



Literature Review on the Bioactivity, Phytochemistry, and Dermatological Potential of *Carthamus tinctorius* L.

Virsa Handayani^{1,2*}, Akrom², Aktsar Roskiana Ahmad³

¹Faculty of Pharmacy, Universitas Muslim Indonesia, Makassar, Indonesia.

²Faculty of Pharmacy, Ahmad Dahlan University, Yogyakarta, Indonesia.

³Magister of Pharmacy, Postgraduate Program, Universitas Muslim Indonesia, Makassar, Indonesia.

Received: November 15, 2025

Revised: January 21, 2026

Accepted: February 25, 2026

Published: February 28, 2026

Corresponding Author:

Virsa Handayani

virsa.handayani@umi.ac.id

DOI: [10.29303/jppipa.v12i2.13479](https://doi.org/10.29303/jppipa.v12i2.13479)

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Abstract: This study systematically reviews the bioactivity, phytochemistry, and dermatological potential of *Carthamus tinctorius* L. using a structured synthesis of nine eligible research articles. The purpose of this review is to consolidate scientific evidence regarding the antioxidant activity, phytochemical composition, molecular mechanisms, and skin-related relevance of this plant across diverse study designs. The findings indicate that *Carthamus tinctorius* contains polysaccharides, phenolic compounds, flavonoids, and fatty acids that exhibit strong antioxidant activity, enzyme inhibition, and cellular protective effects. Several studies demonstrate its ability to modulate oxidative pathways, inhibit collagen-degrading enzymes, and support skin barrier integrity, highlighting its promising dermatological applications. Variations in bioactivity were influenced by genotype, environmental conditions, and extraction techniques, underscoring the importance of plant origin and processing methods. Overall, the review concludes that *Carthamus tinctorius* possesses significant potential as a natural source of therapeutic compounds relevant to skin health, anti-aging applications, and future product development. This synthesis also identifies methodological gaps that may guide further experimental, molecular, and formulation-based research.

Keywords: Natural actives; Oxidative defense; Plant-derived compounds; Skin regeneration; Therapeutic botanicals

Introduction

Research on *Carthamus tinctorius* L. has garnered increasing scholarly attention due to its array of bioactive compounds and their significance in pharmaceutical, phytochemical, and dermatological fields. This plant is characterized by the presence of polysaccharides, phenolics, flavonoids, and essential fatty acids, which collectively confer robust antioxidant capabilities (Jaradat et al., 2024; Lin et al., 2022; Zemour et al., 2019). These compounds render it a promising natural resource for mitigating oxidative stress, a principal contributor to skin aging and structural deterioration.

The biochemical composition of *Carthamus tinctorius* is influenced by variations in genotype, environmental factors, and extraction methodologies

(Golkar & Taghizadeh, 2018; Li et al., 2025; Sülüs & Leblebici, 2022). This indicates that its therapeutic efficacy is shaped by intricate biological and ecological interactions. The extensive range of its bioactivity positions *Carthamus tinctorius* as a noteworthy candidate for the development of plant-derived dermatological formulations, substantiated by empirical evidence of its antioxidant, anti-inflammatory, and anti-aging properties (Bacchetti et al., 2020; Zemour et al., 2019).

Nonetheless, despite a plethora of investigations examining individual facets of this plant, a comprehensive synthesis that consolidates its bioactivity, phytochemistry, and dermatological significance within a unified framework remains absent (Latif & Nawaz, 2025; Lok et al., 2025; Mashele, 2025). This deficiency underscores the necessity for a structured assessment capable of integrating existing

How to Cite:

Handayani, V., Akrom, & Ahmad, A. R. (2026). Literature Review on the Bioactivity, Phytochemistry, and Dermatological Potential of *Carthamus tinctorius* L. *Jurnal Penelitian Pendidikan IPA*, 12(2), 27–33. <https://doi.org/10.29303/jppipa.v12i2.13479>

scientific data and elucidating its pharmacological potential.

Consequently, the aim of this study is to perform a systematic literature review that delineates the biological activities, chemical constituents, and prospective dermatological applications of *Carthamus tinctorius* L., thereby establishing a coherent scientific basis for forthcoming experimental and formulation-centric research.

