Journal of
Food and Pharmaceutical Sciences

Review Article

Quercetin Isolation Methods from Various Plant Samples by Traditional Extraction Method, Microwave, and Ultrasonic Assisted Extraction Techniques: A Review

I Putu Gede Rama Raditya, Ni Made Pitri Susanti, Luh Putu Mirah Kusuma Dewi*

Departement of Pharmacy, Faculty of Mathematics and Natural Science, Udayana University, Bali, Indonesia
*Corresponding author: Luh Putu Mirah Kusuma Dewi | Email: putumirah@unud.ac.id

Received: 29 April 2025; Revised: 12 July 2025; Accepted: 14 July 2025; Published: 30 September 2025

Abstract: Free radicals are highly reactive atoms with unpaired electrons, produced by factors like radiation, pollution, and poor diet, causing oxidative stress and cell damage. Antioxidants counteract these effects, with natural ones like flavonoids being safer than synthetic types. Quercetin, a flavonoid found in various plants, has strong antioxidant, anti-inflammatory, and anticancer properties due to its hydroxyl groups. This review compiles recent studies on plants containing quercetin, isolation methods, and analytical instruments used in the process. Research was sourced from Google Scholar and PubMed, focusing on Scopus, SINTA, and Google Scholar-indexed journals from 2014-2024. Articles selected were in English or Indonesian, had full-text access, and reported total quercetin content. Quercetin is found in tamarind, basil, guava, and moringa leaves, cabbage, Dutch Eggplant Peel, red beans, propolis, Fenugreek Seeds, *Melastoma sanguineum Sims* fruits, *Flos Sophorae Immaturus*, and mangkokan. Isolation techniques include maceration, Soxhlet, Ultrasound-Assisted Extraction (UAE), Microwave-Assisted Extraction (MAE), and a combination of both (MUAE), with ethanol, acetone, and methanol commonly used as solvents. For quantifying quercetin, instruments like High-Performance Liquid Chromatography (HPLC), UV-Vis Spectrophotometry, and Mass Spectrometry (MS) are employed. Among the reviewed methods, UAE, MAE, and MUAE stand out as the most eco-friendly and efficient for quercetin extraction, making them ideal for sustainable natural product research.

Keywords: Antioxidant; Quercetin; Maceration; Soxhlet; UAE; MAE; MUAE

---

1. INTRODUCTION

Free radicals are molecules, atoms, or groups of atoms that contain one or more unpaired electrons which increases their reactivity [1]. Amin et al. (2013) state that free radicals may arise from complex chemical processes occurring in the body, environmental pollutants, radiation, dangerous chemicals, toxins, and consumption of fast foods or foods deep-fried at high temperatures [2]. Free radicals are capable of damaging cells through destruction of proteins which disrupts enzyme activity as well as harming nucleic acids like DNA, leading to potential cell mutations. This leads to abnormal, uncontrolled growth and development of cells which may ultimately result in cell death [1]. While the human body possesses mechanisms to neutralize free radicals, having insufficient antioxidants or excessive amounts of free radicals produced can cause oxidative stress [3]. Compounds that are able to remove, clean and resist the effects of free radicals are termed as antioxidants. Molecules capable of modulating or deactivating free radical species within the organism are known as antioxidants [4]. The action of antioxidants is to stabilize free radicals by giving electrons which are deficient to free radicals to avert chain reactions that would lead to the generation of more free radicals. In addition, antioxidants are important in ensuring that the oxidation reaction does not proceed further in the body [5].

The human body naturally does not possess antioxidant reserves. Therefore, under conditions of chronic exposure to abundant quantities of free radicals, an external (exogenous) supply of antioxidants is necessary [6]. This demand can be satisfied by ingestion of synthetic antioxidants which are readily available in stores. However, some synthetic antioxidants such as BHA (Butyl Hydroxy Anisol), BHT (Butyl Hydroxy Toluen), PG (Propyl Galate) and TBHQ (Tert-Butyl Hydroquinone) are already known to have carcinogenic properties [6]. Hence, it is advisable to use natural antioxidants. Hidroxyl element bonded with carbon on aromatic ring of flavonoids enable capturing free radicals making it effective as antioxidant. It captures free radicals effectively and donates a single hydrogen atom to stabilize peroxy radicals [7]. Quercetin is a flavonoid with active compounds present in various plants. Quercetin is also effective in treating hyperglycemia as well as serving as an anti-inflammatory, antioxidant, and has anticancer properties. Its phenolic hydroxy group endows it with strong antioxidant properties yielding a high degree of efficiency in combating free radicals [7]. This activity is further enhanced by its conjugated ring system and the presence of multiple hydroxyl groups, particularly at positions 3, 5, 7, 3′, and 4′, which allow for effective electron delocalization and hydrogen atom donation key mechanisms in neutralizing reactive oxygen species [8].

Because of these reasons, quercetin isolation methods from various plants shall be explored. Conducting a literature review will provide elucidate in which plants quercetin is present, the several methods of isolation, and the instruments that are employed in isolating quercetin from numerous plant samples. It is hoped provide a foundation for other researchers for furthering their research on methodologies for quercetin isolation from assorted plant samples.

2. MATERIALS AND METHODS

The review was prepared using the databases Google Scholar and PubMed. The journals utilized are listed in Scopus, Science and Technology Index (SINTA), and Google Scholar. This review incorporated journals published from 2014 to 2024. The two keywords used in searching the journals were quercetin and the isolation technique. Some criteria for inclusion and exclusion were defined for the journal selection process.

Some of the inclusion criteria for the literature search were articles published in either English or Indonesian, as well as articles that reported complete results for total quercetin. The articles which did not have all relevant sections were the exclusion criteria. After analysis, the selected journals were integrated into one summary that provided methods of isolation that could be used along with the relevant detection tools. The selection of journals used in this study was based on the limited number of publications directly listed in the Scopus database, especially those discussing natural compounds such as quercetin. Given that this topic has not been widely published in Scopus journals, a search was conducted of Scopus-indexed journals to ensure their scientific quality, validity, and relevance. Despite these limitations, the selected journals still address relevant topics and are sourced from reliable publications, particularly those focusing on natural compounds commonly used in Asia, such as quercetin. Figure 1 shows the overall process of the study.

