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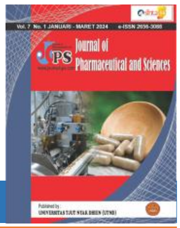

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Phytochemical Effects of Marigold (*Tagetes erecta*) on Photoaging: A Systematic Review

Efek Fitokimia Bunga Marigold (*Tagetes erecta*) Terhadap Fotoaging: Tinjauan Literatur Sistematis

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Abstract

Photoaging is a major contributor to premature skin aging and is primarily caused by chronic exposure to ultraviolet (UV) radiation. UV induced oxidative stress, inflammation, and extracellular matrix degradation result in wrinkles, pigmentation, and loss of skin elasticity. This systematic review aimed to evaluate the phytochemical mechanisms of *Tagetes erecta* and assess its potential clinical relevance in preventing photoaging. A systematic literature search was conducted in PubMed, Science Direct, and Europe PMC for studies published between 2016 and 2026, following PRISMA 2020 guidelines. Studies were included if they investigated *Tagetes erecta* or phytochemical compounds known to be present in *Tagetes erecta* (e.g., lutein, zeaxanthin, flavonoids, phenolic acids) in UV-induced photoaging models. The findings indicate that *Tagetes erecta* contains bioactive compounds that reduce reactive oxygen species (ROS), enhance endogenous antioxidant defenses, suppress matrix metalloproteinase (MMP) expression, and preserve collagen integrity. Clinical studies evaluating carotenoids and related phytochemicals also found in *Tagetes erecta* reported improvements in minimal erythema dose, skin elasticity, hydration, pigmentation, and wrinkle appearance. Notably, only one study directly investigated *Tagetes erecta* in the context of photoaging, however, the available evidence is still limited and insufficient to establish strong clinical conclusions. Therefore, current clinical evidence remains largely indirect. Overall, *Tagetes erecta* represents a promising phytochemical source with strong mechanistic support, although further well-designed clinical studies are required.

***Keywords*: Photoaging, Tagetes erecta, Marigold, Phytochemicals, Skin Aging**

Abstrak

Fotoaging merupakan salah satu penyebab utama penuaan kulit dini yang terutama disebabkan oleh paparan kronis radiasi ultraviolet (UV). Stres oksidatif akibat UV, inflamasi, serta degradasi matriks ekstraseluler menyebabkan munculnya keriput, hiperpigmentasi, dan penurunan elastisitas kulit. Tinjauan sistematis ini bertujuan untuk mengevaluasi mekanisme fitokimia dari *Tagetes erecta* serta menilai relevansi klinisnya dalam mencegah fotoaging. Pencarian literatur sistematis dilakukan pada basis data PubMed, Science Direct, dan Europe PMC untuk publikasi tahun 2016 hingga 2026 dengan mengikuti pedoman PRISMA 2020. Studi yang diikutsertakan adalah penelitian yang mengevaluasi *Tagetes erecta* atau senyawa fitokimia yang diketahui terkandung di dalamnya (seperti lutein, zeaxanthin, flavonoid, dan asam fenolat) pada model photoaging akibat paparan UV. Hasil menunjukkan bahwa *Tagetes erecta* mengandung senyawa bioaktif yang mampu menurunkan *Reactive Oxygen Species* (ROS), meningkatkan sistem antioksidan endogen, menghambat ekspresi *Matrix Metalloproteinase* (MMP), serta menjaga integritas kolagen. Studi klinis yang mengevaluasi karotenoid dan fitokimia terkait yang juga terdapat dalam *Tagetes erecta* melaporkan perbaikan pada dosis eritema minimal, elastisitas kulit, hidrasi, pigmentasi, serta tampilan keriput. Namun demikian, hanya satu penelitian yang secara langsung mengevaluasi *Tagetes erecta* dalam konteks photoaging, sehingga bukti yang tersedia masih terbatas dan belum cukup kuat untuk menarik kesimpulan klinis yang definitif. Oleh karena itu, bukti klinis saat ini masih bersifat tidak langsung. Secara keseluruhan, *Tagetes erecta* merupakan sumber fitokimia yang menjanjikan dengan dukungan mekanistik yang kuat, namun masih diperlukan penelitian klinis yang lebih lanjut dan terkontrol dengan baik.

Kata Kunci: Fotoaging, Tagetes erecta, Gumitir, Fitokimia, Penuaan Kulit.