Method

This investigation employed a meticulously structured Systematic Literature Review (SLR) methodology to facilitate a systematic, transparent, and replicable evaluation of the extant scientific literature pertaining to the bioactivity, phytochemical properties, and dermatological significance of *Carthamus tinctorius* L. The rationale for selecting the SLR approach stemmed from the imperative to generate a comprehensive synthesis exclusively grounded in previously published empirical data. This methodological framework affords precise regulation of inclusion criteria while promoting consistency throughout the review process. A total of nine publications fulfilled the eligibility criteria, encompassing a variety of research themes, including polysaccharide composition (Lin et al., 2022), seed oil components (Jaradat et al., 2024; Zemour et al., 2019), phenolic profiles (Golkar & Taghizadeh, 2018; Sülüs & Leblebici, 2022), antioxidant and pro-oxidant dynamics (Bacchetti et al., 2020), cellular oxidative pathways (Alshareef et al., 2024), and genotype-dependent responses to environmental and biochemical stressors (Li et al., 2025; (Golkar & Taghizadeh, 2018).

Data extraction was executed utilizing a standardized extraction sheet specifically crafted to systematically capture critical study attributes, encompassing research objectives, methodological frameworks, phytochemical constituents, biological activities, molecular mechanisms, and acknowledged limitations. This procedure was congruent with established extraction methodologies commonly employed in phytochemistry and antioxidant investigations (Bacchetti et al., 2020; Lin et al., 2022). The review unfolded through sequential phases—initial screening, comprehensive text evaluation, and structured data extraction—ensuring consistency and analytical coherence across all incorporated sources.

The processes of identification, screening, and eligibility assessment were meticulously documented using a PRISMA 2020-compliant flow diagram generated through the Watase Uake platform, thereby

enhancing methodological transparency and traceability. Data synthesis was performed through an integrated narrative and thematic framework, facilitating the organization of findings into coherent analytical domains such as bioactivity patterns, variations in phytochemical composition, and dermatological implications. This synthesis additionally underscored methodological deficiencies, including the limited application of cellular-level assays and insufficient mechanistic elucidations (Alshareef et al., 2024; Bacchetti et al., 2020; Jaradat et al., 2024).

In summary, the systematically constructed and transparently executed methodological procedures delineated in this review provide a solid foundation for the advancement of phytodermal and pharmaceutical research pertaining to *Carthamus tinctorius* L.

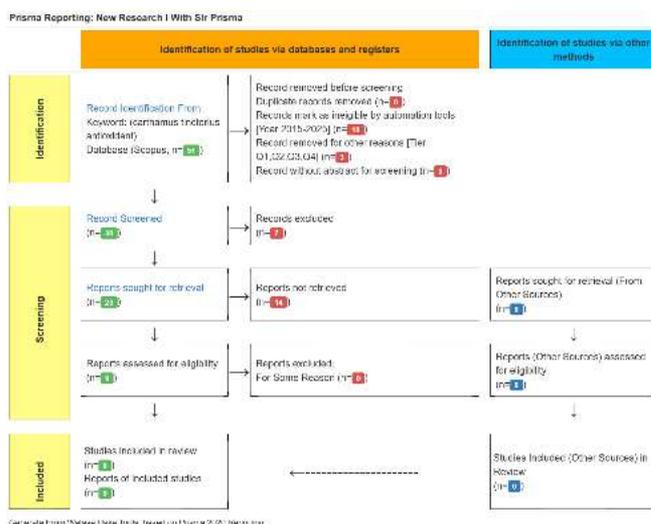


Figure 1. PRISMA 2020 flow diagram of the study selection process.

Result and Discussion

Results

The keyword mapping (Figure 1) reveals that scholarly investigations on *Carthamus tinctorius* predominantly focus on its antioxidant mechanisms, regulation of oxidative stress, phenolic compounds, and stress-responsive metabolites (Hong et al., 2022; Liu et al., 2025; Rajasreelatha et al., 2026). This underscores a strong scientific emphasis on the plant's biochemical pathways and its ability to modulate oxidative processes.