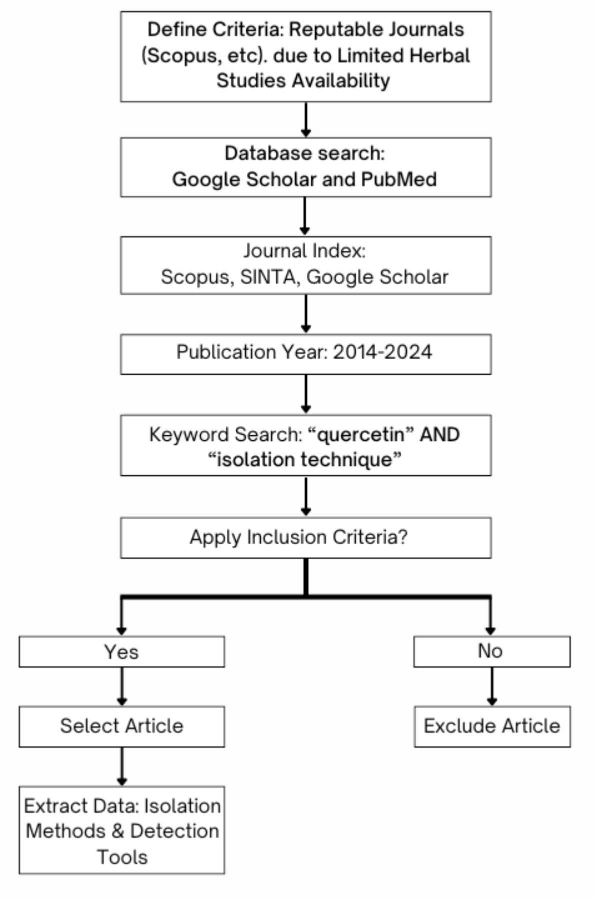

Figure 1. Flowchart of the Literature Review Process

3. RESULTS AND DISCUSSION

Quercetin is a widely utilized flavonoid in traditional and modern medicine that can be easily obtained, since it can be extracted from various parts of many different plants. These include the leaves of tamarind, basil, guava, and moringa, as well as cabbage, Dutch eggplant, red beans, propolis, fenugreek seeds, *Melastoma sanguineum Sims* fruits, *Flos Sophorae Immaturus*, and mangkokan flowers.

From 40 retrieved journals where "quercetin" and "isolation method" were used as keywords, 17 journals met the criteria of containing results regarding quercetin levels. The articles responded to the question of how to isolate quercetin by using a number of methods and solvents, including maceration, soxhlet, UAE (Ultrasonic Assisted Extraction), MAE (Microwave Assisted Extraction), and MUAE (Microwave-Ultrasound Assisted Extraction). A total of 17 articles were reviewed, 6 of them were using the maceration method, 3 applied the soxhlet method, 3 more used UAE, 3 others used MAE, and 2 of them used the MUAE method.

The utilized samples for maceration method were tamarind leaves, basil leaves, and guava leaves. Extraction can be done using solvents like n-hexane or ethanol in varying concentrations as can be seen in table 1 below. A spectrophotometric determination of quercetin content was performed on the extracts of 5 samples with the remaining sample being analyzed on HPLC (High Performance Liquid Chromatography).

Table 1. Results of the Review of the Maceration Method.

Material	Preparation	Instrument	Result	Reference
Tamarind Leaves	Tamarind leaves with n-hexane, stirred for 1 hour, for 3x24 hours. Remacerated with 70% ethanol.	Spectrophotometer UV-Vis with $\lambda = 361.8$ nm.	The 70% ethanol extract contains 24.684 mg/g of quercetin.	[9]
	Tamarind leaves with n-hexane, stirred 1 hour, for 3×24 hours. Remacerated with 96% ethanol.	Spectrophotometer UV-Vis with $\lambda = 361.8$ nm.	The 96% ethanol extract contains 31.26 mg/g of quercetin.	[10]
Basil Leaves	Basil leaves powder with 1500 mL of 96% ethanol, stirred periodically for 3x24 hours. Remaceration with 1200 mL of 96% ethanol. The results were combined with the previous filtrate.	HPLC (Shimadzu DGU-20A5R). C18 column with membrane filter 0.45 µm. Flow rate 1.2 mL/min. The mobile phase consisted of methanol: aqua bidestilata (59:41, v/v). Chromatograms were recorded at $\lambda = 374$ nm.	The 96% ethanol extract contained 0.0158 mg/g quercetin.	[11]
Guava Leaves	Guava leaves powder with 96% ethanol, occasionally stirred for 3x24 hours. Remacerated with fresh 96% ethanol.	Spectrophotometer UV-Vis with $\lambda = 258.0$ nm.	The 96% ethanol extract contained 0.00357 mg/g quercetin.	[12]
	Guava leaves powder with 1 L of 95% ethanol, occasionally stirred the first 6 hours for 24 hours. Remacerated 2x with the same solvent and method.	Spectrophotometer UV-Vis with $\lambda = 425.0$ nm.	The 95% ethanol extract contained 11.73 mg/g quercetin.	[13]
	Guava leaves powder with 500 ml of 96% ethanol, for 3x24 hours with initial stirring using a stirrer for 30 minutes.	Spectrophotometer UV-Vis with $\lambda = 366.0$ nm.	The 96% ethanol extract contains 14.6 mg/g quercetin.	[14]

In these 3 journals listed below, utilized the soxhlet method. The samples used were Dutch Eggplant peel, red bean, and propolis. The extraction process as well as calculation of quercetin concentration from the extracts by using appropriate solvents was done with ethanol in different concentrations, acetone, distilled water, and methanol. Quercetin levels were also calculated by UV-Vis Spectrophotometer and HPLC.

Table 2. Results of the Review of the Soxhlet Extraction Method.

