corylifols A-E	Phenols and stilbenes(prenylated phenolics)	Anticancer, antidiabetic, neuroprotective, antibacterial, anti-HIV	[84]
Limonene, caryophyllene, α-Humulene	Volatile oils/monoterpenes and sesquiterpenes	Antimicrobial, anti-inflammatory, insecticidal, aromatic	[85]
β-sitosterol, stigmasterol	Phytosterols	Immunomodulatory, anti-inflammatory, cholesterol-lowering,hypolipidimic	[86]
Olic acid, linoleic acid, palmitic acid	Fatty acids/seed oil components	Skin healing, moisturizing, antioxidant, nutritional value	[87]
Pasoralone, bavastin, corylidin	Minor phenolic compounds	Antifungal, wound healing, hepatoprotective	[88]

Table: 7 Phytoconstituents and biological actives of Psoralea corylifolia L

Herbal active used in under eye gel: shown table 8

Herbs	Active Compounds	Uses	Reference
Aloe Vera	Polysaccharides, Glycoproteins	Deep hydration, anti-inflammatory, promotes healing	[89]
Witch Hazel	Tannins, Flavonoids	Tightens skin, reduces swelling, soothes irritation	[90]
Chamomile	Bisabolol, Apigenin	Calms redness, reduces puffiness, antioxidant-rich	[91]
Coffee arabika	Caffeine, Chlorogenic Acid	Boosts circulation, reduces dark circles and puffiness	[29]
Green Tea	Catechins (EGCG), Polyphenols	Antioxidant, firms skin, protects against UV damage	[92]
Licorice Root	Glabridin, Liquiritin	Brightens skin, fades pigmentation, anti-inflammatory	[93]
Turmeric	Curcumin	Anti-inflammatory, antioxidant, helps fade dark spots	[28]

Neem	Azadirecta Indica	Antibacterial, soothes irritation, purifies skin	[94]
Cucumbar	Cucurbitacins, Vitamin C	Hydrates, cools, reduces puffiness and inflammation	[95]
Black Tea	Theaflavins, Catechins	Firms skin, reduces signs of fatigue, antioxidant-rich	[96]

Table:8 herbal actives used in under eye gel

***In-situ* gel technology- the smart shift from liquid to gel**

The word "*in-situ*" means "in place." So, *in-situ* gel technology is a liquid or semi-liquid solution that transforms into a gel when applied to your skin. In situ gel technology refers to a liquid or semi-liquid formulation that, when applied to the skin, turns into a gel. Environmental conditions such as temperature, pH, or ionic concentration drive this transformation essentially, the gel forms in place. *"In-situ"* gel is a unique skincare solution that starts as a liquid and transforms into a gel when applied to your skin[97]. The transition occurs as a result of your skin's natural circumstances, such as temperature, pH, and minerals in perspiration and tears[98]. Consider applying a little, watery serum beneath your eyes; within seconds, it changes into a soft gel that remains put and works overtime. This is the miracle of *in-situ* gel technology[99].

***In-situ* gel for under eye care:**

The under-eye area is sensitive and vulnerable to puffiness, dryness, and dark circles. Traditional creams have a tendency to slide off or evaporate fast. In contrast, in situ gels include: Stay on the skin for longer, allowing herbal compounds more time to operate. Slowly release actives, providing your skin with a consistent dosage of moisture and healing. Feel light and non-greasy, great for delicate skin. It's similar to a skincare recipe that responds in real time to the needs of your skin[58].

***In-situ* gel ideal for herbal formulations:**

In-situ gel technology is considerably more effective when combined with natural compounds such as aloe vera, chamomile, or caffeine. These herbal actives are gradually released over time, decreasing discomfort and improving outcomes[100].

Polymers

Polymers are the unsung heroes of modern society. You interact with them on a daily basis—whether you're brushing your teeth, wearing a raincoat, or simply breathing. Polymers are huge molecules composed of smaller, repeating building blocks known as monomers. Consider a long train made up of identical vehicles or a string of pearls, with each pearl representing a monomer. When hundreds or thousands of these monomers come together, they form a polymer. What's the outcome? Depending on how the monomers are ordered, a material can be flexible, strong, squishy, rigid, or even transparent[101][102].

Types of polymers:

There are main two types of polymers-

1. Natural

2. Synthetic

Natural polymers:

Natural polymers produced by living organisms play important roles in biological systems. The commonly used natural polymers and their applications in herbal formulations are listed in Table 9

Natural polymers and their uses:

Polymer	Sources	Uses	References
Pectin	Present in apples and citrus fruits.	Soft gels are formed, hydration is provided, and herbal actives are held in situ.	[103]
Alginic Acid	Extracted from the seaweed	Creates a moisturizing gel that soothes and protects.	[104]
Gellan Gum	Made by friendly bacteria	Turns liquid into gel on skin, which is ideal for slow-release administration.	[105]
Xyloglucan	From the tamarind seeds	Improves skin texture, mimics hyaluronic acid, and increases moisture.	[106]
Carrageenan	From the red algae	Smoothes and thickens, giving gels a velvety feel.	[107]
Guar Gum	From the guar beans	Natural thickening aids the stability and spreadability of herbal mixes.	[108]
Agar-Agar	from the marine algae	Cools and firms, commonly seen in soothing gel masks.	[109]
Chitosan	From the crustacean shells (eco-safe)	Antibacterial,tightens and protects fragile skin.	[110]
Pullulan	From the fermented starch	Forms a breathable coating; giving skin a smooth, elevated appearance.	[111]
Locust Bean Gum	From the carob tree seeds	Adds creaminess, helps maintain moisture, and improves skin feel.	[112]

Table: 9 natural polymers and their uses

Humans invented synthetic polymers. Chemists design and create these materials to satisfy specific requirements such as durability, flexibility, heat resistance, and transparency. Common synthetic polymers and their applications are presented in Table 10.

Polymer	**Source**	**Use**	**Reference**
Polyethylene (PE)	Ethylene	Plastic bags, bottles, containers, toys, insulation for wires	[113]
Polypropylene (PP)	Propylene	Food containers, automotive parts, textiles, medical syringes	[114]
Polyvinyl Chloride (PVC)	Vinyl chloride	Pipes, window frames, raincoats, flooring, credit cards	[115]
Polystyrene (PS)	Styrene	Disposable cutlery, CD cases, insulation foam, packaging materials	[116]
Polyethylene Terephthalate (PET)	Ethylene glycol + Terephthalic acid	Water bottles, food packaging, synthetic fibers (like polyester)	[117]
Polytetrafluoroethylene (PTFE / Teflon)	Tetrafluoroethylene	Non-stick cookware, gaskets, seals, insulation for cables	[118]
Nylon (Polyamide)	Adipic acid + Hexamethylenediamine	Fabrics, ropes, toothbrush bristles, parachutes	[119]
Acrylic (PMMA)	Methyl methacrylate	Transparent glass substitute, lenses, display screens, signage	[120]
Polyurethane (PU)	Diisocyanates + Polyols	Foam cushions, insulation panels, coatings, adhesives	[121]
Bakelite (Phenol-formaldehyde resin)	Phenol + Formaldehyde	Electrical insulators, kitchenware handles, vintage radios	[122]

Table: 10 Synthetic polymers and their uses

These polymers are more than just thickeners; they are intelligent delivery systems. They: Help herbal compounds such as aloe, chamomile, and caffeine stay active for a longer period of time. Make a soft gel layer that hydrates and protects. Make the product feel light, silky, and non-greasy, which is ideal for delicate under-eye skin.