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Introduction

Photoaging is one of the main causes of premature skin aging and is largely driven by chronic exposure to ultraviolet (UV) radiation. UV radiation induces oxidative stress, inflammation, DNA damage, and degradation of the dermal extracellular matrix. These processes lead to visible skin changes such as wrinkles, uneven pigmentation, reduced elasticity, and impaired skin barrier function [1–3].

At the molecular level, UV exposure increases the production of reactive oxygen species (ROS) and activates signaling pathways such as nuclear factor kappa B (NF-κB) and activator protein-1 (AP-1). This activation promotes the expression of matrix metalloproteinases (MMPs), which degrade collagen and accelerate skin aging [1,4]. For this reason, antioxidant-based strategies especially those derived from natural sources have gained significant attention for preventing and reducing photoaging-related skin damage [2,4].

Numerous clinical and experimental studies have shown that dietary and topical antioxidants can protect the skin from UV-induced damage. Carotenoid-rich interventions, including lutein, zeaxanthin, lycopene, and mixed carotenoids, have been reported to increase minimal erythema dose, reduce UV-induced pigmentation, improve skin hydration and elasticity, and suppress inflammatory responses [5–7]. Oral intake of carotenoids from natural sources such as tomatoes, kale, paprika, and avocado has also been associated with improved collagen–elastin balance and skin firmness [8,9].

Among natural antioxidant sources, marigold (*Tagetes erecta*) is recognized as a rich source of bioactive phytochemicals, particularly xanthophyll carotenoids such as lutein and zeaxanthin, as well as flavonoids and phenolic compounds [10,11]. Experimental studies have demonstrated that *Tagetes erecta* extracts exhibit strong antioxidant, anti-inflammatory, and anti-aging effects, including reduced oxidative stress and preservation of collagen structure [12,13]. In vitro and animal studies further suggest that marigold-derived compounds can reduce UV-induced photoaging by modulating inflammatory pathways and limiting matrix degradation.

Despite growing evidence on the benefits of carotenoids and phytochemicals for skin health, most clinical studies have focused on mixed carotenoid supplements or tomato-based products rather than marigold-specific preparations [5,6]. To date, no systematic review has comprehensively evaluated the phytochemical mechanisms and clinical relevance of *Tagetes erecta* specifically in the context of photoaging.

Therefore, this systematic review aims to critically analyze the phytochemical mechanisms of *Tagetes erecta* in inhibiting photoaging and to assess its potential clinical implications by integrating evidence from in vitro, animal, and human studies. This review seeks to fill an important gap in the literature and support the future development of marigold-based nutraceutical and cosmeceutical interventions for photoaging prevention.

Methods

This systematic review followed PRISMA 2020 guidelines and was registered in PROSPERO (CRD420251179056). A comprehensive search was conducted in PubMed, ScienceDirect, Europe PMC, and OpenAlex for studies published between January 2016 and December 2026. Keywords included combinations of: "photoaging", "UV radiation", "skin aging", "*Tagetes erecta*", "marigold", "lutein", "zeaxanthin", "phytochemicals", and "antioxidants".

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Studies were included if they:

1. Investigated *Tagetes erecta* extracts or preparations, or
2. Investigated phytochemicals known to be present in *Tagetes erecta* (e.g., lutein, zeaxanthin, flavonoids, phenolic acids)
3. Evaluated outcomes related to UV induced photoaging (in vitro, animal, or human studies)

Studies involving phytochemicals from non *Tagetes erecta* sources were included only to support mechanistic and clinical plausibility. These were not considered equivalent to whole-extract effects due to differences in phytochemical composition and potential synergistic interactions. Reviews, editorials, non-peer-reviewed articles, and non-English publications were excluded.

Data extracted included study design, sample size, intervention type, phytochemical composition, and outcomes related to oxidative stress, inflammation, and skin aging parameters.

Results and Discussion

Figure 1 illustrates the study selection process in accordance with the PRISMA guidelines. A total of 56 records were identified across PubMed (n = 29), Science Direct (n = 8), and Europe PMC (n = 14). After removing four duplicate records, 52 articles remained for title and abstract screening, of which 10 were excluded due to irrelevance. Subsequently, 42 full-text articles were assessed for eligibility, with two articles unavailable for retrieval. Eighteen articles were excluded following full-text evaluation because they did not sufficiently address phytochemical mechanisms or photoaging-related outcomes. Ultimately, 18 studies met the inclusion criteria and were included in the qualitative synthesis.