Material	Preparation	Instrument	Result	Reference
Dutch Eggplant Peel	Eggplant peel powder was wrapped and fed into the soxhlet apparatus with 99% ethanol solvent. Temperature ±90°C for 5 hours.	Spectrophotometer UV-Vis with λ = 420 nm.	The quercetin content obtained was 0.0877 mg/g.	[15]
Red Beans	10 g of refined red beans were dissolved with 250 mL of 60 w/w% acetone. Temperature 70° C for 6 hours.	HPLC (Knauer Smartline, Germany). Eurospher II 100-5 C18 column (250 x 20 mm, particle size 5 µm). Flow rate at 1 ml/min at 15°C. The mobile phase consisted of acetonitrile and water (80:20). Chromatograms were recorded at λ = 260 nm.	The quercetin content obtained was 24.6 mg/g.	[16]
Propolis	12 g propolis powder with 300 ml solvent (8:2, 240 ml methanol and 60 ml distilled water). Temperature 60°C for 6 hours.	HPLC (Knauer, Germany). C18 column (250 x 6.4 mm). Flow rate at 0.8 ml/min. The mobile phase consisted of acetonitrile and formic acid-water. Chromatograms were recorded at λ = 270 nm.	The quercetin content obtained was 678.5 mg/g.	[17]

With Ultrasound Assisted Extraction (UAE), extraction of quercetin was done on Fenugreek Seeds, cabbages, and Melastoma sanguineum Sims fruits. This method used a wide range of solvents that included n-hexane, dichloromethane (DCM), MeOH, methanol, water, and ethanol. Level results were obtained by analysis using UHPLC-DAD (Ultra High-Performance Liquid Chromatography with Diode Array Detector), HPLC and LC-MS instruments.

Table 3. Results of the Review of the Ultrasound-Assisted Extraction Method.

Material	Preparation	Instrument	Result	Reference
Fenugreek Seeds	100 mg of seeds were phased with n-hexane, DCM, and MeOH. 200 mL of solvent, sonicated 1 hour using UAE, then macerated 24 hours with continuous stirring.	UHPLC-DAD (Thermo Scientific Vanquish). ThermoFisher Scientific Hypersil GOLD C18 column (150 x 2.1 mm, 1.9 µm particle size) at 40^{o}C. Flow rate at 0.75 mL/min. The mobile phase used involved mobile phase (A) 0.5% formic acid in water; (B) EtOH (75:25) with an isocratic elution. Chromatograms were recorded at λ = 267nm.	The resulting quercetin content was 0.45705 mg/g.	[18]
Cabbages	2 grams of cabbage with 20 mL of solvent (methanol:water, 60:40). For 40 minutes at 30^{o}C. Cooled and centrifuged at 5000 rpm for 10 minutes.	HPLC (Agilent Technologies). C18 Agilent Eclipse Zorbax XDB column (250 x 4.6 mm, particle size 5 µm). Flow rate at 1 mL min-1. The mobile phase for gradient elution were water containing 0.2% TFA in water (A) and 100 % methanol (B). Chromatograms were recorded at λ = 270 nm.	The resulting quercetin content was 1.3789 mg/g.	[19]
	2 grams of cabbage with 20 mL of solvent (methanol:water, 80:20). For 40 minutes at 30^{o}C. Cooled and centrifuged at 5000 rpm for 10 minutes.		The resulting quercetin content was <1.3789 mg/g.	
Melastoma sanguineum Sims fruits	0.2 grams of powder with ethanol. For 34.29 minutes at 60^{o}C. Then centrifuged at 4200 x g for 30 min.	Liquid Chromatography- Tandem Mass Spectrometry (SCIEX). Acquity UPLC® HSS T3 column (100 mm x 2.1, 1.8 µm particle size) (Waters, Milford, MA, USA) at 40^{o}C. Mobile phase consisted: A (0.1% formic acid in water) B (methanol) with gradient method, flow rate at 0.3 mL/min. Injection volume at 2 µL. MS: Negative ESI, temperature 550^{o}C, Multiple Reaction monitoring (MRM) detection mode. Capillary voltage: -4500V.	The resulting quercetin content was 0.00139 mg/g (dry weight (DW)).	[20]

Quercetin can be obtained using Microwave Assisted Extraction (MAE) where Deep Eutectic Solvents (DES), Ionic Liquid (IL), and acetone were used as solvents. The quercetin content in the sample was calculated using HPLC which was performed on the extracted sample which included red bean, *Flos Sophorae Immaturus*, and mangkokan.

Table 4. Results of the Review of the Microwave-Assisted Extraction Method.

Material	Preparation	Instrument	Result	Reference
Red Beans	10 grams of nuts with 60 w/w% acetone in a solvent:simplisia ratio of 10:1. For 1 minute with 800W microwave power. Filtered and dried in the oven for 24 hours at 45°C.	HPLC (Knauer Smartline, Germany). Eurospher II 100-5 C18 column (250 x 20 mm, particle size 5 µm). Flow rate at 1 ml/min at 15°C. The mobile phase of acetonitrile and water (80:20). Chromatograms were recorded at λ = 260 nm.	The resulting quercetin content was 35.8 mg/g.	[16]
	10 grams of nuts with 60 w/w% acetone in a solvent:simplisia ratio of 10:1. For 1 minute with 640W microwave power. Filtered and dried in the oven for 24 hours at 45°C.		The resulting quercetin content was 9.48 mg/g.	
Flos Sophorae Immaturus	2 grams with choline chloride and 1,4-butanediol in a molar ratio of 1:2 with 25% of water into a 100 mL reaction bottle. For 20 minutes minutes with 600W microwave power. Then centrifuged and filtered.	HPLC Agilent 1200 reversed phase, Diamonsil TM C18 column (250 mm × 4.6 mm, 5 µm particle size Dikma, Beijing, China). Flow rate at 0.6 mL/min at 30°C. The mobile phase consisted 0.1% phosphate solution (A) and acetonitrile (B) with gradient method. Chromatograms were recorded at λ = 360 nm.	The resulting quercetin content was 27.59 mg/g.	[21]
Nothopanax scutellarium	1 gram with 1-butyl-3-methylimidazolium tetrafluoroborate combined with sodium chloride (1:10). For 10 minutes, with an IL concentration of 1.5 mol ratio of 10 mL/g with 10W microwave power. Then filtered.	HPLC (Shimadzu). C18 bonded-silica gel column (150 x 4.6 mm, 5 µm particle size) (GL Sciences, Japan). Flow rate at 1 mL/min. Mobile phase consisted of methanol:Aqua Pro Injection:glacial acetic acid (65:34:1). Chromatograms were recorded at λ = 370 nm	The resulting quercetin content was 26.13 mg/g.	[22]

The extraction of quercetin was also carried out using propolis and moringa leaves. Two other articles approached the subject using the Microwave-Ultrasound Assisted Extraction (MUAE) technique. Quantitative extraction of quercetin was performed applying HPLC after the extraction process, in which methanol and ethanol along with water were used for solvent.