Strategies for developing herbal under eye *in-situ* gel:

The strategies may follow-

Building the base: to build up the base we have to add the

This formula uses plant-based extracts like calendula and babchi to brighten, smooth, and reduce puffiness and dark circles. Hydrating humectants such as glycerin, hyaluronic acid, sodium PCA, propanediol, and panthenol draw in moisture, soothe, and strengthen the skin barrier. Nourishing agents like panthenol, shea butter, and avocado oil further condition the skin, leaving it soft, radiant, and healthy-looking[123].

Choosing gelling system

This formulation uses natural polymers like gellan gum, sodium alginate, pectin, xyloglucan, and pullulan to create a gentle, stable gel for under-eye care. Gellan gum and sodium alginate form clear gels with calcium, allowing controlled release of actives like calendula and bakuchiol while keeping skin hydrated. Pectin adds a mild, soothing gelling effect, xyloglucan boosts moisture and elasticity with hyaluronic acid–like benefits, and pullulan forms a light film that smooths skin and stabilizes herbal extracts. Together, these polymers protect sensitive compounds, ensure effective delivery, and stay gentle for delicate under-eye skin[124].

Making a Difference: When Used Together

Calendula and babchi work beautifully together in under-eye gels. Calendula calms irritation, hydrates, and brightens with its antioxidant and anti-inflammatory properties. Babchi helps reduce pigmentation, supports collagen for firmer skin, and even offers mild sun protection. Combined, they balance each other—calendula soothes and protects while babchi repairs and strengthens—delivering hydration, comfort, and rejuvenation for delicate under-eye skin[77].

Compatibility and Ph

Calendula (Calendula officinalis) is well-suited for sensitive, irritated, and acne-prone skin. It works nicely with humectants like glycerin, panthenol, and sodium PCA to boost hydration. It also blends well with gentle natural gel systems such as pectin, gellan gum, and alginate, staying stable in water-based formulas when protected from heat and sunlight. Its active compounds perform best in a mildly acidic pH of 5.0–6.5, while alkaline conditions should be avoided since they can reduce its antioxidant power[125]. Babchi (Psoralea corylifolia) contains powerful actives like bakuchiol and psoralens, so it needs careful handling in skincare. It works best when paired with soothing ingredients such as calendula, panthenol, and hyaluronic acid to balance its retinol-like effects and minimize irritation. It can be used in gels, serums, or emulsions, but should be applied in controlled amounts, especially around sensitive areas like the under-eye. Bakuchiol stays most stable at a pH of 5.5–6.5, while very low pH levels can make it unstable and increase skin sensitivity. The ideal under-eye gel works best at a pH of about 5.5–6.2, keeping both stability and skin comfort in balance[125][126]. Antioxidants like vitamin E or rosemary extract help shield the herbal actives from breaking down, while mild gelling agents such as gellan gum and pectin, paired with gentle humectants, ensure smooth application, safe delivery, and overall effectiveness of the formula[127].

Stability, safety and preservation

Calendula and babchi are both effective but need careful handling to stay stable and safe. Calendula's flavonoids and oils can break down under light and heat, so it does best at pH 5.0–6.5 with opaque packaging and antioxidants like vitamin E or rosemary extract. Babchi, especially bakuchiol, is more stable but can still oxidize, and raw extracts must be purified to remove psoralens that can cause photosensitivity. A pH of 5.5–6.5 with antioxidants helps keep it safe and effective[77].Both are generally suitable for most skin types, including sensitive skin, though patch testing is recommended. Babchi should be kept at low levels (0.5–1%) for under-eye use.For preservation, gentle systems like potassium sorbate, sodium benzoate, Gluconolactone blends, or small amounts of phenoxyethanol work well within pH 5–6.5. Packaging also matters—airless pumps, opaque tubes, and UV-protective containers help maintain stability, while jars are avoided for under-eye products to reduce contamination[77][128].

Quick formulation safeguards

This formulation is designed for a premium, clear look with about 90% transparency when using clean extracts. It has strong bioadhesion, so it stays in place through blinking but still washes off easily. Functionally, it supports slow release of actives like caffeine for 4–8 hours, helping maintain depuffing effects. At the same time, it's made for comfort—non-stinging, non-greasy, and makeup-friendly—so it feels smooth and wearable all day[129].

Evaluation parameters for herbal under eye in-situ gel

This formulation is clear or lightly tinted for a premium look and keeps skin comfort in mind with a pH of 5.5–6.2. It flows easily in the container but turns into a smooth gel on application, thanks to in-situ gelation triggered by temperature, pH, or ions. The gel spreads without stickiness, adheres well to the skin, and helps deliver actives like bakuchiol and flavonoids in a slow, sustained way for lasting depuffing and anti-aging benefits. Hydration tests show improved moisture retention, especially for dry or aging skin. Safety and stability are ensured through irritation checks, temperature cycling, freeze–thaw studies, and monitoring of color, odor, and texture over time[130].

The current clinical status, limitations, and future prospects of herbal formulations used for under-eye conditions are summarized in Table 11

Herbal formulation	Clinical findings	Limitations	Future scope	Reference
Psoralea corylifolia (Babchi)	shown to enhance pigmentation and control melanin synthesis in small dermatological trials.	Variability in extract quality; restricted penetration and stability in traditional creams.	incorporation for more uniform results and deeper transport into liposomes or nanoemulsion gels.	[131]
Calendula officinalis (Marigold)	Clinical research indicates to the anti-inflammatory and calming properties that reduce discomfort and puffiness.	The effects are unstable in conventional formulations and mild when given alone.	To improve hydration and long-lasting anti-inflammatory effects, use in hydrogel systems.	[132]
Aloe Vera Gel	widely acknowledged for improving periocular skin hydration and reducing swelling.	Effects are temporary and need to be applied frequently.	mixing advanced carriers to increase elasticity and prolong hydration.	[133]
Chamomile Extract	Clinical assessments show a decrease in vascular congestion and puffiness, along with satisfactory	Limited antioxidant power compared to other active ingredients; mild efficacy.	combining with more potent herbal antioxidants to get a synergistic effect.	[131]

	tolerability.			
Licorice Root Extract	Tyrosinase activity has been shown to be restricted, which causes pigmentation-related dark circles to brighten.	instability in traditional gels; different results amongst investigations.	stability in nanodelivery systems to provide a steady depigmenting impact.	[132]
Turmeric Extract	In therapeutic settings, curcumin has potent antioxidant and collagen-supporting properties.	In conventional formulations, solubility and bioavailability are poor.	Nanoemulsion or liposomal encapsulation to enhance penetration and sustained release.	[133]
Green Tea Extract	Clinical trials show enhanced microcirculation along with a decrease in oxidative stress and puffiness.	The concentration of the extract and the formulation base affect the effects.	controlled-release, standardized formulas for consistent anti-aging benefits.	[132]

Table: 11 Clinical status of herbal formulation in under eye causes

Challenges in herbal under eye *in-situ* gel

Formulating herbal under-eye in-situ gels is tricky because both the actives and the delicate eye area need extra care. Calendula and bakuchiol can easily break down from light, heat, or oxidation, so antioxidants, UV-protective packaging, and proper pH control are essential. Herbal extracts also vary in composition, making standardization important for consistent results. Safety is a concern too—babchi must be purified and used in low doses to avoid irritation on thin under-eye skin. Creating a reliable in-situ gel with natural polymers can be complex since they may react unpredictably with herbal blends. Preservation adds another challenge, as herbal systems are prone to microbial growth and require mild, eco-friendly preservatives that won't affect active stability[134].

