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Utilization of Tofu Dregs (Okara) as a Source of Isoflavone Raw Material in Skincare Cosmetics: A Systematic Review

Heny Prabowo[1], Liandhajani[2]
Heny.prabowo46@gmail.com
[1,2]Faculty of Pharmacy, University 17 Agustus 1945 Jakarta, Indonesia

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ABSTRACT

Tofu dregs, commonly known as okara, are an abundant by-product of soybean processing that contains valuable bioactive compounds, particularly isoflavones such as genistein and daidzein. Despite their potential, the utilization of okara as a raw material for skincare cosmetics remains relatively underexplored. This study aims to systematically review the potential of okara-derived isoflavones for cosmetic applications, focusing on extraction methods, biological activities, and formulation strategies. A systematic review was conducted following the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines. Literature searches were performed in PubMed, ScienceDirect, Google Scholar, and PubMed Central (PMC) for publications from 2016 to 2026. From 50 initially identified records, 16 primary studies met the inclusion criteria, consisting of four studies directly investigating okara and 12 studies examining soybean-derived materials or isolated isoflavones. The findings indicate that supercritical fluid extraction using carbon dioxide with 10% ethanol as a co-solvent can enhance isoflavone recovery from okara and produce extracts with antioxidant capacity. Direct studies also demonstrate the presence of genistein and daidzein in okara, although its antioxidant activity in the reported DPPH assay was relatively weak. Meanwhile, indirect evidence from soybean extracts and isolated isoflavones suggests potential photoprotective, anti-inflammatory, collagen-stimulating, and skin-hydrating effects. However, these findings cannot be directly generalized to topical okara formulations. Formulation studies indicate that nanostructured lipid carriers, nanoemulsions, and nanoemulsion-based hydrogels may improve isoflavone stability, skin penetration, and dermal retention. Overall, okara represents a promising and sustainable source of cosmetic bioactive ingredients. Nevertheless, further direct research involving standardized okara extracts, topical efficacy, safety, and long-term stability is necessary before their application in commercial skincare products can be established.

Keywords: *Okara; Soybean Waste; Isoflavone; Anti-aging; Antioxidant.*

Introduction

Tofu dregs, or okara, are the major solid by-product generated during the manufacturing of tofu and soy milk. Okara is produced in large quantities in Indonesia but remains underutilized despite its nutritional value (Nurkhoeriyati & Iswaldi, 2019). It retains dietary fiber, protein, and isoflavones, supporting investigation of its valorization as a source of bioactive ingredients (Nile et al., 2020).

Among the bioactive constituents in soybeans, isoflavones represent an important class of polyphenols. Soybean isoflavones occur as glycosides and

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aglycones, including daidzin, genistin, daidzein, and genistein (Sartini et al., 2014). Studies of biotransformed soybean extracts and isolated isoflavones have reported effects relevant to skin care, but these findings should be distinguished from evidence obtained directly from okara (Leite et al., 2023; Tang et al., 2022).

A focused synthesis is needed to distinguish the extraction conditions and bioactivity findings reported for okara from those reported for whole soybean extracts and isolated isoflavones. The objective of this systematic review is to evaluate the utilization of okara-derived isoflavones in skincare cosmetics, distinguish direct from indirect evidence, and discuss formulation strategies for potential cosmetic application.

Methods

This study was designed as a systematic review following the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) methodology. A comprehensive selection, identification, and analysis of scientific journals and articles was conducted, covering topics related to the valorization and utilization of okara, isoflavone extraction methods from okara and soybeans, the benefits and efficacy of isoflavones, and the formulation of isoflavones in cosmetic preparations. The article selection process followed a structured four-stage PRISMA 2020 framework, comprising identification, screening, eligibility, and inclusion, as detailed in Figure 1. Records retrieved from database searches were independently evaluated by two reviewers based on pre-defined criteria, with exclusions recorded at each operational phase.