Table 5. Results of the Review of the Microwave-Ultrasound Assisted Extraction Method.

Material	**Preparation**	**Instrument**	**Result**	**Reference**
Propolis	1 gram propolis powder with 10 mL of solvent (80:20, methanol:water). Microwave at 300W for 1.5 minutes. Continue with ultrasonics for 10 minutes at 40°C.	HPLC (Knauer, Germany). C18 column (250 x 6.4 mm). Flow rate at 0.8 ml/min. The mobile phase consisted of acetonitrile and formic acid-water. Chromatograms were recorded at λ = 270 nm.	The resulting quercetin content was 445.3 mg/g.	[17]
	1 gram propolis powder with 10 mL of solvent (80:20, methanol:water). Microwave at 300W for 2.5 minutes. Continue with ultrasonics for 10 minutes at 40°C.		The resulting quercetin content was 57.1 mg/g.	
	1 gram propolis powder with 10 mL of solvent (80:20, methanol:water). Microwave at 100W for 1.5 minutes. Continue with ultrasonics for 10 minutes at 40°C.		The resulting quercetin content was 151 mg/g.	
	1 gram propolis powder with 10 mL of solvent (80:20, methanol:water). Microwave at 300W for 1.5 minutes. Continue with ultrasonics for 10 minutes at 70°C.		The resulting quercetin content was 133.4 mg/g.	

From available literature, 17 scientific articles published were available using various methods such as maceration, soxhlet, Ultrasonic Assisted Extraction (UAE), Microwave Assisted Extraction (MAE), and Microwave-Ultrasound Assisted Extraction (MUAE).

3.1. Maceration

Maceration is a process for obtaining specific compounds from a mixture or a solid by soaking the material in an appropriate solvent [23]. Crushed samples are placed in an organic solvent for a predetermined amount of time [24]. Because this method does not involve heating, it preserves the integrity of natural materials, making it cost-effective and simple [24]. Plant sample soaking disrupts cells due to pressure differentials, and the cytoplasmic secondary metabolites move into the organic solvent. Their efficiency improves with lengthened soaking periods [24][25]. During maceration, different ethanol concentrations (60%, 70%, 80%, and 90%) have the potential to affect quercetin concentration in the extract [15]. Greater amounts of quercetin are obtained from higher concentrations of ethanol [9]. Compounds from tamarind, basil, and guava leaves can be extracted using the maceration method with solvents such as ethanol and n-hexane [26]. As shown in Table 1, the quercetin concentration in the extract of tamarind leaves was lower with 70% ethanol than with 96% ethanol, which was 31.26 mg/g [10]. This difference occurs due to the higher water composition in 70% ethanol compared to 96% ethanol. Quercetin is a polar flavonoid with low solubility in water but higher solubility in alcohol and organic solvents [27]. Therefore, quercetin extraction is maximized with higher ethanol concentration due to less water content in the solvent [10]. Additionally, the efficiency of quercetin extraction is influenced by the dielectric constant of the solvent [28]. Solvents with lower dielectric constants, such as high-concentration ethanol, are less polar and better suited for dissolving moderately polar compounds like quercetin. As the ethanol concentration increases, the solvent becomes less polar, enhancing quercetin's solubility and facilitating more efficient extraction during maceration [29].

3.2. Soxhlet

The Soxhlet method involves a fresh solvent extraction process which requires specialized machinery through which systematic extraction with a particular volume of solvent can be carried out under rotary cooling [30]. The Soxhlet method is useful when samples are sensitive to direct heating [31]. Quercetin is not highly resistant to heat, it undergoes significant degradation when heated, especially under weakly basic and oxidative conditions [32]. The study conducted by Buchner *et al.*, 2006, shows that quercetin's concentration decreases markedly during thermal treatment, with complete degradation observed after around 240 minutes under certain conditions [33]. Additionally, heat reduces it's antioxidant activity, indicating that quercetin is sensitive to thermal processing. However, it does produce some stable degradation products with residual antioxidant activity, such as protocatechuic acid, suggesting that while it is thermally labile, some activity-related compounds can persist after heating [33]. Soxhlet technique is applicable to propolis, red beans and Dutch eggplant peel. With an extraction time of 5-6 hours and the optimal temperature range is 60-90°C. Higher temperatures during the extraction increase the efficacy by allowing better solvent access to the pores of the plant material, thus enhancing mass transfer [34]. Extraction time significantly impacts the results in Soxhlet extraction. Longer extraction periods seem to favor higher yield results as is evident in Table 2. For example, quercetin content was measured at 24.6 mg/g when red beans were extracted for 6 hours [16]. The increase in extraction time allows the maximum exposure of the solvent to the raw material, which leads to better solvent access to the cells and enhanced compound removal [35].