Future perspective in herbal under eye in-situ gel

Future herbal under-eye in-situ gels are evolving with smarter, safer, and eco-friendlier approaches. Nanotechnology tools like nanoemulsion and liposomes improve the stability and delivery of actives such as bakuchiol, while also reducing irritation. AI-driven formulation platforms are helping predict ingredient compatibility and skin responses, speeding up development and making products more reliable. Personalized skincare is also on the rise, with gels designed to adapt to individual skin conditions like pH and hydration for better results. At the same time, sustainability is a major focus—using ethically sourced herbs, biodegradable polymers, and simplified eco-friendly formulations that protect the environment while staying effective.

Conclusion

The under-eye area, which is one of the most delicate and the first to exhibit symptoms of aging, necessitates mild yet effective formulas. Conventional creams frequently fail to give long-term advantages due to insufficient active retention and distribution. *In-situ* gel technology provides a smart alternative by converting from liquid to gel upon application, resulting in extended skin contact, controlled release, and increased user comfort. Calendula officinalis and Psoralea corylifolia are important herbal actives in such systems; calendula provides soothing, healing, and antioxidant properties, whereas Babchi, which is high in bakuchiol, promotes anti-aging, pigmentation management, and collagen stimulation. Natural polymers including gellan gum, alginate, pectin, and xyloglucan improve the stability, hydration, and bioadhesion of these formulations, making them more skin-friendly and effective. Despite obstacles such as phytochemical instability, standardization problems, and preservative safety, current advancements in nanotechnology, AI-based formulation design, and sustainable sourcing provide hopeful alternatives. Overall, herbal *in-situ* gels are an innovative and sustainable strategy that combines traditional plant-based therapies and modern drug delivery techniques to provide safe, targeted, and long-lasting care for the under-eye area.

Declaration of Funding: No funding

Ethical Declaration: None

Reference

[1] R. T. Brady and S. Shah-Desai, “Clinical Efficacy of a Novel Topical Formulation on Periorbital Dark Circles: An Objective Analysis.,” *J. Cosmet. Dermatol.*, vol. 24, no. 7, p. e70326, Jul. 2025, doi: 10.1111/jocd.70326.

[2] S. Liew *et al.*, “Lower Eyelid Dark Circles (Tear Trough and Lid-Cheek Junction): A Stepwise Assessment Framework.,” *Aesthetic Surg. J.*, vol. 44, no. 7, pp. NP476–NP485, Jun. 2024, doi: 10.1093/asj/sjae058.

[3] I. E. Sweis and B. C. Cressey, “New Findings in Prominent Lower Eyelid Fat Pads Possibly Contributing to Their Etiology: Two Prospective Studies.,” *Plast. Reconstr. surgery. Glob. open*, vol. 12, no. 11, p. e6340, Nov. 2024, doi: 10.1097/GOX.0000000000006340.

[4] S. Gouigoux, A. Vaidya, M. Naito, Y. Takahashi, and H. Kakizaki, “Microscopic Anatomy of Orbital Septum.,” *Ophthal. Plast. Reconstr. Surg.*, vol. 41, no. 2, pp. 221–224, 2025, doi: 10.1097/IOP.0000000000002805.

[5] I. Coban, O. Derin, S. Sirinturk, Y. Pinar, and F. Govsa, “Anatomical Basis for the Lower Eyelid Rejuvenation.,” *Aesthetic Plast. Surg.*, vol. 47, no. 3, pp. 1059–1066, Jun. 2023, doi: 10.1007/s00266-023-03297-z.

[6] C. L. Bokman *et al.*, “Association of decreased lymphatic vessel density with postoperative eyelid edema,” *Front. Ophthalmol.*, vol. Volume 5-, 2026, doi: 10.3389/fopht.2025.1689146.

[7] S. Montolío-Marzo, E. Montolío-Marzo, C. Martínez-Gil, G. Rodríguez-Iranzo, E. Arias-García, and M. Pérez-López, “Treatment of periorbital hyperpigmentation using light devices,” *Arch. la Soc. Española Oftalmol. (English Ed.*, vol. 99, no. 1, pp. 23–32, 2024, doi: https://doi.org/10.1016/j.oftale.2023.08.010.

[8] X. Nie, S. Hou, and A. Li, “Pigmented skin spots: Morphological characteristics, common causes, and treatment with cosmetic ingredients,” *J. Dermatologic Sci. Cosmet. Technol.*, vol. 2, no. 4, p. 100125, 2025, doi: https://doi.org/10.1016/j.jdsct.2025.100125.

[9] J. A. Bouwstra, A. Nădăban, W. Bras, C. MCabe, A. Bunge, and G. S. Gooris, “The skin barrier: An extraordinary interface with an exceptional lipid organization,” *Prog. Lipid Res.*, vol. 92, p. 101252, 2023, doi: https://doi.org/10.1016/j.plipres.2023.101252.

[10] I. Sagrafena *et al.*, “Structure and function of skin barrier lipids: Effects of hydration and natural moisturizers in vitro,” *Biophys. J.*, vol. 123, no. 22, pp. 3951–3963, 2024, doi: https://doi.org/10.1016/j.bpj.2024.10.006.

[11] R. F. Wang, D. Ko, B. J. Friedman, H. W. Lim, and T. F. Mohammad, “Disorders of hyperpigmentation. Part I. Pathogenesis and clinical features of common pigmentary disorders,” *J. Am. Acad. Dermatol.*, vol. 88, no. 2, pp. 271–288, 2023, doi: https://doi.org/10.1016/j.jaad.2022.01.051.

[12] C. Zhong *et al.*, “Inflammatory response: The target for treating hyperpigmentation during the repair of a burn wound,” *Front. Immunol.*, vol. Volume 14, 2023, doi: 10.3389/fimmu.2023.1009137.

[13] P. Sharma *et al.*, “A comprehensive review of the molecular mechanisms driving skin photoaging and the recent advances in therapeutic interventions involving natural polyphenols,” *South African J. Bot.*, vol. 166, pp. 466–482, 2024, doi: https://doi.org/10.1016/j.sajb.2024.01.035.

[14] M. A. Tanveer, H. Rashid, and S. A. Tasduq, “Molecular basis of skin photoaging and therapeutic interventions by plant-derived natural product ingredients: A comprehensive review.,” *Heliyon*, vol. 9, no. 3, p. e13580, Mar. 2023, doi: 10.1016/j.heliyon.2023.e13580.

[15] P. Ordentlich, “Clinical evaluation of colony-stimulating factor 1 receptor inhibitors,” *Semin. Immunol.*, vol. 54, p. 101514, 2021, doi: https://doi.org/10.1016/j.smim.2021.101514.