This systematic review summarizes current evidence on phytochemical mechanisms associated with *Tagetes erecta* in the prevention of photoaging and explores its potential clinical relevance. To the best of our knowledge, this is the first systematic review specifically focusing on *Tagetes erecta* as a botanical source of bioactive compounds with anti-photoaging potential. Previous reviews on photoaging predominantly emphasized retinoids, synthetic antioxidants, or carotenoids in general, without specifically addressing marigold-derived phytochemicals or structurally related compounds characteristic of *Tagetes erecta* [6,14].

To provide an integrated overview of the available evidence, Table 1 presents the characteristics and main findings of the included studies. The table synthesizes results from studies directly investigating *Tagetes erecta* as well as studies examining phytochemicals with comparable profiles that are also present in *Tagetes erecta*.

Phytochemical Composition and Antioxidant Mechanisms

An important consideration in interpreting Table 1 is the variability in phytochemical composition across different botanical sources. Several studies used carotenoids such as lycopene and β-carotene from various plant and microalgal sources, which differ from *Tagetes erecta*, a species particularly rich in lutein diesters, zeaxanthin, flavonoids, and phenolic compounds. Despite these differences, the observed effects likely reflect shared antioxidant and anti-inflammatory mechanisms. However, compounds such as lycopene and β-carotene may further modulate these effects through complementary or synergistic interactions. In contrast, the unique phytochemical matrix of *Tagetes erecta* may provide distinct multi-target benefits that are not fully replicated by isolated compounds or alternative sources.

The findings indicate that the anti-photoaging effects associated with *Tagetes erecta* are largely attributable to its phytochemical composition, particularly carotenoids such as lutein and zeaxanthin, in addition to flavonoids and phenolic compounds [11,12]. As summarized in Table 1, these compounds exhibit strong antioxidant activity, which plays a central role in counteracting ultraviolet-induced oxidative stress. Chronic UV exposure increases reactive oxygen species production, leading to lipid peroxidation, DNA damage, and cellular dysfunction [1–3]. Experimental studies have demonstrated that carotenoid- and flavonoid-rich extracts reduce intracellular reactive oxygen species levels and enhance endogenous antioxidant defense systems, thereby limiting oxidative damage at the cellular level [12,13].

Anti-inflammatory Effects and Inhibition of Matrix Degradation

Beyond antioxidant activity, phytochemicals commonly found in *Tagetes erecta* also exhibit significant anti-inflammatory effects. Ultraviolet radiation activates inflammatory signaling pathways such as nuclear

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factor kappa B and activator protein-1, which stimulate the expression of pro-inflammatory cytokines and matrix metalloproteinases [1,4]. These enzymes contribute to collagen degradation and wrinkle formation. In vitro and animal studies summarized in Table 1 demonstrate that *Tagetes erecta* extracts or botanically comparable phytochemical sources suppress inflammatory mediator expression and reduce matrix metalloproteinase activity, thereby protecting skin structure from UV-induced damage [13,15]. These findings are consistent with previous reports on plant-derived antioxidants that modulate ultraviolet-related inflammatory responses [16].