3.3. Ultrasonic Assisted Extraction (UAE)

UAE is recognized as an eco-friendly extraction technique for bioactive compounds, as it avoids toxic chemical solvents and additives, employs non-toxic natural components, and offers a sustainable extraction approach [36]. When ultrasonic waves travel through a matrix, they generate alternating compression and rarefaction waves, which can propagate through solid, liquid, or gaseous phases, displacing molecules from their original positions [36]. UAE commonly utilizes solvent blends like methanol-water or ethanol-water to extract compounds from plants such as Fenugreek Seeds, cabbage, and Melastoma sanguineum Sims fruits. The analysis is performed using HPLC and Liquid Chromatography-Tandem Mass Spectrometry. The HPLC system typically employs a C18 column with mobile phases such as 0.5% formic acid in water, ethanol, water containing 0.2% trifluoroacetic acid (TFA), and pure methanol. In UAE, extraction efficiency is influenced by time and the liquid-solid ratio increasing the ratio leads to a rapid rise in yield [37]. However, a drawback of UAE is the potential degradation of active compounds due to ultrasonic waves [38]. The degradation reaction of flavonoids was significantly influenced by the kind of solvent and the temperature applied [39]. Meanwhile, variables like the height of the liquid, the duration of pulses, and the duty cycle influenced how fast the degradation occurred, but did not alter the reaction's characteristics. As the temperature rise, the rate at which quercetin degraded declined [40]. As shown in Table 3, varying the solvent concentration for quercetin extraction from cabbage affects the quercetin levels in the extract. A methanol:water (60:40) solvent yielded the highest quercetin content at 1378.9 µg/mL [19], indicating that 60% methanol effectively penetrates the cabbage cell wall and maximizes quercetin dissolution. In a study conducted by Kumar, 2014, also found that using 60% ethanol for 60 minutes produced lower quercetin levels compared to a 40 minutes extraction, with the latter yielding 1378.9 µg/mL (Table 2) [19]. Prolonging sonication time did not increase quercetin content instead, it negatively impacted extraction by degrading quercetin into 3,4-dihydroxyphenyl acetic acid and subsequently 3-hydroxyphenylacetic acid. This breakdown mechanism may reduce quercetin's bioactivity [19].

3.4. Microwave Assisted Extraction (MAE)

MAE is a technique that uses microwaves to rapidly and efficiently heat solvents, enabling faster selective extraction [41]. Research indicates that MAE improves the efficiency and effectiveness of extracting active compounds from various spices, herbs, and fruits [41]. This method offers benefits such as shorter extraction times, reduced solvent usage, and a high extraction yield, with results comparable to traditional methods like maceration and soxhlet [42]. However, microwave irradiation has the potential to speed up chemical reactions or transformations of certain desired secondary metabolites, and additional factors involved in microwave-assisted extraction such as elevated extraction pressure can alter the chemical composition of the targeted substances [43]. These effects may lead to a decrease in extraction yield. In addition, the efficiency of microwave extraction may be significantly reduced if the target compounds or solvents are nonpolar, or if the solvent has very high viscosity [44]. When performing MAE, several extraction conditions must be optimized, as they influence how microwaves interact with the material [45]. Key factors include the solvent system, solvent-to-material ratio, microwave power, temperature, irradiation time, contact surface area, and stirring [21]. The extraction solvent and it's concentration must possess a specific polarity to efficiently absorb microwaves for heating. The solvent selection should depend on the solubility of the flavonoids [46]. For instance, ethyl acetate is preferred for highly alkylated flavonoids, whereas more polar flavonoids (e.g., those with hydroxyl groups or sugars) are typically extracted using polar solvents like water, ethanol, or acetone [21][47]. In the MAE extraction method, red beans, Flos Sophorae Immaturus, and Nothopanax scutellarium were analyzed using HPLC. Quercetin was extracted from red beans using 60% acetone, yielding an extract with 35.8 mg/g of quercetin (Table 4). These findings demonstrate that acetone (polarity index: 5.1) is an appropriate solvent since quercetin, being a polar flavonoid dissolves well in polar solvents. Generally, higher microwave power improves flavonoid extraction yield. This occurs because the system absorbs more microwave energy at greater power levels, leading to more thorough cell rupture and the full release of flavonoids [16][21]. As shown in Table 4, red bean quercetin extracted at 800W yields a higher concentration (35.8 mg/g) compared to 640W. However, exceeding an optimal power level reduces extraction efficiency [17][48]. The decline is attributed to quercetin degradation and solvent loss caused by excessive heat and power [17].

3.5. Microwave-Ultrasound Assisted Extraction

MUAE is a method that employs both microwave and ultrasonic waves to enhance the transfer of compounds from solid materials into solvents [49]. The underlying concept of MUAE is that the synergistic effect of microwaves and ultrasonic waves can boost both the extraction efficiency and the final yield. In this method, propolis is processed using HPLC with a C18 column for analysis. Key factors such as microwave power, extraction duration, and ultrasonic temperature greatly influence the extraction outcome. According to Heidari et al. (2019), as illustrated in Table 5, applying 300W microwave power yielded an extract with 44.53% quercetin, which was higher than the results obtained at 100W [17]. However, exceeding 300W led to a reduction in quercetin content, likely due to structural degradation of quercetin and solvent evaporation under high temperatures and power [17]. Another critical factor is the microwave exposure time. As seen in Table 5, extending the microwave time to 2.5 minutes resulted in lower quercetin content (5.71%) compared to 1.5 minutes. Prolonged extraction time appears to degrade quercetin and reduce the solid-to-solvent ratio, leading to diminished extraction efficiency [17]. The temperature during ultrasonication can also affect extraction outcomes. Higher ultrasonic temperatures result in lower extraction yields. For instance, Table 5 shows that a temperature of 70°C produces a quercetin content of 13.34%, which is lower than that obtained at 40°C. This decrease may be attributed to the diminished sonochemical effect of bubble formation near the solvent's boiling point. At this stage, the bubbles fail to produce sufficient shear force to break down the cell structure [17][50]. From the explanation of the 5 quercetin extraction methods presented earlier, we can determine the assessment parameters of each method. For the maceration method, key parameters are solvent concentration, soaking duration, and stirring, with higher ethanol concentration increasing quercetin yield. In the soxhlet method, temperature, solvent type, and extraction time are crucial, with longer times and higher temperatures improving yield. For UAE, solvent concentration, sonication time, and temperature are important, with optimal conditions directly affecting yield. In MAE, microwave power, solvent-to-sample ratio, extraction time, and temperature influence yield, though excessive power may degrade quercetin at very high power. Lastly, for MUAE, microwave power, ultrasound duration, temperature, and solvent concentration are critical, with high power and optimized ultrasound time yielding the best results.