Table 1. Literature Review on the Bioactivity, Phytochemistry, and Dermatological Potential of *Carthamus tinctorius* L

Research Title	Authors & Year	Key Insights	Underlying Theory	Research Methods	Research Findings	Study Limitations	Relevance to Your Planned Research
Chemical Structures and Antioxidant Activities of Polysaccharides from <i>Carthamus tinctorius</i> L.	Lin et al. (2022)	Two polysaccharides (CTLP-1 and CTLP-2) were isolated, structurally characterized, and shown to possess strong antioxidant activity.	Structure-activity relationships of polysaccharides; free radical theory (DPPH, ABTS).	Polysaccharide isolation; structural analysis (GC, FTIR, NMR); antioxidant assays (DPPH, ABTS, FRAP).	CTLP-1 and CTLP-2 showed high scavenging capacity, Fe ²⁺ -chelating ability, and strong reducing power.	No biological assays on skin cells or anti-aging functions were conducted.	Highly relevant to the fitodermal and anti-aging potential of Kasumba Turate and provides a foundation for <i>in silico</i> and molecular docking analyses.
Phenol Content and Antioxidant and Antiaging Activity of Safflower Seed Oil	Zemour et al. (2019)	Phenolic content and anti-aging activity vary across genotypes and climatic conditions.	Relationship between phenolics, antioxidant capacity, and anti-aging activity; elastase and collagenase inhibition theory.	TPC, DPPH, anti-elastase and anti-collagenase assays; multi-year genotype evaluation.	Highest TPC observed in warmer years; elastase inhibition 32-70%; collagenase inhibition 47-72%.	No skin cell models used; substantial inter-annual variability.	Strongly supports fitodermal and anti-aging themes; relevant for formulation and mechanistic discussion.
Antioxidant and Pro-Oxidant Properties of <i>Carthamus tinctorius</i> , HSYA, and SYA	Bacchetti et al. (2020)	Safflower extracts exhibit biphasic effects: antioxidant at low doses and pro-oxidant at high doses.	Dual-role polyphenol theory dependent on concentration and cellular environment.	ORAC, DPPH, LDL oxidation assays; fibroblast oxidative stress model (t-BOOH).	Protective effects at low concentrations; pro-oxidant effects at high concentrations.	No detailed pathway analysis; assessed only in fibroblasts.	Important for establishing safe active-ingredient concentrations in fitodermal formulations and understanding skin-related antioxidant mechanisms.
Evaluation of Antioxidant and Oxidative Stress Activity of <i>Carthamus tinctorius</i> L. Extract in Lung Cancer A549 Cells	Alahmad i et al. (2023)	Safflower extract enhances SOD, CAT, and GSH, increases ROS, and induces apoptosis via SMAC/BAX pathways.	ROS-mediated apoptosis; intrinsic mitochondria l pathway activation.	Measurement of ROS, LPO, NO, SOD, CAT, GSH, LDH; PCR analysis of SMAC and BAX.	Dose-dependent apoptosis induction and elevation of antioxidant enzymes.	Focused on cancer cells rather than skin; active compounds were not isolated.	Relevant for explaining molecular antioxidant pathways (e.g., Nrf2/Keap1) and supportive for understanding bioactive mechanisms of natural products.
Phytochemical Composition and Antidiabetic, Anti-Obesity, Antioxidant, and	Jaradat et al. (2024)	Major fatty acid identified as linoleic acid (79%); strong antioxidant, antilipase, anti-amylase, and	Mechanisms of free-radical scavenging and enzymatic inhibition (lipase, amylase).	GC-MS profiling; DPPH; lipase inhibition; α-amylase inhibition; cytotoxicity assays.	Strong antioxidant activity (IC ₅₀ = 13.18 µg/mL) and significant metabolic inhibitory effects.	No dermatological activity assessed; minor compounds not extensively	Useful for understanding oil composition of Kasumba Turate and its potential dermatological applications.