This method was selected for its ability to generate a comprehensive literature synthesis from prior studies. Article searches were conducted digitally from May to June 2026 using the PubMed, ScienceDirect, Google Scholar, and PubMed Central (PMC) databases. To optimize search results, Boolean operators ("AND", "OR") were applied with the following keywords: ("Okara" OR "Tofu Dregs" OR "Soybean Waste") AND ("Isoflavone" OR "Daidzein" OR "Genistein") AND ("Skin Care" OR "Cosmetics" OR "Anti-aging")

Inclusion Criteria

Articles published between 2016 and 2026; articles available in full-text form; articles written in English or Indonesian; articles discussing the utilization of okara waste, soybean/okara isoflavones, or the use of soybean-derived isoflavones in skin care cosmetics; articles representing primary research conducted in laboratory settings or through direct testing, and not reviews of primary research journals; and articles published in indexed scientific journals with clearly defined research methodologies.

Exclusion Criteria

Articles published before 2016; articles that are partially available (not full-text); non-primary research publications, including editorials, opinion pieces, conference proceedings, narrative reviews, and letters to the editor, articles not relevant to the research topic, articles with unclear research methodologies, articles with incomplete data or those that cannot be scientifically evaluated.

A total of 50 articles were retrieved from the initial search. Following a screening process based on title, abstract, and full-text evaluation in accordance with the PRISMA guidelines, 16 studies meeting the inclusion criteria were selected. Data extracted from each article included the author's name, publication year, study design, sample size, research variables, and main findings. A descriptive analysis was conducted to evaluate the use of isoflavones from okara as a skin care cosmetic ingredient.

Results and Discussion

The initial search identified 50 records from PubMed (n = 12), ScienceDirect (n = 15), Google Scholar (n = 13), and PubMed Central (n = 10). The extraction table presented below summarizes 16 primary studies, comprising four studies directly investigating okara and 12 studies investigating soybean-derived materials or isolated isoflavones. The latter provide indirect evidence relevant to the potential cosmetic applications of okara-derived isoflavones. Evidence from oral supplementation studies is considered separately from topical and laboratory findings because it does not directly establish the efficacy of topical okara formulations.

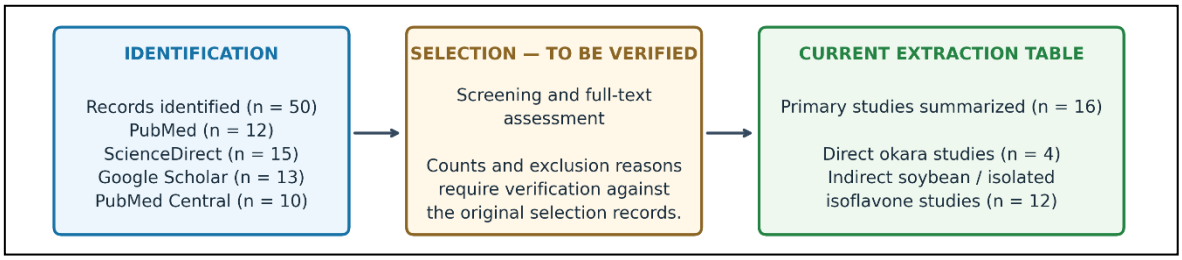


Figure 1. Flow Diagram for Study Selection

The reviewed literature included extraction studies using both soybean seeds and okara. For soybean seeds, a mixed-solvent system of ethanol, water, and propanediol was investigated with ultrasonic-bath assistance. The reported optimized mixture contained 32.8% ethanol, 39.2% water, and 27.8% propanediol (v/v/v) (Bibow et al., 2025). This provides indirect methodological evidence rather than a direct test on okara. In contrast, supercritical fluid extraction was investigated directly in okara using CO2 at 20–40 MPa and 40–80°C, with up to 10%

ethanol as a co-solvent. Ethanol addition enhanced isoflavone extraction (Díaz-de-Cerio et al., 2024).