[16] T. Do, A. White, R. Keating, and G. Matusov, “SEVERE PERIORBITAL EDEMA AS A WINDOW INTO A RARE SYSTEMIC CONDITION,” *Ann. Allergy, Asthma Immunol.*, vol. 133, no. 6, Supplement, pp. S136–S137, 2024, doi: https://doi.org/10.1016/j.anai.2024.08.561.

[17] E. J. Hollick *et al.*, “Corneal and Scleral Problems Caused by Skin-Lightening Creams.,” *Cornea*, vol. 38, no. 10, pp. 1332–1335, Oct. 2019, doi: 10.1097/ICO.0000000000002027.

[18] B. Grassiri, Y. Zambito, and A. Bernkop-Schnürch, “Strategies to prolong the residence time of drug delivery systems on ocular surface,” *Adv. Colloid Interface Sci.*, vol. 288, p. 102342, 2021, doi: https://doi.org/10.1016/j.cis.2020.102342.

[19] T.-P. Huynh, S. N. Mann, and N. A. Mandal, “Botanical compounds: effects on major eye diseases.,” *Evid. Based. Complement. Alternat. Med.*, vol. 2013, p. 549174, 2013, doi: 10.1155/2013/549174.

[20] K. Patel and D. K. Patel, “Chapter 26 - The Beneficial Role of Rutin, A Naturally Occurring Flavonoid in Health Promotion and Disease Prevention: A Systematic Review and Update,” in *Bioactive Food as Dietary Interventions for Arthritis and Related Inflammatory Diseases (Second Edition)*, Second Edition., R. R. Watson and V. R. Preedy, Eds., Academic Press, 2019, pp. 457–479. doi: https://doi.org/10.1016/B978-0-12-813820-5.00026-X.

[21] A. Elbouzidi *et al.*, “Biochemical insights into specialized plant metabolites: Advancing cosmeceutical applications for skin benefits,” *J. Agric. Food Res.*, vol. 19, p. 101651, 2025, doi: https://doi.org/10.1016/j.jafr.2025.101651.

[22] A. M. Thawabteh, A. Jibreen, D. Karaman, A. Thawabteh, and R. Karaman, "Skin Pigmentation Types, Causes and Treatment-A Review.," *Molecules*, vol. 28, no. 12, Jun. 2023, doi: 10.3390/molecules28124839.

[23] A. Aizaz *et al.*, "Synthesis and characterization of aloe vera and hyaluronic acid-infused agar-agar/ gelatin-based biopolymeric gel for potential skincare applications," *J. Drug Deliv. Sci. Technol.*, vol. 100, p. 106017, 2024, doi: https://doi.org/10.1016/j.jddst.2024.106017.

[24] D. Li *et al.*, "Extraction and purification, structural characteristics, biological activities, applications, and quality control of Aloe vera polysaccharides: A review.," *Int. J. Biol. Macromol.*, vol. 329, no. Pt 2, p. 147927, Nov. 2025, doi: 10.1016/j.ijbiomac.2025.147927.

[25] P. Mikulska *et al.*, "Ashwagandha (Withania somnifera)-Current Research on the Health-Promoting Activities: A Narrative Review.," *Pharmaceutics*, vol. 15, no. 4, Mar. 2023, doi: 10.3390/pharmaceutics15041057.

[26] R. Arya *et al.*, "Harnessing the Antibacterial, Anti-Diabetic and Anti-Carcinogenic Properties of Ocimum sanctum Linn (Tulsi).," *Plants (Basel, Switzerland)*, vol. 13, no. 24, Dec. 2024, doi: 10.3390/plants13243516.

[27] B. Iskandar, V. Antasya, M. Nasution, N. Frimayanti, C. Peng-Wei, and S. Khairani, "Optimizing carrot extract serum (Daucus carota L.) for anti-aging: efficacy in moisturizing and pore size reduction using Box-Behnken design method," *J. ILMU KEFARMASIAN Indones.*, vol. 23, p. 250, 2025, doi: 10.35814/jifi.v23i2.1566.

[28] Y. Nie and Y. Li, "Curcumin: a potential anti-photoaging agent.," *Front. Pharmacol.*, vol. 16, p. 1559032, 2025, doi: 10.3389/fphar.2025.1559032.

[29] G. Ruse *et al.*, "Coffea arabica: An Emerging Active Ingredient in Dermato-Cosmetic Applications.," *Pharmaceuticals (Basel).*, vol. 18, no. 2, Jan. 2025, doi: 10.3390/ph18020171.

[30] M. A. Salem *et al.*, "Coriander (Coriandrum sativum L.) essential oil and oil-loaded nano-formulations as an anti-aging potentiality via TGFβ/SMAD pathway.," *Sci. Rep.*, vol. 12, no. 1, p. 6578, Apr. 2022, doi: 10.1038/s41598-022-10494-4.

[31] H. A. Hausenblas, D. Hooper, and S. Hooper, "Effectiveness of Cucumis sativus L. Supplementation on Mood, Anxiety, and Sleep Quality: A Randomized Double-Blind Placebo-Controlled Study.," *Heal. Sci. reports*, vol. 8, no. 7, p. e70979, Jul. 2025, doi: 10.1002/hsr2.70979.

[32] H. Akhtar *et al.*, "Bioactive Potential and Health Benefits of Trigonella foenum-graecum L.: A Comprehensive Review.," *Food Sci. Nutr.*, vol. 13, no. 9, p. e70887, Sep. 2025, doi: 10.1002/fsn3.70887.

[33] K. J. Gohil, J. A. Patel, and A. K. Gajjar, "Pharmacological Review on Centella asiatica: A Potential Herbal Cure-all.," *Indian J. Pharm. Sci.*, vol. 72, no. 5, pp. 546–556, Sep. 2010, doi: 10.4103/0250-474X.78519.

[34] C. Di Pietro Fernandes *et al.*, "Nutraceutical Potential of Grape (Vitis vinifera L.) Seed Oil in Oxidative Stress, Inflammation, Obesity and Metabolic Alterations.," *Molecules*, vol. 28, no. 23, Nov. 2023, doi: 10.3390/molecules28237811.

[35] L. Capasso *et al.*, "Epigallocatechin Gallate (EGCG): Pharmacological Properties, Biological Activities and Therapeutic Potential.," *Molecules*, vol. 30, no. 3, Feb. 2025, doi: 10.3390/molecules30030654.

[36] W. M. Otang and A. J. Afolayan, "Antimicrobial and antioxidant efficacy of Citrus limon L. peel

extracts used for skin diseases by Xhosa tribe of Amathole District, Eastern Cape, South Africa," *South African J. Bot.*, vol. 102, pp. 46–49, 2016, doi: https://doi.org/10.1016/j.sajb.2015.08.005.

[37] S. Wahab *et al.*, "Glycyrrhiza glabra (Licorice): A Comprehensive Review on Its Phytochemistry, Biological Activities, Clinical Evidence and Toxicology.," *Plants (Basel, Switzerland)*, vol. 10, no. 12, Dec. 2021, doi: 10.3390/plants10122751.

[38] K. Shahane *et al.*, "An Updated Review on the Multifaceted Therapeutic Potential of Calendula officinalis L.," *Pharmaceuticals (Basel).*, vol. 16, no. 4, Apr. 2023, doi: 10.3390/ph16040611.