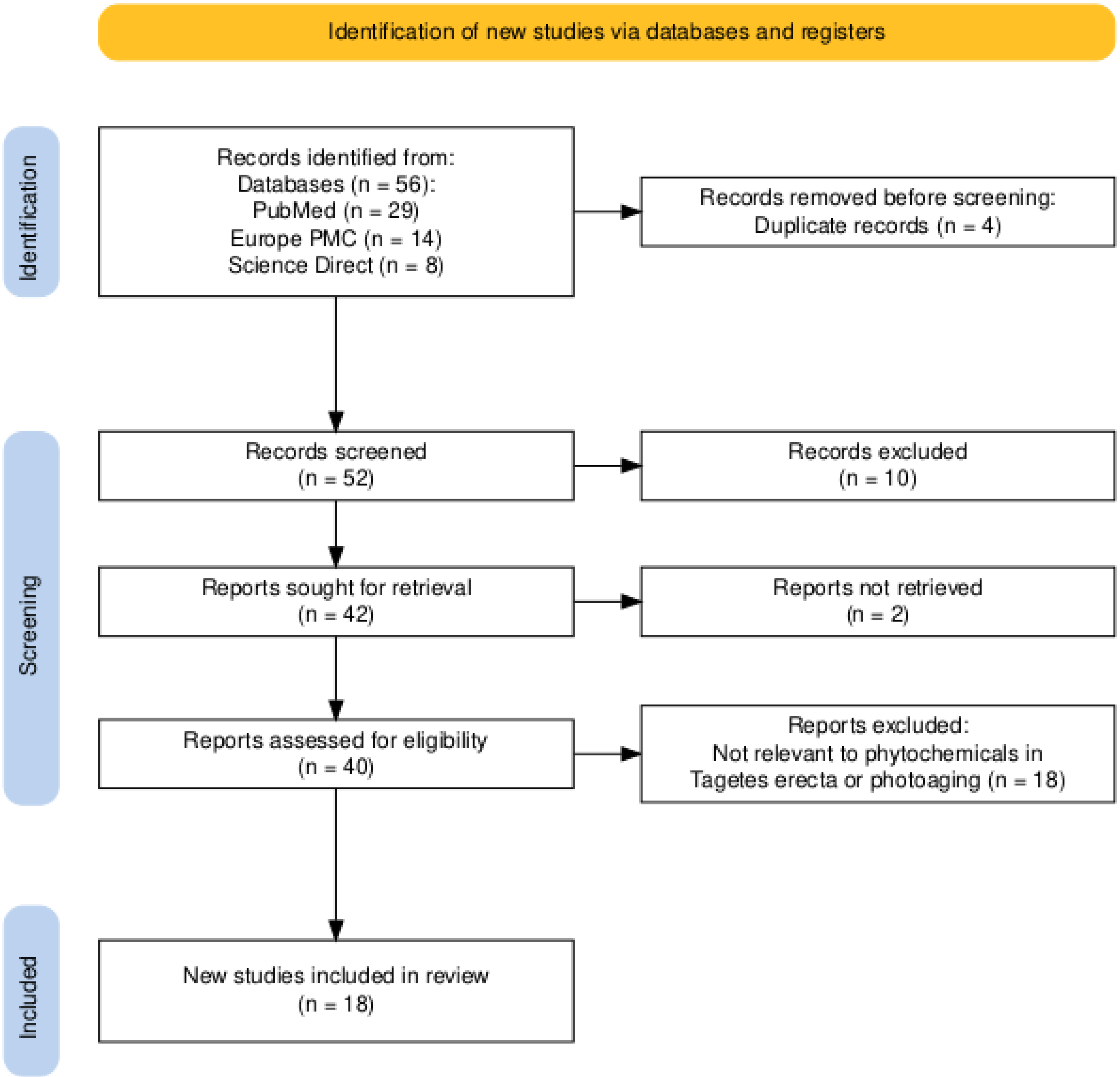

Figure 1. PRISMA Flow Chart

Extracellular Matrix Protection and Antiglycation Activity

Protection of the dermal extracellular matrix represents another key mechanism linked to phytochemicals characteristic of *Tagetes erecta*. Several studies included in Table 1 report that carotenoid-rich interventions improve collagen integrity, elastin balance, and overall dermal architecture following ultraviolet exposure [8,17]. In addition, antiglycation effects have been observed in flavonoid- and phenolic-rich extracts, which may help prevent collagen stiffening caused by advanced glycation end products [15]. This mechanism is particularly relevant in photoaged skin, where glycation contributes to reduced elasticity and increased wrinkle formation.

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Table 1. Characteristics and Main Findings of the Included Studies