Genistein and daidzein have been identified in okara (Nile et al., 2020). In the broader soybean literature, genistein has shown photoprotective and anti-inflammatory effects in experimental models (Tang et al., 2022), biotransformed soybean extracts have stimulated type-I collagen production (Bezerra et al., 2022; Leite et al., 2023), and oral soy protein with isoflavones has improved skin hydration in postmenopausal women (Rizzo et al., 2023). These findings support further investigation but do not establish equivalent efficacy for topical okara extracts. Fermentation of black soybean okara has also been studied as a means of producing isoflavones (Lai et al., 2025).

Table 1. Journal Extraction Review

No.	Author, Year	Article Title	Study Design	Research Subject	Main Findings
1	Díaz-de-Cerio et al. (2024)	Isoflavone-rich extracts from okara using supercritical fluid extraction: Kinetic modeling and characterization	In vitro experimental (SFE and kinetic modeling)	Okara (soybean dregs)	SFE efficiently recovered lipid fractions and bioactive compounds from okara. 10% ethanol co-solvent significantly enhanced phenolic and isoflavone extraction. Extracts demonstrated effective antioxidant capacity.
2	Rizzo et al. (2023)	Soy Protein Containing Isoflavones Improves Facial Signs of Photoaging and Skin Hydration in Postmenopausal Women	Prospective randomized double-blind controlled trial	44 postmenopausal women, Fitzpatrick types I–III	Oral soy protein supplementation significantly reduced wrinkle severity and pigmentation over 24 weeks and improved facial skin hydration without affecting sebum production.

3	Wongkarn et al. (2025)	Biochemical Mechanism of Thai Fermented Soybean Extract on UVB-Induced Skin Keratinocyte Damage and Inflammation	In vitro experimental	Human epidermal keratinocytes (HaCaT)	Dichloromethane fraction of Thai fermented soybean extract and its active isoflavones protected skin cells from UVB-induced death by suppressing apoptosis, inflammatory mediators, and intracellular ROS.
4	Setyani et al. (2026)	Effect of topical soy extract cream on TNF-α and VEGF expression in a sub-chronic UVB-induced skin injury model in BALB/c mice	In vivo experimental (post-test-only control group)	30 male BALB/c mice	Topical soy extract cream (10% and 20%) significantly reduced TNF-α expression from UVB exposure and enhanced VEGF expression for angiogenesis-driven skin tissue repair.
5	Leite et al. (2023)	Biotransformed soybean cream as a new nutraceutical for skin care: collagen stimulation in vitro and ex vivo	In vitro and ex vivo experimental	Human dermal fibroblasts and human skin explants	Biotransformed soybean extract enhanced type-I collagen expression at cellular and explant levels. The cream was safe, did not harm natural skin microbiota, and shows high nutricosmetic potential.

6	Tang et al. (2022)	Genistein protects against ultraviolet B-induced wrinkling and photoinflammation in in vitro and in vivo models	In vitro, in vivo, and observational	120 human volunteers, keratinocytes, and mice	Genistein-rich diet improved skin elasticity in humans. In vitro, genistein suppressed UVB-induced pro-inflammatory cytokines. Topical genistein significantly reduced UVB-induced skin wrinkle severity in animals.
7	Anjum et al. (2022)	Comparative nutritional and antimicrobial analysis of Himalayan black and yellow soybean and their okara	In vitro laboratory experimental	Himalayan black and yellow soybeans and their okara	Black soybeans and their okara had significantly higher phytochemical content, antioxidant activity, and antimicrobial properties than yellow soybean varieties.
8	Agustina et al. (2025)	Antioxidant Activity Testing of Okara and Formulation of a Face Scrub Preparation with Okara as Active Ingredient	Laboratory experimental (formulation and antioxidant testing)	Okara extract and topical face scrub preparation	Okara showed weak DPPH antioxidant activity (IC50 477.636 ppm). Face scrub formulations at 2.5%, 5%, and 7.5% were evaluated for physical quality and irritation and met the reported test requirements.
9	Sulistyowati et al. (2019)	Development and validation for free aglycones	Descriptive experime	Soybean seeds from Anjasmoro,	Significant isoflavone differences among varieties. Argomulyo