[39] J. F. Islas *et al.*, "An overview of Neem (Azadirachta indica) and its potential impact on health," *J. Funct. Foods*, vol. 74, p. 104171, 2020, doi: https://doi.org/10.1016/j.jff.2020.104171.

[40] J. Sun, J. Ren, X. Hu, Y. Hou, and Y. Yang, "Therapeutic effects of Chinese herbal medicines and their extracts on diabetes," *Biomed. Pharmacother.*, vol. 142, p. 111977, 2021, doi: https://doi.org/10.1016/j.biopha.2021.111977.

[41] N. Hudz *et al.*, "Mentha piperita: Essential Oil and Extracts, Their Biological Activities, and Perspectives on the Development of New Medicinal and Cosmetic Products.," *Molecules*, vol. 28, no. 21, Nov. 2023, doi: 10.3390/molecules28217444.

[42] J. Dimitrijevic *et al.*, "Punica granatum L. (Pomegranate) Extracts and Their Effects on Healthy and Diseased Skin.," *Pharmaceutics*, vol. 16, no. 4, Mar. 2024, doi: 10.3390/pharmaceutics16040458.

[43] H. Wang, "Beneficial medicinal effects and material applications of rose.," *Heliyon*, vol. 10, no. 1, p. e23530, Jan. 2024, doi: 10.1016/j.heliyon.2023.e23530.

[44] F. Anaeigoudari, A. Anaeigoudari, and A. Kheirkhah-Vakilabad, "A review of therapeutic impacts of saffron (Crocus sativus L.) and its constituents.," *Physiol. Rep.*, vol. 11, no. 15, p. e15785, Aug. 2023, doi: 10.14814/phy2.15785.

[45] A. Zielińska and I. Nowak, "Abundance of active ingredients in sea-buckthorn oil.," *Lipids Health Dis.*, vol. 16, no. 1, p. 95, May 2017, doi: 10.1186/s12944-017-0469-7.

[46] S. Mahajan, P. Avad, and J. Langade, "Efficacy and Safety of Shatavari (Asparagus racemosus) Root Extract for Perimenopause: Randomized, Double-Blind, Placebo-Controlled Study.," *Int. J. Womens. Health*, vol. 17, pp. 4057–4073, 2025, doi: 10.2147/IJWH.S544267.

[47] M. Wójciak, W. Pacuła, I. Sowa, M. Feldo, F. Graczyk, and D. Załuski, "Hamamelis virginiana L. in Skin Care: A Review of Its Pharmacological Properties and Cosmetological Applications.," *Molecules*, vol. 30, no. 13, Jun. 2025, doi: 10.3390/molecules30132744.

[48] G. Santos, E. Delgado, B. Silva, B. S. Braz, and L. Gonçalves, "Topical Ocular Drug Delivery: The Impact of Permeation Enhancers.," *Pharmaceutics*, vol. 17, no. 4, Mar. 2025, doi: 10.3390/pharmaceutics17040447.

[49] P. Agarwal and I. D. Rupenthal, "Non-aqueous formulations in topical ocular drug delivery – A paradigm shift?," *Adv. Drug Deliv. Rev.*, vol. 198, p. 114867, 2023, doi: https://doi.org/10.1016/j.addr.2023.114867.

[50] S. N. A. Papadopoulou, T. Adamantidi, D. Kranas, P. Cholidis, C. Anastasiadou, and A. Tsoupras, "A Comprehensive Review on the Valorization of Bioactives from Marine Animal By-Products for Health-Promoting, Biofunctional Cosmetics.," *Mar. Drugs*, vol. 23, no. 8, Jul. 2025, doi: 10.3390/md23080299.

[51] S. Purnamawati, N. Indrastuti, R. Danarti, and T. Saefudin, "The Role of Moisturizers in Addressing Various Kinds of Dermatitis: A Review.," *Clin. Med. Res.*, vol. 15, no. 3–4, pp. 75–87, Dec. 2017, doi: 10.3121/cmr.2017.1363.

[52] Z. D. Draelos, "The science behind skin care: Moisturizers.," *J. Cosmet. Dermatol.*, vol. 17, no. 2, pp. 138–144, Apr. 2018, doi: 10.1111/jocd.12490.

[53] A. Kawee-Ai, "Advancing Gel Systems with Natural Extracts: Antioxidant, Antimicrobial Applications, and Sustainable Innovations.," *Gels (Basel, Switzerland)*, vol. 11, no. 2, Feb. 2025, doi: 10.3390/gels11020125.

[54] C. Oliveira, C. Coelho, J. A. Teixeira, P. Ferreira-Santos, and C. M. Botelho, "Nanocarriers as Active Ingredients Enhancers in the Cosmetic Industry-The European and North America Regulation Challenges.," *Molecules*, vol. 27, no. 5, Mar. 2022, doi: 10.3390/molecules27051669.

[55] B. Mubeen *et al.*, "Phytochemicals as Multi-Target Therapeutic Agents for Oxidative Stress-Driven Pathologies: Mechanisms, Synergies, and Clinical Prospects," *Phyton-International J. Exp. Bot.*, vol. 94, no. 7, pp. 1941–1971, 2025, doi: https://doi.org/10.32604/phyton.2025.064056.

[56] E. F. Costa, W. V Magalhães, and L. C. Di Stasi, "Recent Advances in Herbal-Derived Products with Skin Anti-Aging Properties and Cosmetic Applications.," *Molecules*, vol. 27, no. 21, Nov. 2022, doi: 10.3390/molecules27217518.

[57] F. Alam, G. N. Khan, and M. H. H. Bin Asad, "Psoralea corylifolia L: Ethnobotanical, biological, and chemical aspects: A review.," *Phytother. Res.*, vol. 32, no. 4, pp. 597–615, Apr. 2018, doi: 10.1002/ptr.6006.

[58] R. Alsheikh *et al.*, "Thermosensitive in situ gels for ocular drug delivery: Advances in polymer-based formulations," *Eur. J. Pharm. Sci.*, vol. 218, p. 107439, 2026, doi: https://doi.org/10.1016/j.ejps.2026.107439.

[59] S. Liu, L. Li, X. Zhang, and Q. Meng, "Nanotherapies from an oncologist doctor's view," *Smart Mater. Med.*, vol. 4, pp. 183–198, 2023, doi: https://doi.org/10.1016/j.smaim.2022.07.005.

[60] J. Li *et al.*, "Classification, gelation mechanism and applications of polysaccharide-based hydrocolloids in pasta products: A review," *Int. J. Biol. Macromol.*, vol. 248, p. 125956, 2023, doi: https://doi.org/10.1016/j.ijbiomac.2023.125956.

[61] S. Wang, G. Zuo, J. Kim, and H. Sirringhaus, "Progress of Conjugated Polymers as Emerging Thermoelectric Materials," *Prog. Polym. Sci.*, vol. 129, p. 101548, 2022, doi: https://doi.org/10.1016/j.progpolymsci.2022.101548.

[62] S. Kumar, N. Chauhan, B. Tyagi, P. Yadav, A. K. Samanta, and A. K. Tyagi, "Exploring bioactive compounds and antioxidant properties of twenty-six Indian medicinal plant extracts: A correlative analysis for potential therapeutic insights," *Food Humanit.*, vol. 1, pp. 1670–1679, 2023, doi: https://doi.org/10.1016/j.foohum.2023.11.016.