4. CONCLUSION

Quercetin is a flavonoid present in a wide range of plant samples, including fruits (e.g., apples, berries), vegetables (e.g., onions, tomatoes, cabbages), seeds, leaves, and medicinal plants like Ginkgo biloba and *Hypericum perforatum*. It's widespread occurrence in common plants makes it easily accessible from natural sources. Several methods can be utilized for the isolation of quercetin from these plant materials. Maceration, Soxhlet extraction, Ultrasonic Assisted Extraction (UAE), Microwave Assisted Extraction (MAE), and Microwave-Ultrasound Assisted Extraction (MUAE) method can be used for the extraction of quercetin. To detect and quantify quercetin levels, analytical instruments such as High Performance Liquid Chromatography (HPLC), Spectrophotometry, and Mass Spectrometry are commonly used. Together, these methods and instruments enable effective extraction and precise quantification of quercetin from various plant samples.

The review systematically compares traditional methods (maceration, soxhlet) with modern techniques (UAE, MAE, MUAE), offering insights into their effectiveness in quercetin extraction. This helps researchers choose the most suitable method based on their specific needs, such as yield, time, or solvent usage. It also underscores the drawbacks of certain methods, such as the high solvent consumption in Soxhlet extraction or the potential for compound degradation in UAE due to prolonged sonication. It also highlights greener alternatives like UAE and MAE, which reduce solvent use and energy consumption. Among the reviewed methods, UAE, MAE, and MUAE emerge as the most environmentally responsible and technically efficient for quercetin extraction, ideal for those aiming to implement sustainable practices in natural product research.

Funding: This research received no external funding.

Acknowledgments: The authors would like to thank all those who have helped write this review article.

Conflicts of interest: There is no conflict of interest in this article. This article is written independently without affiliation with other parties.

References

[1] T. M. Fauzi, “Peran Antioksidan Vitamin C Pada Keadaan Stres Oksidatif Dan Hubungan Dengan Kadar Malondialdehid (MDA) Di Dalam Tubuh,” *Maj. Ilm. Methoda*, vol. 8, no. 2, pp. 61–67, 2018.

[2] M. H. Amin, I. B. Pidada, and C. S. Utami, “Imunotoksisitas pewarna makanan terhadap histopatologi Peyer’s patch goblet mencit (The immunotoxicity of food additive on histopatology of mice Peyer’s patch goblet),” *J. Bios Logos*, vol. 3, no. 1, 2013, doi: 10.35799/jbl.3.1.2013.14504.

[3] M. Anisa, L. Hardia, and A. B. Budiyanto, “Literature Review : Aktivitas Antioksidan Ekstrak Tongkol Jagung (Zea mays L.),” *JIKES J. Ilmu Kesehat.*, vol. 2, no. 1, pp. 1–13, 2023, doi: 10.71456/jik.v2i1.601.

[4] A. . Pratiwi, Yusran, Islawati, and Artati, “Analisis Kadar Antioksidan pada Ekstrak Daun Binahong Hijau Anredera cordifolia (Ten.) Steenis,” *Bioma J. Biol. Makassar*, vol. 8, no. August 2022, pp. 66–74, 2023, [Online]. Available: https://journal.unhas.ac.id/index.php/bioma

[5] A. Adawiah, D. Sukandar, and A. Muawanah, “Aktivitas Antioksidan dan Kandungan Komponen Bioaktif Sari Buah Namnam,” *J. Kim. Val.*, vol. 1, no. November, pp. 130–136, 2015, doi: 10.15408/jkv.v0i0.3155.

[6] S. Rahayu, N. Kurniasih, and V. Amalia, “Ekstraksi dan Identifikasi Senyawa Flavonoid dari Limbah Kulit Bawang Merah sebagai Antioksidan Alami,” *al-Kimiya*, vol. 2, no. 1, pp. 1–8, 2015, doi: 10.15575/ak.v2i1.345.

[7] J. Farah, “Ekstrak Etil Asetat Daun Jambu Biji Merah (Psidium Guajava L.) Sebagai Antioksidan Secara in Vitro,” *JFL J. Farm. Lampung*, vol. 8, no. 2, pp. 78–86, 1970, doi: 10.37090/jfl.v8i2.143.

[8] W. Cai, Y. Chen, L. Xie, H. Zhang, and C. Hou, “Characterization and density functional theory study of the antioxidant activity of quercetin and its sugar-containing analogues,” *Eur. Food Res. Technol.*, vol. 238, no. 1, pp. 121–128, 2014, doi: 10.1007/s00217-013-2091-x.

[9] E. Yunita and Z. Khodijah, “Pengaruh Konsentrasi Pelarut Etanol saat Maserasi terhadap Kadar Kuersetin Ekstrak Daun Asam Jawa (Tamarindus indica L.) secara Spektrofotometri UV-Vis Effect of the Different Ethanol Concentration during Maceration on Quercetin Level of Tamarind (Tamarin,” *Pharm.*

J. Indones., vol. 17, no. 02, pp. 273–280, 2020, [Online]. Available: https://jurnalnasional.ump.ac.id/index.php/PHARMACY/article/view/6841

[10] E. Yunita, S. Fatimah, D. Yulianto, V. Trikuncahyo, and Z. Khodijah, “POTENSI DAUN ASAM JAWA (Tamarindus indica L.) SEBAGAI ALTERNATIF ANTIINFLAMASI: STUDI IN SILICO,” *J. Kefarmasian Akfarindo*, vol. 4, no. 2, pp. 42–50, 2019, doi: 10.37089/jofar.v0i0.68.

[11] E. Kurniawati, T. P. Lestari, and K. K. Pertiwi, “VALIDASI METODE ANALISIS KUERSETIN DARI EKSTRAK ETANOL DAUN KEMANGI (Ocimum sanctum L) SECARA SPEKTROFOTOMETRI UV-Vis,” *J. Ilm. Manuntung*, vol. 10, no. 1, pp. 72–81, 2024, doi: 10.51352/jim.v10i1.780.