No.	Author & Year	Study Design	Sample Size	Experimental / Clinical Model	Intervention Characteristics	Highlighted Phytochemical / Antioxidant Compounds	Outcome Measures	Key Findings
Clinical Study of *Tagetes erecta*								
1	Kang et al., 2018	In vitro + in vivo	NR	Fibroblasts and mice	*Tagetes erecta* methanol extract	Lutein, flavonoids	Antioxidant capacity, wrinkles	Significant anti-aging and antioxidant effects
Clinical Study of phytochemical compounds that are also found in *Tagetes erecta*								
1	Havas et al., 2022	In vitro + ex vivo	NR	Human skin models under intense solar irradiation	*Dunaliella salina* extract	β-carotene, carotenoids	Glycation, inflammation, oxidative stress	Reduced protein glycation and inflammatory markers, counteracting skin aging
2	Baswan et al., 2020	Double-blind RCT	65	Human volunteers	Oral mixed carotenoids	Lutein, lycopene, β-carotene	UVA-induced pigmentation	Significant reduction in pigmentation and improved photoprotection
3	Henning et al., 2022	Pilot clinical study	39	Healthy women	Daily avocado consumption	Carotenoids, MUFAs	Skin elasticity, firmness	Improved elasticity and firmness
4	Peres et al., 2016	In vitro formulation study	NR	Sunscreen systems	Rutin-enriched UV filter	Rutin (flavonoid)	Critical wavelength	Enhanced UVA protection with good skin compatibility
5	Morse et al., 2018	Open-label clinical trial	40	Human skin	Anti-aging skincare formula	Mixed antioxidants	MED	Increased MED and good tolerability
6	Schwartz et al., 2016	Clinical intervention	30	Female subjects	Oral supplement + topical serum	Zeaxanthin	Hydration, wrinkle count	Increased hydration and reduced wrinkles
7	Yatsuhashi et al., 2022	Clinical trial	44	Human volunteers	Oral paprika xanthophylls	Capsanthin, capsorubin	Skin moisture	Significant improvement in skin moisture
8	Carrascosa et al., 2017	Double-blind RCT	30	Healthy subjects	Oral antioxidant complex	Mixed carotenoids	MED	Significant increase in MED
9	Grether-Beck et al., 2017	Double-blind crossover RCT	65	Human volunteers	Oral lycopene or lutein	Lycopene, lutein	UV-induced molecular markers	Reduced UV-induced skin damage
10	Sohail et al., 2022	Controlled clinical study	30	Human skin	Topical lycopene emulgel	Lycopene	Elasticity, hydration, TEWL	Improved biophysical skin parameters
11	Groten et al., 2019	Double-blind RCT	65	Human volunteers	Tomato phytonutrients	Lycopene, phytoene	UV response markers	Balanced UV response and reduced erythema
12	Meinke et al., 2017	Clinical intervention	29	Human skin	Oral kale extract	Lutein, β-carotene	Collagen I/elastin index	Improved dermal structural indices
13	Vanella et al., 2023	In vitro study	NR	Human keratinocytes	Flower waste + snail mucus extract	Polyphenols	UVB-induced damage	Reduced oxidative and inflammatory damage
14	Kang et al., 2018	In vitro + in vivo	NR	Fibroblasts and mice	*Tagetes erecta* methanol extract	Lutein, flavonoids	Antioxidant capacity, wrinkles	Significant anti-aging and antioxidant effects
15	Lee et al., 2020	In vitro study	NR	Human keratinocytes	*Agastache rugosa* extract	Polyphenols	Inflammation, barrier function	Reduced inflammation and improved barrier integrity
16	Juturu et al., 2016	Double-blind RCT	60	Human volunteers	Oral lutein & zeaxanthin	Lutein, zeaxanthin	Skin tone, pigmentation	Improved skin tone and lightening
17	Auh & Madhavan, 2021	Animal study	NR	UV-exposed mice	Marigold + rosemary extract	Lutein, phenolics	Wrinkle depth, collagen	Reduced photoaging and preserved collagen
18	Idris et al., 2023	Phytochemical analysis	NR	*Tagetes minuta* extracts	Water & ethanol extracts	Phenolics, flavonoids	Cytotoxicity, composition	Rich phenolic antioxidant profile

