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MINI REVIEW

Exploring the Phytochemical Potential of *Erythrina* Species: A Review on Extraction Methods and Bioactive Properties

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Erythrina species, are well-known for their abundance of medicinal properties such as antioxidant, anti-inflammatory, antibacterial and anticancer due to their bioactive compounds. This article aims to provide a brief review on the impact of different extraction methods, from traditional techniques (*e.g.* Soxhlet extraction; maceration), to newer and more eco-friendly approaches (*e.g.* ultrasound-assisted extraction (UAE); microwave-assisted extraction (MAE)) on the bioactivities. A review was done using databases such as PubMed, Scopus, Web of Science and Google Scholar, searching for terms like Erythrina genus, extraction method, extraction conditions, phytochemicals and bioactivities. As a result, 5 different extraction methods were found to be the most frequently used for extraction of *Erythrina* species, which are Soxhlet extraction, maceration, decoction, UAE and MAE. It was also showed that UAE and MAE are the most ideal extraction techniques as it improved extraction efficiency, preserve bioactive compounds and increased bioactivity retention. Hence, this mini-review is a discussion on the influence of extraction condition such as extraction temperature and extraction time that may affect the bioactivity of *Erythrina* species from the previous studies.

Keywords: Bioactivity, Extraction condition, Extraction method, *Erythrina*, Phytochemicals.

INTRODUCTION

The *Erythrina* genus, part of the Fabaceae family, encompassing approximately 120 species, is predominantly found in tropical and subtropical regions [1,2]. Renowned for its traditional medicinal applications, it is used to address various ailments. This genus is widely recognized for its ethnopharmacological significance and rich source of bioactive compounds such as alkaloids, flavonoids, terpenoids and pterocarpans, which are known for their diverse biological activities [1,3]. These compounds exhibit remarkable antioxidant, anti-inflammatory, antibacterial and anticancer properties [2,4-6]. *Erythrina* species have also been shown to alleviate inflammatory pain by leveraging their antioxidant effects and modulating inflammatory signaling pathways [2,7]. Although *in vitro* and *in vivo* studies have produced encouraging findings, research involving clinical trials and toxicity evaluations remains scarce [2]. Nevertheless, the lack of documented drug interactions highlights the potential safety of *Erythrina* plants for medicinal purposes [2].

Efficient extraction methods are vital for enhancing the yield of bioactive compounds from plant materials. Advanced techniques such as microwave-assisted, ultrasound-assisted, pressurized liquid-assisted and supercritical fluid extraction are increasingly replacing traditional methods (Soxhlet extraction, decoction extraction and maceration extraction), offering higher efficiency and reduced environmental impact [8]. Response surface methodology (RSM) has become a popular tool for optimizing extraction processes, as it integrates experimental design with empirical modeling to predict and maximize yields [9]. This approach minimizes the number of experiments required to identify optimal extraction conditions [8,9]. The extraction process plays a pivotal role in phytochemical analysis, directly influencing the isolation of bioactive compounds and subsequent analytical steps [10]. Researchers are also investigating eco-friendly alternatives, such as deep eutectic solvents, for bioactive compound extraction [10]. In summary, optimized extraction methods are fundamental for enhancing efficiency and yield in phytochemical studies.

Recent studies underscore an increasing focus on natural products and plant-derived bioactive compounds, driven by their health-promoting properties and eco-friendly characteristics [11,12]. Innovative green extraction methods, such as supercritical fluid extraction and ultrasound-assisted extraction, are being developed to mitigate the environmental impacts of traditional techniques [13]. These approaches offer potential for enhanced selectivity and productivity, though challenges in standardization and scalability remain. Researchers advocate for the interdisciplinary strategies that integrate advanced extraction technologies with high-throughput bioassays and structure elucidation tools [14]. Despite progress, significant gaps persist, including the need for comparative evaluations of extraction methods and deeper insights into structure-bioactivity relationships. Moreover, addressing the bioavailability and bioaccessibility of compounds such as polyphenols is essential, given their promising role in preventing non-communicable diseases [15].

This review aims to provide the extraction conditions used for *Erythrina* species, with a particular focus on their impact on bioactivities. By evaluating the current state of research, the review will highlight optimal extraction parameters, comparison of traditional and advanced methodologies and identify knowledge gaps for future studies. Such insights are critical for harnessing the full potential of *Erythrina* species in developing bioactive-rich products with significant health benefits. This study conducted a review of the extraction conditions of the *Erythrina* genus in relation to its bioactivities. A literature search was performed using PubMed, Scopus, Web of Science and Google Scholar databases. The search process utilized keywords such as *Erythrina* genus, extraction method, extraction conditions, phytochemicals and bioactivities.