[12] T. K. Wardani, Ahwan, and F. Qonitah, “Penetapan Kadar Kuersetin Ekstrak Etanol Pada Daun Jambu Biji (Psidium Guajava L) Dengan Metode Spektrofotometri Uv-Vis Dan Profil Kromatografi Lapis Tipis,” *JFST J. Sains dan Kesehat.* , vol. 02, no. 01, pp. 13–23, 2024, [Online]. Available: https://jurnalkes.com/index.php/jfst/index

[13] Z. Zulharmitta, U. Kasypiah, and H. Rivai, “Pembuatan Dan Karakterisasi Ekstrak Kering Daun Jambu Biji (Psidium guajava L.),” *J. Farm. Higea*, vol. 4, no. 2, pp. 147–157, 2017, [Online]. Available: https://jurnalfarmasihigea.org/index.php/higea/article/view/70

[14] B. Ihsan, P. Rahmani, and A. Shalas, “Validation Method of a TLC-Densitometry for Determination of Quercetin in Extract and Herbal Products of Leaves Guava (Psidium guajava L.),” *Pharm. J. Indones.*, vol. 5, no. 1, pp. 45–51, 2019.

[15] Siswarni MZ, Yusrina Ika Putri, and Rizka Rinda P, “EKSTRAKSI KUERSETIN DARI KULIT TERONG BELANDA (Solanum betaceum Cav.) MENGGUNAKAN PELARUT ETANOL DENGAN METODE MASERASI DAN SOKLETASI,” *J. Tek. Kim. USU*, vol. 6, no. 1, pp. 36–42, 2017, doi: 10.32734/jtk.v6i1.1563.

[16] S. Aghajanian, S. Kazemi, S. Esmaeili, S. Aghajanian, and A. A. Moghadamnia, “Sequential microwave-assisted extraction for isolation of quercetin from red kidney bean,” *Int. J. Eng. Trans. A Basics*, vol. 33, no. 1, pp. 12–17, 2020, doi: 10.5829/ije.2020.33.01a.02.

[17] G. Heidari, G. D. Najafpour, M. Mohammadi, and A. A. Moghadamnia, “Microwave ultrasound assisted extraction: Determination of quercetin for antibacterial and antioxidant activities of Iranian propolis,” *Int. J. Eng. Trans. B Appl.*, vol. 32, no. 8, pp. 1057–1064, 2019, doi: 10.5829/ije.2019.32.08b.01.

[18] R. Ahmad *et al.*, “Ultrasonic-assisted extraction of fenugreek flavonoids and its geographical-based comparative evaluation using green UHPLC-DAD analysis,” *Ultrason. Sonochem.*, vol. 95, no. January, p. 106382, 2023, doi: 10.1016/j.ultsonch.2023.106382.

[19] B. Kumar *et al.*, “Ultrasound Assisted Extraction of Quercetin From Cabbage,” *Int. J. Pharm. Sci. Res.*, vol. 5, no. 9, pp. 3779–3783, 2014, doi: 10.13040/IJPSR.0975-8232.5(9).3779-83.

[20] T. Zhou *et al.*, “Ultrasound-assisted extraction and identification of natural antioxidants from the fruit of Melastoma sanguineum Sims,” *Molecules*, vol. 22, no. 2, pp. 1–15, 2017, doi: 10.3390/molecules22020306.

[21] G. Wang *et al.*, “Efficient extraction of flavonoids from Flos Sophorae Immaturus by tailored and sustainable deep eutectic solvent as green extraction media,” *J. Pharm. Biomed. Anal.*, vol. 170, pp. 285–294, 2019, doi: 10.1016/j.jpba.2018.12.032.

[22] I. A. Rahmi, M. Jufri, and A. Mun’im, “Extraction of quercetin from nothopanax scutellarium leaves via ionic liquid-based microwave-assisted extraction,” *Pharmacogn. J.*, vol. 12, no. 6, pp. 1512–1517, 2020, doi: 10.5530/pj.2020.12.207.

[23] N. Ecem-Bayram and Y. C. Gercek, “Appropriate maceration duration for the extraction of propolis,”

Fresenius Environ. Bull., vol. 28, no. 1, pp. 188–192, 2019.

[24] A. Yulianingtyas, "OPTIMASI VOLUME PELARUT DAN WAKTU MASERASI PENGAMBILAN FLAVONOID DAUN BELIMBING WULUH (AVERRHOA BILIMBI L.)," *Ann. Emerg. Med.*, vol. 63, no. 4, pp. 477–478, 2014, doi: 10.1016/j.annemergmed.2013.08.024.

[25] H. Nurhasnawati, S. Sukarmi, and F. Handayani, "PERBANDINGAN METODE EKSTRAKSI MASERASI DAN SOKLETASI TERHADAP AKTIVITAS ANTIOKSIDAN EKSTRAK ETANOL DAUN JAMBU BOL (Syzygium malaccense L.)," *J. Ilm. Manuntung*, vol. 3, no. 1, pp. 91–95, 2017, doi: 10.51352/jim.v3i1.96.

[26] A. C. Nnamudi, V. O. Onyeche, O. Ebohon, and I. N. E.- Ogaranya, "Nigerian Medicinal Plants for the Management of Liver Diseases: A Review," *European J. Med. Plants*, vol. 31, no. 12, pp. 29–51, 2020, doi: 10.9734/ejmp/2020/v31i1230302.

[27] S. Sukmawati, H. Widiastuti, and M. Miftahuljanna, "ANALISIS KADAR KUERSETIN PADA EKSTRAK ETANOL DAUN MIANA (Plectranthus scutellarioides (L.) R.Br.) SECARA HPLC (High Performance Liquid Chromatography)," *J. Ilm. As-Syifaa*, vol. 11, no. 1, pp. 38–44, 2019, doi: 10.33096/jifa.v11i1.462.

[28] H. A. H. Abd-Elsalam, M. Gamal, I. A. Naguib, M. A. Al-Ghobashy, H. E. Zaazaa, and M. Abdelkawy, "Development of green and efficient extraction methods of quercetin from red onion scales wastes using factorial design for method optimization: A comparative study," *Separations*, vol. 8, no. 9, 2021, doi: 10.3390/separations8090137.