[63] A. Yıldırım, R. Yücer, A. Şen, and L. Bitiş, "Herbal ingredients in anti-aging cream formulations: A comprehensive review of their bioactive components, molecular mechanisms, and dermatological benefits," *Pharmacol. Res. - Nat. Prod.*, vol. 8, p. 100365, 2025, doi: https://doi.org/10.1016/j.prenap.2025.100365.

[64] Arushi, A. Behera, N. K. Sethiya, and S. Shilpi, "A systematic study on herbal cream for various clinical and therapeutic application: current status and future prospects," *J. Herb. Med.*, vol. 45, p. 100880, 2024, doi: https://doi.org/10.1016/j.hermed.2024.100880.

[65] I. Zournatzis, V. Liakos, S. Papadopoulos, and E. Wogiatzi, “Calendula officinalis - A comprehensive review,” *Pharmacol. Res. - Nat. Prod.*, vol. 6, p. 100140, 2025, doi: https://doi.org/10.1016/j.prenap.2024.100140.

[66] A. Fernandes, P. M. Rodrigues, M. Pintado, and F. K. Tavaria, “A systematic review of natural products for skin applications: Targeting inflammation, wound healing, and photo-aging,” *Phytomedicine*, vol. 115, p. 154824, 2023, doi: https://doi.org/10.1016/j.phymed.2023.154824.

[67] E. Deveci, “Nanoemulsions in cosmetics: Enhancing efficacy and stability,” *J. Dermatologic Sci. Cosmet. Technol.*, vol. 2, no. 3, p. 100107, 2025, doi: https://doi.org/10.1016/j.jdsct.2025.100107.

[68] D. Moslemi, A. M. Nokhandani, M. T. Otaghsaraei, Y. Moghadamnia, S. Kazemi, and A. A. Moghadamnia, “Management of chemo/radiation-induced oral mucositis in patients with head and neck cancer: A review of the current literature,” *Radiother. Oncol.*, vol. 120, no. 1, pp. 13–20, 2016, doi: https://doi.org/10.1016/j.radonc.2016.04.001.

[69] L. Chen, X. Yin, A. Tang, and Y. Yang, “Global landscape and translational trajectories of flavonoid-based wound-healing research,” *Drug Discov. Today*, vol. 30, no. 10, p. 104461, 2025, doi: https://doi.org/10.1016/j.drudis.2025.104461.

[70] H. Zhang, T. Song, R. Kang, F. Ren, J. Liu, and J. Wang, “Plant bioactive compounds alleviate photoinduced retinal damage and asthenopia: Mechanisms, synergies, and bioavailability,” *Nutr. Res.*, vol. 120, pp. 115–134, 2023, doi: https://doi.org/10.1016/j.nutres.2023.10.003.

[71] D. Liu, S. Pan, and J. Sun, “Natural phenolic acids as promising antimicrobial candidates in food industry: A review,” *Int. J. Food Microbiol.*, vol. 443, p. 111413, 2025, doi: https://doi.org/10.1016/j.ijfoodmicro.2025.111413.

[72] O. Kunik, D. Saribekova, G. Lazzara, and G. Cavallaro, “Emulsions based on fatty acid from vegetable oils for cosmetics,” *Ind. Crops Prod.*, vol. 189, p. 115776, 2022, doi: https://doi.org/10.1016/j.indcrop.2022.115776.

[73] L. Shen *et al.*, “Potential Immunoregulatory Mechanism of Plant Saponins: A Review,” *Molecules*, vol. 29, no. 1, 2024, doi: 10.3390/molecules29010113.

[74] N. Zouine, N. El Ghachtouli, S. El Abed, and S. I. Koraichi, “A comprehensive review on medicinal plant extracts as antibacterial agents: Factors, mechanism insights and future prospects,” *Sci. African*, vol. 26, p. e02395, 2024, doi: https://doi.org/10.1016/j.sciaf.2024.e02395.

[75] R. Kruthika *et al.*, “A report on novel association of Corynespora cassiicola inciting target leafspot on babchi (Psoralea corylifolia) in India,” *Physiol. Mol. Plant Pathol.*, vol. 131, p. 102278, 2024, doi: https://doi.org/10.1016/j.pmpp.2024.102278.

[76] A. Cariola, M. El Chami, J. Granatieri, and L. Valgimigli, “Anti-tyrosinase and antioxidant activity of meroterpene bakuchiol from Psoralea corylifolia (L.),” *Food Chem.*, vol. 405, p. 134953, 2023, doi: https://doi.org/10.1016/j.foodchem.2022.134953.

[77] F. M. Mariana *et al.*, *Comprehensive review of the skin use of bakuchiol : physicochemical properties , sources , bioactivities , nanotechnology delivery systems , regulatory and toxicological concerns*, vol. 0123456789. 2024. doi: 10.1007/s11101-024-09926-y.

[78] A. Vazir, A. Joshi, K. Kumar, and V. Rajput, “International Journal of Pharmaceutics and Drug Analysis,” pp. 8–13, 2023.

[79] S. Bhardwaj, P. K. Gaur, A. Tiwari, M. Nagar, and G. Noida, “Development of Topical Nanoemulgel Using Combined Therapy for Treating Psoriasis,” vol. 20, no. 1, pp. 42–54, 2022,

doi: 10.1089/adt.2021.112.

[80] A. Alalaiwe *et al.*, "The active compounds derived from Psoralea corylifolia for photochemotherapy against psoriasis-like lesions: The relationship between structure and percutaneous absorption," *Eur. J. Pharm. Sci.*, vol. 124, pp. 114–126, 2018, doi: https://doi.org/10.1016/j.ejps.2018.08.031.

[81] S. Chen *et al.*, "Mechanistic study of cytochrome P450 enzyme-mediated cytotoxicity of psoralen and isopsoralen," *Food Chem. Toxicol.*, vol. 180, p. 114011, 2023, doi: https://doi.org/10.1016/j.fct.2023.114011.

[82] J. Liu, W. Zhang, Y. Li, X. Li, Y. Li, and F. Guo, "Flavonoids extract from the seeds of Psoralea corylifolia L. (PFE) alleviates atherosclerosis in high-fat diet-induced LDLR−/− mice," *Phytomedicine*, vol. 98, p. 153983, 2022, doi: https://doi.org/10.1016/j.phymed.2022.153983.

[83] S. Ranjan and S. Khan, "Natural anti-aging innovations: Bakuchiol role in longevity and stress resilience through DAF-16 pathway activation," *Biochem. Biophys. Res. Commun.*, vol. 770, p. 151932, 2025, doi: https://doi.org/10.1016/j.bbrc.2025.151932.

[84] N. Xing, X. Meng, and S. Wang, "Isobavachalcone: A comprehensive review of its plant sources, pharmacokinetics, toxicity, pharmacological activities and related molecular mechanisms.," *Phytother. Res.*, vol. 36, no. 8, pp. 3120–3142, Aug. 2022, doi: 10.1002/ptr.7520.

[85] D. M. Mohammed *et al.*, "Essential oils: antimicrobial, antioxidant properties, and their applications in food preservation—a comprehensive review," *Phytochem. Rev.*, vol. 25, no. 3, pp. 2439–2487, 2026, doi: 10.1007/s11101-025-10202-w.