This review incorporates reports on the five different extraction methods and conditions of different *Erythrina* species. All the reviewed journals included extraction methods and conditions specifically for *Erythrina* leaves. The results showed that previous studies focusing on the bioactivities such as wound healing, anti-inflammatory and antioxidant properties. Table-1 provides a summary of each extraction methods and conditions that are frequently apply on the extraction of *Erythrina* species and their bioactivity involved.

Although the *Erythrina* genus comprises 120-130 species distributed in tropical and subtropical regions [16,17]. *Erythrina* is usually derived from the Greek word "Eruthros", which means "red" and it depicts crimson species [16]. Different parts of the plant have been used in traditional medicine as nervine sedative, collyrium in ophthalmia, antiasthmatic, antiepileptic, antiseptic and as an astringent [6,16,18]. The extraction of bioactive compounds from *Erythrina* species has been performed using various techniques, ranging from conventional solvent-based extractions to modern, green extraction technologies [19].

Traditional methods such as maceration, Soxhlet extraction and decoction have been widely used due to their simplicity and cost-effectiveness [19,20]. Maceration, one of the oldest extraction techniques, involves soaking plant materials in solvents such as ethanol, methanol or distilled water for extended periods. For instance, maceration of *Erythrina subumbrans* with 96% ethanol at 25-26 ºC for 72 h resulted in flavonoid- and alkaloid-rich extracts that exhibited significant anti-inflammatory properties by inhibiting hemolysis [21]. Despite its widespread use, maceration is time-consuming and requires large amounts of solvents, making it inefficient for large-scale applications.

Another conventional method, Soxhlet extraction, uses heat and continuous solvent cycling to enhance compound recovery. This method was utilized for *E. variegata* Linn., where Soxhlet extraction using 80% ethanol for 8 h effectively extracted flavonoids and alkaloids associated with wound-healing properties. The findings indicate that both 5% and 10% ethanolic leaf extracts exhibit wound-healing activity [16]. However, the requirement for high temperatures in Soxhlet extraction may lead to the degradation of heat-sensitive compounds, reducing their bioactivity [22]. Decoction, another traditional method, is extensively used in ethnobotanical practices, particularly for extracting alkaloids and tannins. Studies on *E. velutina* revealed that decoction produced extracts with significant cytotoxic and genotoxic activity, indicating its effectiveness in extracting potent bioactive compounds. Testing with 10 different concentrations of the aqueous extract (0.125-1.25%) demonstrated root growth inhibition across all concentrations after 96 h of treatment [23]. However, prolonged boiling can degrade volatile compounds, potentially reducing their therapeutic efficacy.

To overcome the limitations of traditional extraction methods, researchers have explored modern green extraction technologies such as ultrasound-assisted extraction (UAE) and microwave assisted extraction (MAE), which offer enhanced efficiency and reduced environmental impact [19,24]. UAE utilizes ultrasonic waves to create cavitation in the solvent, breaking cell walls and facilitating the release of bioactive compounds. This method significantly reduces extraction time while preserving compound integrity [25,26]. Mohanta *et al.* [27] studied that UAE was effectively applied to *E. suberosa*, where 20 min extraction with distilled water yielded flavonoid- and tannin-rich extracts that demonstrated strong antioxidant, anticancer