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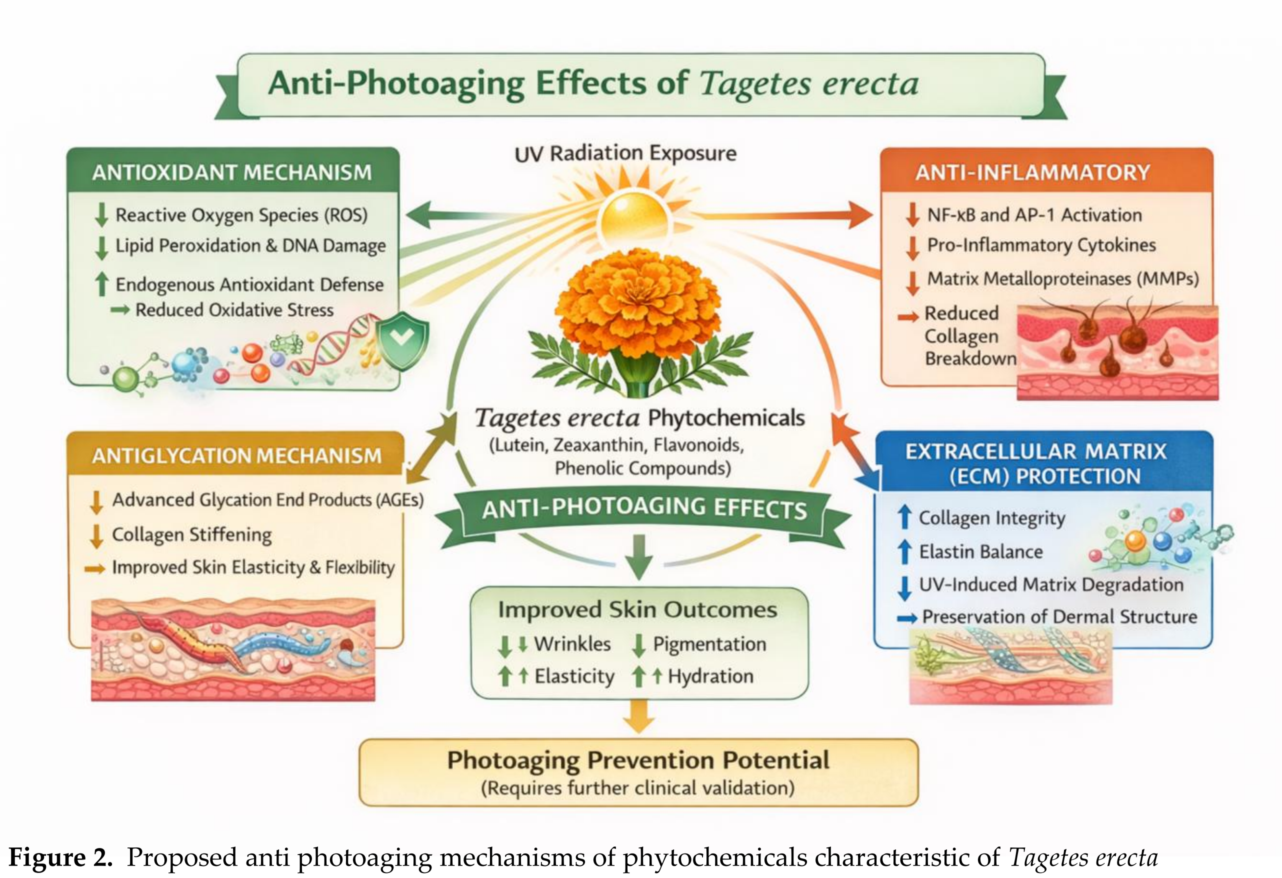

Figure 2. Proposed anti photoaging mechanisms of phytochemicals characteristic of *Tagetes erecta*

Clinical Relevance and Translational Potential

Although direct clinical trials specifically evaluating standardized *Tagetes erecta* extracts in photoaging are limited, indirect clinical evidence from studies on carotenoids and flavonoids that are also abundant in *Tagetes erecta* supports its translational potential. Randomized controlled trials summarized in Table 1 have demonstrated that oral supplementation with lutein, zeaxanthin, lycopene, and mixed carotenoids increases minimal erythema dose, reduces ultraviolet-induced pigmentation, and improves skin hydration, elasticity, and firmness [5–7,18,19]. Given that *Tagetes erecta* is a major natural source of lutein and zeaxanthin, these findings provide biologically plausible support for its role in photoaging prevention.

Topical applications further reinforce this concept. Clinical studies indicate that topical formulations containing carotenoids or flavonoids, whether derived from marigold or other botanical sources, improve skin hydration, elasticity, and wrinkle appearance [20,21]. In addition, flavonoids such as rutin enhance ultraviolet protection and improve skin compatibility when incorporated into topical formulations [22].

Conclusions and Future Directions

Based on this systematic review, the majority of evidence supporting the potential role of *Tagetes erecta* in preventing photoaging is derived from preclinical studies demonstrating antioxidant, anti-inflammatory, and extracellular matrix–protective effects. The available clinical evidence is primarily based on carotenoids and other phytochemicals that are structurally similar and also present in *Tagetes erecta*, which have shown beneficial effects on various skin parameters. However, only one study directly evaluated *Tagetes erecta* in the context of photoaging, and thus the current clinical evidence remains limited. Therefore, the potential of *Tagetes erecta* as a promising phytochemical source should be interpreted with caution. Further well designed clinical trials are required to establish its efficacy and safety in humans.

Conflict of Interest

The authors declare that there is no conflict of interest regarding the publication of this manuscript. The authors have no personal, financial, or professional relationships that could be construed as having influenced the representation or interpretation of the reported research findings.

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