		daidzein and genistein in soybeans (Glycine max (L.) Merr.) using RP HPLC method	ntal with HPLC	Argomuly o, and Dena 2 varieties	had highest daidzein (29.68 mg/100g);
10	Murdali n et al. (2025)	Potential of Glycine max-Based Cream in Restoring Skin Structure Through PDGF and Collagen Modulation After UVB Exposure	In vivo experime ntal (post-test only control group)	30 male BALB/c mice exposed to UVB	Soy extract cream affected PDGF levels ($p = 0.001$). Collagen density did not differ significantly between groups ($p = 0.088$).
11	Bibow et al. (2025)	An Innovative Approach for Maximum Recovery of Isoflavones from Glycine max by the Design of Experiments Method	Experime ntal using DOE and extraction methods	Soybean seeds (Glycine max)	Three-solvent mixture yielded highest isoflavone extraction. Optimal composition: 32.8% ethanol, 39.2% water, 27.8% propanediol.
12	Bezerra et al. (2022)	Soybean extract modified by Aspergillus awamori stimulates greater collagen-I synthesis in	In vitro cell culture experime ntal	Human dermal fibroblasts (HDFa) and murine fibroblasts (L929)	Biotransformation by A. awamori increased aglycone isoflavones. Extract was safe and significantly enhanced type-I collagen synthesis in human fibroblasts.

		human fibroblasts			
13	Wójciak et al. (2024)	ROS Scavenging Effect of Selected Isoflavones in Provoked Oxidative Stress Conditions	In vitro cell culture experimental	Human skin fibroblasts (BJ) and keratinocytes (HaCaT)	Coumestrol and biochanin A showed strong ROS-scavenging activity. Genistein, daidzein, and glycitein exhibited weaker but present antioxidant activity.
14	Spanou et al. (2023)	Development and characterization of gel-like matrix containing genistein for skin application	Formulation experimental and in vitro permeability testing	Genistein, NLCs, HaCaT cells, porcine ear skin	NLC gel-like matrix protected genistein from UV degradation, showed no toxicity to keratinocytes, and improved dermal genistein retention versus free form.
15	Nile et al. (2020)	Soybean processing waste: Potential antioxidant, cytotoxic and enzyme inhibitory activities	Chemical analysis and in vitro bioactivity testing	Okara and cancer cell lines	Okara is rich in genistein and daidzein; demonstrated antioxidant, anti-inflammatory, enzyme inhibitory, and cytotoxic effects against HeLa and MCF-7 cancer cells.
16	Nemitz et al. (2019)	In vitro skin permeation/retention of daidzein, genistein and glycitein from soybean	Formulation experimental and Franz Diffusion	IAF, nanoemulsions, hydrogels, porcine ear skin	Incorporation of IAF into nanoemulsion and hydrogel systems enhanced penetration and retention of isoflavones across all

		isoflavone-rich nanoemulsions and hydrogels	permeability testing		skin layers, with highest accumulation in the dermis.

Okara valorization may create added value through recovery of bioactive compounds. Nile et al. (2020) reported dietary fiber and crude protein contents of 56 and 33 g/100 g dry matter, respectively. Biotransformation is a separate strategy for modifying the isoflavone profile: Aspergillus awamori-treated soybean extracts showed increased aglycone content and collagen-I deposition in human fibroblasts (Bezerra et al., 2022). These soybean findings should not be interpreted as direct evidence for the same response to okara formulations.

Extraction conditions influence the compounds recovered and should be interpreted in relation to the starting material. The ethanol–water–propanediol method was optimized for soybean seeds (Bibow et al., 2025), whereas supercritical CO2 with ethanol was studied directly in okara and recovered lipid fractions and bioactive compounds (Díaz-de-Cerio et al., 2024). Further comparative work is required before transferring extraction conditions from soybean seeds to okara.