TABLE-1
TYPES OF EXTRACTION METHOD AND CONDITION OF *Erythrina* GENUS

Extraction method	*Erythrina* species	Extraction condition			Bioactivity	Highlight of results and conclusion	Ref
		Solvent type	Temp.	Time			
Maceration method	*E. subumbrans*	96% ethanol	25-26 ºC	3 × 24 h	Anti-inflammatory	The *in vitro* study confirmed that *E. subumbrans* extract inhibits hemolysis in human red blood cells with an IC_{50} of 75.61 ± 0.366 µg/mL, while the IC_{50} of sodium diclofenac is 49.97 ± 0.001 µg/mL. The *in vivo* study revealed that all doses of ESE and sodium diclofenac significantly reduced edema in rats' paws at 180 min.	[21]
Soxhlet extraction	*E. variegata* Linn.	80% ethanol	Not available	8 h	Wound healing	In acute dermal toxicity test the application of 10% (w/w) ointment formulation the site of application no signs of dermal toxicity were observed in mice. Both 5% and 10% (w/w) ointments significantly reduced period of epithelialization and increased wound contraction rate and tensile strength.	[16]
Decoction method	*E. velutina* Willd.	Distilled water	100 ºC	Not available	Anti-inflammatory	The presence of five different cells abnormalities was recorded: chromosome bridging, lagging chromosomes, chromosome fragments, disturbed metaphase and disturbed anaphase. These results suggest inhibitory and genotoxic activity of the decoction of *E. velutina* on *Allium cepa*.	[23]
Ultrasonic-assisted extraction (UAE)	*E. suberosa*	Distilled water	Not available	20 min	Antimicrobial, anticancer and wound healing	The protocol adopted here for the synthesis of silver nanoparticles can be applied to other metal nanoparticles due to highly oxidized in nature of *E. suberosa* leaf extract and is very likely to be able to reduce metals under different physiological conditions. Moreover, the abundancy and the biomedical applications such as antimicrobial, anticancer and wound healing nature of *E. suberosa* leaf extract mediated AgNPs potentially attracts for the up-scaling of metallic nanomaterials to explore various catalytic as well as biomedical applications.	[27]
Microwave-assisted extraction (MAE)	*E. velutina* Willd.	80% ethanol	40 ºC	Not available	Antioxidant	The leaves of the species presented greater DPPH free radical scavenging capacity. The results obtained indicate that different parts of *E. velutina* have potential photoprotective properties. These can be exploited more fully using processes that lead to an increase in the metabolites responsible.	[30]

and wound healing properties. Compared to the conventional methods, UAE provides higher extraction efficiency with minimal solvent usage, making it a more sustainable approach [28]. Another advanced technique, microwave-assisted extraction (MAE), employs microwave energy to rapidly heat plant materials and solvents, accelerating the extraction process [29]. MAE was successfully utilized for *E. velutina* Willd., where 80% ethanol at 40 ºC resulted in extracts with enhanced DPPH radical scavenging activity, indicating a high antioxidant potential [30]. Unlike Soxhlet extraction, MAE minimizes prolonged heat exposure, reducing the risk of compound degradation while improving overall yield [31]. Both UAE and MAE have been recognized as effective, energy-efficient techniques for extracting heat-sensitive and antioxidant-rich compounds, making them promising alternatives to conventional extraction methods [32].

The efficiency of an extraction method is influenced by several key factors, including solvent type, temperature, extraction time and the target bioactive compounds [33,34]. Studies have demonstrated that ethanol, particularly in concentrations between 80% and 96%, is an effective solvent for extracting flavonoids and alkaloids from the *Erythrina* species [35]. The selection of an appropriate temperature is also critical, as lower temperatures help preserve compound stability, while higher temperatures may enhance yield but risk degradation [36,37]. Future research should focus on the optimizing extraction parameters through comparative studies to establish standardized protocols for different *Erythrina* species. Furthermore, the combination of modern extraction techniques, such as MAE coupled with enzymatic pretreatment or UAE integrated with high-pressure processing, may further enhance efficiency and bioactivity retention. As advancements in extraction technology continue to evolve, the optimization of these methods will be crucial for maximizing the recovery of bioactive compounds from *Erythrina*, ultimately contributing to their potential applications in pharmaceuticals, nutraceuticals and functional foods.

Conclusion

The optimization of extraction conditions plays a crucial role in determining the yield, bioactivity and pharmacological potential of *Erythrina* extracts. While traditional methods like maceration, Soxhlet extraction and decoction remain useful, they exhibit limitations in efficiency and sustainability. Modern techniques such as ultrasound-assisted extraction (UAE) and microwave-assisted extraction (MAE) have demonstrated superior extraction efficiency, shorter processing times and enhanced bioactivity retention, making them ideal alternatives for phytochemical research. However, standardization of extraction protocols, eco-friendly solvent integration and hybrid extraction technologies will be essential for future advancements in the *Erythrin*a based drug discovery and nutraceutical development. By refining extraction methodologies and understanding the structure-bioactivity relationship of its bioactive compounds, *Erythrina* species can be further explored for pharmaceutical, nutraceutical and functional food applications.

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CONFLICT OF INTEREST

The authors declare that there is no conflict of interests regarding the publication of this article.

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