[86] S. Babu and S. Jayaraman, "An update on β-sitosterol: A potential herbal nutraceutical for diabetic management," *Biomed. Pharmacother.*, vol. 131, p. 110702, 2020, doi: https://doi.org/10.1016/j.biopha.2020.110702.

[87] X. Wang, Y. Jia, and H. He, "The Role of Linoleic Acid in Skin and Hair Health: A Review.," *Int. J. Mol. Sci.*, vol. 26, no. 1, Dec. 2024, doi: 10.3390/ijms26010246.

[88] Y. Jiao *et al.*, "Antifungal activity of paeonol against Botrytis cinerea by disrupting the cell membrane and the application on cherry tomato preservation.," *Front. Microbiol.*, vol. 15, p. 1509124, 2024, doi: 10.3389/fmicb.2024.1509124.

[89] M. Sánchez, E. González-Burgos, I. Iglesias, and M. P. Gómez-Serranillos, "Pharmacological Update Properties of Aloe Vera and its Major Active Constituents.," *Molecules*, vol. 25, no. 6, Mar. 2020, doi: 10.3390/molecules25061324.

[90] X. Liu *et al.*, "Revealing the Therapeutic Potential: Investigating the Impact of a Novel Witch Hazel Formula on Anti-Inflammation and Antioxidation.," *J. Cosmet. Dermatol.*, vol. 24, no. 2, p. e16662, Feb. 2025, doi: 10.1111/jocd.16662.

[91] J. K. Srivastava, E. Shankar, and S. Gupta, "Chamomile: A herbal medicine of the past with bright future.," *Mol. Med. Rep.*, vol. 3, no. 6, pp. 895–901, Nov. 2010, doi: 10.3892/mmr.2010.377.

[92] X.-Q. Zheng *et al.*, "Green Tea Catechins and Skin Health.," *Antioxidants (Basel, Switzerland)*, vol. 13, no. 12, Dec. 2024, doi: 10.3390/antiox13121506.

[93] M. H. Kang *et al.*, "Antioxidant and Anti-Melanogenic Activities of Heat-Treated Licorice (Wongam, Glycyrrhiza glabra × G. uralensis) Extract.," *Curr. Issues Mol. Biol.*, vol. 43, no. 2, pp. 1171–1187, Sep. 2021, doi: 10.3390/cimb43020083.

[94] H. Gopinath and K. Karthikeyan, “Neem in Dermatology: Shedding Light on the Traditional Panacea.,” *Indian J. Dermatol.*, vol. 66, no. 6, p. 706, 2021, doi: 10.4103/ijd.ijd_562_21.

[95] P. K. Mukherjee, N. K. Nema, N. Maity, and B. K. Sarkar, “Phytochemical and therapeutic potential of cucumber.,” *Fitoterapia*, vol. 84, pp. 227–236, Jan. 2013, doi: 10.1016/j.fitote.2012.10.003.

[96] Sen, A. K., Sen, D. B., Zanwar, A. S., Balaraman, R., Shah, U., & Maheshwari, R. A. (2022). Catechins and theaflavins: an overview on therapeutic application.

[97] N. Yadav, A. Parashar, and V. Sethi, “Development and Assessment of In-Situ Gel Formulation for Ocular Pain and Inflammation,” *Int. J. Newgen Res. Pharm. Healthc.*, pp. 248–254, 2024, doi: 10.61554/ijnrph.v2i1.2024.71.

[98] L. B. Baker, “Physiology of sweat gland function: The roles of sweating and sweat composition in human health.,” *Temp. (Austin, Tex.)*, vol. 6, no. 3, pp. 211–259, 2019, doi: 10.1080/23328940.2019.1632145.

[99] Y. Wu *et al.*, “Research progress of in-situ gelling ophthalmic drug delivery system.,” *Asian J. Pharm. Sci.*, vol. 14, no. 1, pp. 1–15, Jan. 2019, doi: 10.1016/j.ajps.2018.04.008.

[100] P. Rachmawati, “Basics: A Review: In Situ Gel Dosage Forms for Herbal Medicine Delivery.,” *Int. J. Pharm. Compd.*, vol. 27, no. 1, pp. 24–29, 2023.

[101] O. I. Oluwole *et al.*, “Recent Trends in the Application of Polymer-Based Biomaterials in Advancing Regenerative Medicine: A Review of Critical Roles,” *Next Res.*, vol. 7, p. 101500, 2026, doi: https://doi.org/10.1016/j.nexres.2026.101500.

[102] S. Zhang, G. Curtzwiler, L. Hamachi, Y. Huang, and A. Kathuria, “Editorial: Recent advances in sustainable polymer materials,” *Front. Mater.*, vol. Volume 12, 2025, doi: 10.3389/fmats.2025.1576384.

[103] N. S. Said, I. F. Olawuyi, and W. Y. Lee, “Pectin Hydrogels: Gel-Forming Behaviors, Mechanisms, and Food Applications.,” *Gels (Basel, Switzerland)*, vol. 9, no. 9, Sep. 2023, doi: 10.3390/gels9090732.

[104] S. Lomartire and A. M. M. Gonçalves, “Algal Phycocolloids: Bioactivities and Pharmaceutical Applications.,” *Mar. Drugs*, vol. 21, no. 7, Jun. 2023, doi: 10.3390/md21070384.

[105] A. I. Mendes *et al.*, “Gellan gum spongy-like hydrogel-based dual antibiotic therapy for infected diabetic wounds.,” *Bioeng. Transl. Med.*, vol. 8, no. 3, p. e10504, May 2023, doi: 10.1002/btm2.10504.

[106] W. Nie and A. M. Deters, “Tamarind Seed Xyloglucans Promote Proliferation and Migration of Human Skin Cells through Internalization via Stimulation of Proproliferative Signal Transduction Pathways.,” *Dermatol. Res. Pract.*, vol. 2013, p. 359756, 2013, doi: 10.1155/2013/359756.

[107] F. Jabeen, Zil-E-Aimen, R. Ahmad, S. Mir, N. S. Awwad, and H. A. Ibrahium, “Carrageenan: structure, properties and applications with special emphasis on food science.,” *RSC Adv.*, vol. 15, no. 27, pp. 22035–22062, Jun. 2025, doi: 10.1039/d5ra03296b.

[108] D. Mudgil, S. Barak, and B. S. Khatkar, “Guar gum: processing, properties and food applications-A Review.,” *J. Food Sci. Technol.*, vol. 51, no. 3, pp. 409–418, Mar. 2014, doi: 10.1007/s13197-011-0522-x.

[109] K. C. Saini, A. Rani, S. K. Gupta, and P. Sharma, “Algae a Potential Source in Cosmetics: Current

Status, Challenges, and Economic Implications.,” *Indian J. Microbiol.*, vol. 64, no. 4, pp. 1445–1460, Dec. 2024, doi: 10.1007/s12088-024-01263-0.

[110] M. Muthu, J. Gopal, S. Chun, A. J. P. Devadoss, N. Hasan, and I. Sivanesan, “Crustacean Waste-Derived Chitosan: Antioxidant Properties and Future Perspective.,” *Antioxidants (Basel, Switzerland)*, vol. 10, no. 2, Feb. 2021, doi: 10.3390/antiox10020228.