Direct evidence for okara includes antioxidant testing and preliminary topical formulation work. Agustina et al. (2025) reported an IC50 of 477.636 ppm in the DPPH assay, indicating weak antioxidant activity under the tested conditions. Face scrub formulations containing 2.5%, 5%, and 7.5% okara were evaluated for physical characteristics and irritation. These results concern the tested okara material and formulations; they do not isolate the contribution of individual isoflavones.

Anti-inflammatory findings from soybean and isolated isoflavone studies provide indirect support for cosmetic research on okara. In UVB-exposed skin cells, genistein suppressed pro-inflammatory mediators including CXCL1, IL-1, and MIF (Tang et al., 2022). A Thai fermented soybean fraction and its active isoflavones, daidzein and glycitein, reduced inflammatory responses associated with IL-6, IL-8, COX-2, and iNOS (Wongkarn et al., 2025). Topical soy extract cream was also investigated for TNF-α and VEGF responses in a UVB-induced mouse skin injury model (Setyani et al., 2026). These studies did not test topical okara extract.

Additional indirect evidence concerns collagen synthesis and skin hydration. Biotransformed soybean extracts increased collagen-I production in cellular and skin explant models (Bezerra et al., 2022; Leite et al., 2023). In a mouse study, soy extract cream affected PDGF levels, but the difference in collagen density between groups was not statistically significant (Murdalin et al., 2025). In a separate clinical trial, oral soy protein containing isoflavones improved facial skin hydration after 24

weeks (Rizzo et al., 2023). The oral route and non-okara starting materials limit direct extrapolation to topical okara cosmetics.

The greatest challenge in formulating aglycone isoflavones lies in their very low water solubility and susceptibility to photodegradation. Advanced drug delivery systems are essential to ensure formulation stability and precise transdermal penetration. Recommended formulation strategies include Nanostructured Lipid Carriers (NLCs), Nanoemulsions (NE), and Hydrogels (HNE). In NLC-based systems, genistein encapsulated within a gel-like NLC matrix protected the bioactive compound from UV-induced photodegradation, preserved antioxidant capacity, and demonstrated safety in keratinocytes, reducing systemic permeation while selectively enhancing dermal retention (Spanou et al., 2023). Nanoemulsion formulations — liquid or incorporated into hydrogels — are also highly effective against solubility challenges. Liquid nanoemulsions showed the highest isoflavone release and retention profiles (daidzein, glycitein, genistein) in the dermal region compared to hydrogels, offering formulators flexibility in adjusting penetration depth (Nemitz et al., 2019).

Conclusion

Okara shows potential as a sustainable, high-value raw material for skincare cosmetic applications due to its rich content of bioactive isoflavones, particularly genistein and daidzein. However, this systematic review highlights that while strong bioactivities including antioxidant protection, anti-inflammatory actions, type-I collagen stimulation, photoprotection, and skin hydration are widely documented, a substantial portion of the current efficacy evidence is indirect, derived from whole soybean extracts, fermented soy products, or isolated aglycone isoflavones. Direct evidence on okara formulations remains predominantly focused on extraction optimization, basic antioxidant activity, and preliminary physical scrub preparations. To overcome the formulation challenges of aglycone isoflavones, such as poor aqueous solubility and photolability, advanced drug delivery systems including Nanostructured Lipid Carriers (NLCs), Nanoemulsions (NE), and Nanoemulsion-based Hydrogels (HNE) have been investigated for soybean isoflavones and may inform future development of okara formulations; their performance with standardized okara extracts requires direct evaluation.

Recomendation

Future research must prioritize direct in vitro, ex vivo, and clinical evaluation of standardized okara extracts to validate their specific therapeutic efficacy and safety profiles on human skin. Furthermore, comprehensive long-term and accelerated stability studies under commercial packaging conditions are required,

alongside technical and economic feasibility assessments for scaling up extraction and formulation processes from laboratory to industrial manufacturing scales.

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