Research Title	Authors & Year	Key Insights	Underlying Theory	Research Methods	Research Findings	Study Limitations	Relevance to Your Planned Research
Cytotoxic Activities of <i>Carthamus tinctorius</i> Seed Oil		cytotoxic activities.				characterized.	
In Vitro Evaluation of Phenolic and Osmolyte Compounds under Salinity Stress	Golkar & Taghizadeh (2018)	Salinity increases TPC, TFC, DPPH activity, MDA, and secondary metabolites.	Stress-induced enhancement of secondary metabolites; ROS-phenolic response theory.	Callus cultures of four genotypes; TPC/TFC assays; DPPH; ion analysis; proline and MDA profiling.	Salt-tolerant genotypes accumulated higher antioxidant metabolites.	Specific compounds not isolated; no linkage to human or dermatological applications.	Relevant for ethnopharmacological perspectives – environmental stress influencing bioactive content in Kasumba Turate.
Antioxidant Capacity and Boron Toxicity Response in Safflower Cultivars	Sülüs & Leblebici (2022)	Boron-tolerant cultivars exhibit higher antioxidant activity.	Relationship between stress tolerance and antioxidant enzyme activity.	Antioxidant enzyme assays and gene expression analyses.	Tolerant cultivars showed enhanced antioxidant enzyme responses; sensitive ones showed weaker responses.	No identification of specific bioactive compounds; no health-related analysis.	Supports cultivar selection for Kasumba Turate research and explains phenotypic variability in bioactivity.

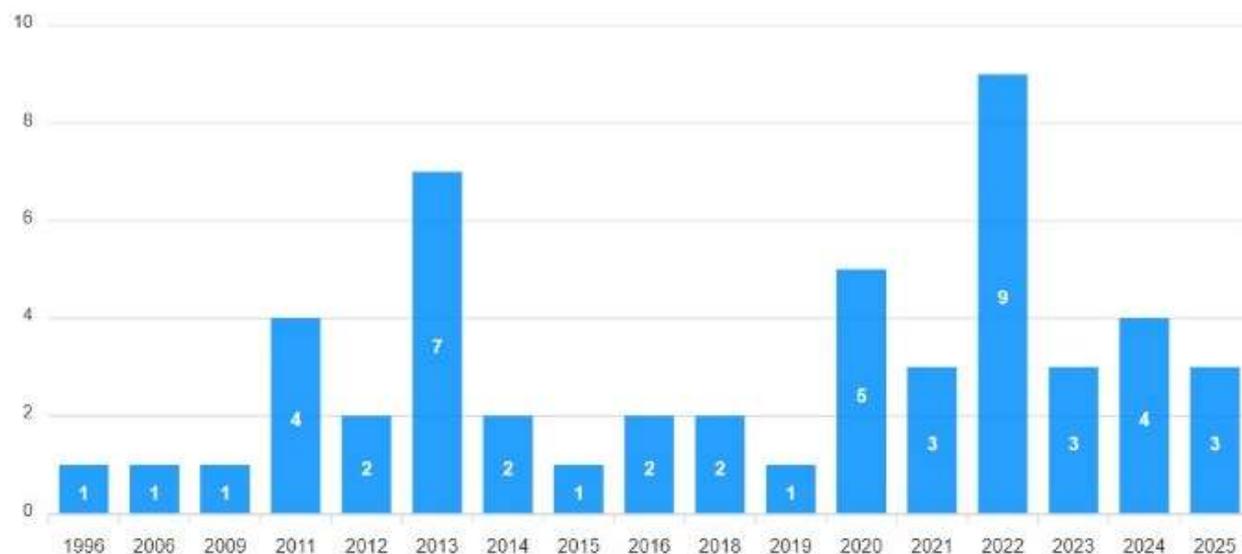


Figure 2. Annual publication trends extracted from keyword search outcomes.

The publication trend (Figure 2) illustrates a pattern of fluctuating but gradually increasing research activity over the past decade, with a notable peak in 2022. This signifies a growing interest in the phytochemical diversity of safflower and its potential biological applications. The PRISMA screening process (Figure 3) identified nine relevant studies examining the

polysaccharides, phenolic content, fatty acids, antioxidant pathways, and stress-induced metabolic responses in the plant. Collectively, these investigations unveil a comprehensive array of bioactive characteristics, including free-radical scavenging, metal-chelating activity, enzymatic inhibition, and modulation of oxidative pathways. Notable variations in bioactivity

across different genotypes and environmental stress conditions further suggest that safflower's phytochemical composition is dynamic and significantly influenced by its cultivation environment.