[111] M.-B. Coltelli, S. Danti, K. De Clerck, A. Lazzeri, and P. Morganti, “Pullulan for Advanced Sustainable Body- and Skin-Contact Applications.,” *J. Funct. Biomater.*, vol. 11, no. 1, Mar. 2020, doi: 10.3390/jfb11010020.

[112] K. Nasrallah, S. Khaled, S. El Khatib, and M. Krayem, “Nutritional, biochemical and health properties of Locust beans and its applications in the food industry: a review.,” *J. Food Sci. Technol.*, vol. 61, no. 4, pp. 621–630, Apr. 2024, doi: 10.1007/s13197-023-05765-5.

[113] H. Wang, J. Shah, S.-E. Hawwat, Q. Huang, and A. Khatami, “A comprehensive review of polyethylene pipes: Failure mechanisms, performance models, inspection methods, and repair solutions,” *J. Pipeline Sci. Eng.*, vol. 4, no. 2, p. 100174, 2024, doi: https://doi.org/10.1016/j.jpse.2024.100174.

[114] A. Alsabri, F. Tahir, and S. G. Al-Ghamdi, “Environmental impacts of polypropylene (PP) production and prospects of its recycling in the GCC region,” *Mater. Today Proc.*, vol. 56, pp. 2245–2251, 2022, doi: https://doi.org/10.1016/j.matpr.2021.11.574.

[115] J. Yang *et al.*, “Critical advances and assessment on chemo-biological conversions of waste polyvinyl chloride,” *Sci. Total Environ.*, vol. 956, p. 177170, 2024, doi: https://doi.org/10.1016/j.scitotenv.2024.177170.

[116] A. Singh, A. Chauhan, and R. Gaur, “A comprehensive review on the synthesis, properties, environmental impacts, and chemiluminescence applications of polystyrene (PS),” *Discov. Chem.*, vol. 2, no. 1, p. 47, 2025, doi: 10.1007/s44371-025-00125-y.

[117] J. Qiu *et al.*, “A comprehensive review on enzymatic biodegradation of polyethylene terephthalate,” *Environ. Res.*, vol. 240, p. 117427, 2024, doi: https://doi.org/10.1016/j.envres.2023.117427.

[118] L. Liu, H. Li, and G. Avgouropoulos, “A review of porous polytetrafluoroethylene reinforced sulfonic acid-based proton exchange membranes for fuel cells,” *Int. J. Hydrogen Energy*, vol. 50, pp. 501–527, 2024, doi: https://doi.org/10.1016/j.ijhydene.2023.08.270.

[119] J. A. Lee, J. Y. Kim, J. H. Ahn, Y.-J. Ahn, and S. Y. Lee, “Current advancements in the bio-based production of polyamides,” *Trends Chem.*, vol. 5, no. 12, pp. 873–891, 2023, doi: https://doi.org/10.1016/j.trechm.2023.10.001.

[120] C. Mounika, T. Tadge, M. Keerthana, R. Velyutham, and G. Kapusetti, “Advancements in poly(methyl Methacrylate) bone cement for enhanced osteoconductivity and mechanical properties in vertebroplasty: A comprehensive review,” *Med. Eng. Phys.*, vol. 120, p. 104049, 2023, doi: https://doi.org/10.1016/j.medengphy.2023.104049.

[121] S. Wu, S. Ma, Q. Zhang, and C. Yang, “A comprehensive review of polyurethane: Properties, applications and future perspectives,” *Polymer (Guildf).*, vol. 327, p. 128361, 2025, doi: https://doi.org/10.1016/j.polymer.2025.128361.

[122] A. Dorieh *et al.*, “Phenol formaldehyde resin modified by cellulose and lignin nanomaterials: Review and recent progress,” *Int. J. Biol. Macromol.*, vol. 222, pp. 1888–1907, 2022, doi: https://doi.org/10.1016/j.ijbiomac.2022.09.279.

[123] A. Selwyn and S. Govindaraj, "Study of plant-based cosmeceuticals and skin care," *South African J. Bot.*, vol. 158, pp. 429–442, 2023, doi: https://doi.org/10.1016/j.sajb.2023.05.039.

[124] F. Lalebeigi *et al.*, "Recent advances on biomedical applications of gellan gum: A review," *Carbohydr. Polym.*, vol. 334, p. 122008, 2024, doi: https://doi.org/10.1016/j.carbpol.2024.122008.

[125] N. Tamta *et al.*, "Formulation Development, Phytochemical Characterization and In Vitro Pharmacological Assessment of Calendula officinalis Extract for Dermatological Applications," 2026, doi: 10.25258/ijddt.16.19s.96.

[126] A. Yang *et al.*, "A review of Psoralea corylifolia L.: a valuable plant with profound biological significance," *Front. Pharmacol.*, vol. Volume 15, 2025, doi: 10.3389/fphar.2024.1521040.

[127] J. Milutinov, V. Krstonošić, D. Ćirin, M. Hadnađev, M. Đanić, and N. Pavlović, "Development and evaluation of quercetin topical emulgels: Physicochemical and rheological properties, stability and sun protective potential," *J. Mol. Liq.*, vol. 417, p. 126568, 2025, doi: https://doi.org/10.1016/j.molliq.2024.126568.

[128] J. E. Fanning, S. A. McGee, and O. I. Ibrahim, "Human Clinical Trials Using Topical Bakuchiol Formulations for the Treatment of Skin Disorders: A Systematic Review.," *J. Drugs Dermatol.*, vol. 23, no. 4, pp. 239–243, Apr. 2024, doi: 10.36849/JDD.7763.

[129] X. Tang, J. Liu, R. Yan, and Q. Peng, "Carbohydrate polymer-based bioadhesive formulations and their potentials for the treatment of ocular diseases: A review," *Int. J. Biol. Macromol.*, vol. 242, p. 124902, 2023, doi: https://doi.org/10.1016/j.ijbiomac.2023.124902.

[130] S.-H. Lin and S. Hsu, "Smart hydrogels for in situ tissue drug delivery," *J. Biomed. Sci.*, vol. 32, no. 1, p. 70, 2025, doi: 10.1186/s12929-025-01166-2.

[131] J.-H. Wang *et al.*, "Effects of bavachin and its regulation of melanin synthesis in A375 cells.," *Biomed. reports*, vol. 5, no. 1, pp. 87–92, Jul. 2016, doi: 10.3892/br.2016.688.

[132] D. Prabhu Venkatesh, G. S, P. Ramani, R. S, and K. Ramalingam, "In Vitro Evaluation of Antioxidant and Anti-inflammatory Potentials of Herbal Formulation Containing Marigold Flower (Calendula officinalis L.) Tea.," *Cureus*, vol. 15, no. 8, p. e43308, Aug. 2023, doi: 10.7759/cureus.43308.

[133] A. Surjushe, R. Vasani, and D. G. Saple, "Aloe vera: a short review.," *Indian J. Dermatol.*, vol. 53, no. 4, pp. 163–166, 2008, doi: 10.4103/0019-5154.44785.

[134] F. A. Ansari, M. Perazzolli, F. M. Husain, A. S. Khan, N. Z. Ahmed, and R. P. Meena, "Novel decontamination approaches for stability and shelf-life improvement of herbal drugs: A concise review," *The Microbe*, vol. 3, p. 100070, 2024, doi: https://doi.org/10.1016/j.microb.2024.100070.