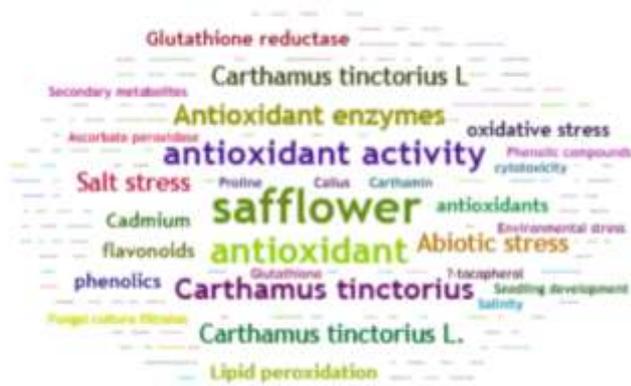


Figure 3. word cloud visualization

Discussion

The integrated findings indicate that *Carthamus tinctorius* exhibits consistent antioxidant potential, attributable to its polysaccharides, phenolics, flavonoids, and fatty acids (Bai et al., 2025; Sun et al., 2020; Wu et al., 2021). The plant's capacity to enhance enzymatic defenses, regulate reactive oxygen species (ROS), and display both antioxidant and controlled pro-oxidant activities implies a complex yet beneficial biochemical profile (Sharma et al., 2019). These attributes align with the growing interest in natural agents that provide cellular protection, particularly concerning skin health and aging.

The rising frequency of publications underscores safflower's emerging significance as a valuable botanical resource with interdisciplinary relevance (Gupta, 2022). The intersection of phytochemistry, stress physiology, and oxidative biology supports the expanding investigation of its molecular mechanisms and therapeutic potential (Altanam et al., 2025; Fatima et al., 2021; Mubeen et al., 2025; Muscolo et al., 2024). Importantly, the stress-responsive enhancement of bioactive metabolites and genotype-specific antioxidant profiles highlights that the selection of plant varieties and cultivation practices are pivotal in optimizing bioactive yield an essential consideration for developing standardized botanical ingredients (Głuchowska et al., 2025; Osei et al., 2025).

Despite robust biochemical evidence, there remains a significant gap in dermatology-focused studies. While numerous cellular investigations illustrate the modulation of oxidative pathways, apoptosis signaling, and membrane integrity preservation, only a limited number directly assess these mechanisms in skin models. This gap represents a substantial opportunity

for future research, especially in developing anti-aging formulations, preserving collagen and elastin, and modulating oxidative stress relevant to dermatological applications (Altay Benetti et al., 2023).

In summary, this synthesis of results positions *Carthamus tinctorius* as a multifunctional botanical with significant potential for phytodermal innovation. The plant's diverse antioxidant mechanisms, coupled with its environmentally responsive phytochemical profile (Malik et al., 2025; Sharma, 2024), provide a solid foundation for further experimental validation and targeted application in advanced formulations aimed at enhancing skin health (He et al., 2024).

Conclusion

This review elucidates that *Carthamus tinctorius* exhibits a robust and varied antioxidant profile, which is substantiated by its polysaccharides, phenolic compounds, flavonoids, and fatty acids. The accumulation of evidence suggests that its bioactive composition is significantly influenced by both genotype and environmental factors, which in turn contribute to its dynamic metabolic responses and augmented antioxidant efficacy. Although the plant demonstrates promising implications for skin protection, oxidative stress modulation, and prospective anti-aging applications, research specifically focused on dermatological contexts remains scant. The cumulative findings underscore the necessity of progressing research towards skin-relevant models, mechanistic pathways, and formulation-centered assessments to fully exploit the phytodermal potential of *Carthamus tinctorius*.

Acknowledgments

The author sincerely thanks the Faculty of Pharmacy, Universitas Muslim Indonesia, for providing research facilities and academic support. Appreciation is also extended to all colleagues whose contributions strengthened this study.

Author Contributions

Conceptualization and writing—original draft, V.H.; review and editing, V.H. and A.R. All authors have read and agreed to the published version of the manuscript.

Funding

This study was supported by the Universitas Muslim Indonesia.

Conflicts of Interest

The authors declare no conflict of interest in the preparation of this article.

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