[29] J. Ahamad, S. Amin, and S. R. Mir, "Optimization of ultrasound-assisted extraction of charantin from Momordica charantia fruits using response surface methodology," *J. Pharm. Bioallied Sci.*, vol. 7, no. 4, pp. 304–307, 2015, doi: 10.4103/0975-7406.168032.

[30] O. R. Alara, N. H. Abdurahman, and C. I. Ukaegbu, "Soxhlet extraction of phenolic compounds from Vernonia cinerea leaves and its antioxidant activity," *J. Appl. Res. Med. Aromat. Plants*, vol. 11, no. June, pp. 12–17, 2018, doi: 10.1016/j.jarmap.2018.07.003.

[31] S. Idawati, A. Hakim, and Y. Andayani, "Pengaruh Metode Isolasi a-mangostin dari Kulit Buah Manggis (Garcinia mangostana L.) terhadap Rendemen α-mangostin," *J. Penelit. Pendidik. IPA*, vol. 5, no. 2, pp. 144–148, 2019, doi: 10.29303/jppipa.v5i2.167.

[32] H. Chaaban *et al.*, "Effect of heat processing on thermal stability and antioxidant activity of six flavonoids," *J. Food Process. Preserv.*, vol. 41, no. 5, pp. 1–12, 2017, doi: 10.1111/jfpp.13203.

[33] N. Buchner, A. Krumbein, S. Rohn, and L. W. Kroh, "Effect of thermal processing on the flavonols rutin and quercetin," *Rapid Commun. Mass Spectrom.*, vol. 24, pp. 1457–1466, 2010, doi: 10.1002/rcm.

[34] F. Satrianegara *et al.*, "The Effect of Various Extraction Methods and Solvents on the Phytochemical Contents and Antioxidant Capacities of Safflower Florets (Carthamus Tinctorius L.) from South Sulawesi," *Trends Sci.*, vol. 21, no. 7, 2024, doi: 10.48048/tis.2024.7576.

[35] D. R. Wijaya, M. Paramitha, and N. P. Putri, "C. Kata kunci: Oleoresin, jahe, ekstraksi, soklet," *J. Konversi*, vol. 8, no. 1, pp. 9–16, 2019.

[36] P. Das, P. K. Nayak, and R. krishnan Kesavan, "Ultrasound assisted extraction of food colorants: Principle, mechanism, extraction technique and applications: A review on recent progress," *Food Chem. Adv.*, vol. 1, no. July, p. 100144, 2022, doi: 10.1016/j.focha.2022.100144.

[37] A. Pandey, T. Belwal, K. C. Sekar, I. D. Bhatt, and R. S. Rawal, "Optimization of ultrasonic-assisted extraction (UAE) of phenolics and antioxidant compounds from rhizomes of Rheum moorcroftianum using response surface methodology (RSM)," *Ind. Crops Prod.*, vol. 119, no. April, pp. 218–225, 2018, doi:

10.1016/j.indcrop.2018.04.019.

[38] M. F. Manzoor *et al.*, "Novel extraction, rapid assessment and bioavailability improvement of quercetin: A review," *Ultrason. Sonochem.*, vol. 78, p. 105686, 2021, doi: 10.1016/j.ultsonch.2021.105686.

[39] A. Antony and M. Farid, "Efecto de las temperaturas sobre los polifenoles durante la extracción," *Appl. Sci.*, vol. 12, no. 4, 2022, [Online]. Available: https://www.mdpi.com/2076-3417/12/4/2107

[40] L. Qiao *et al.*, "Sonochemical effects on 14 flavonoids common in citrus: Relation to stability," *PLoS One*, vol. 9, no. 2, pp. 1–10, 2014, doi: 10.1371/journal.pone.0087766.

[41] R. Farida and F. C. Nisa, "Ekstraksi Antosianin Limbah Kulit Manggis Metode Microwave Assisted Extraction (Lama Ekstraksi dan Rasio Bahan : Pelarut)," *J. Pangan dan Agroindustri*, vol. 3, no. 2, pp. 362–373, 2015.

[42] S. Enggiwanto, F. Istiqomah, K. Daniati, and O. Roanisca, "Ekstraksi Mae Daun Pelawan," vol. 1, no. 2, pp. 50–55, 2018.

[43] N. Flórez, E. Conde, and H. Domínguez, "Microwave assisted water extraction of plant compounds," *J. Chem. Technol. Biotechnol.*, vol. 90, no. 4, pp. 590–607, 2015, doi: 10.1002/jctb.4519.

[44] H. F. Zhang, X. H. Yang, and Y. Wang, "Microwave assisted extraction of secondary metabolites from plants: Current status and future directions," *Trends Food Sci. Technol.*, vol. 22, no. 12, pp. 672–688, 2011, doi: 10.1016/j.tifs.2011.07.003.

[45] K. Tanruean, S. Luangkamin, T. Srisurat, W. Bunmusik, and P. Suttiarporn, "Optimization of Microwave-Assisted Extraction Process for Production of Polyphenol-Rich Crude Extract from Cinnamomum iners Leaves," *Appl. Sci.*, vol. 15, no. 3, pp. 1–18, 2025, doi: 10.3390/app15031265.

[46] M. Tzanova, V. Atanasov, Z. Yaneva, D. Ivanova, and T. Dinev, "Selectivity of current extraction techniques for flavonoids from plant materials," *Processes*, vol. 8, no. 10, pp. 1–30, 2020, doi: 10.3390/pr8101222.

[47] M. C. Dias, D. C. G. A. Pinto, and A. M. S. Silva, "Plant flavonoids: Chemical characteristics and biological activity," *Molecules*, vol. 26, no. 17, pp. 1–16, 2021, doi: 10.3390/molecules26175377.

[48] Z. Rusli, B. L. Sari, N. F. Utami, and S. Sabila, "Optimization Of Microwave-Assisted Extraction Of Flavonoids From Binahong (Anredera cordifolia) Leaves Using Respon Surface Methodology," *J. Fitofarmaka Indones.*, vol. 7, no. 3, pp. 10–19, 2020, doi: 10.33096/jffi.v7i3.596.

[49] S. K. Chew, W. H. Teoh, S. L. Hong, and R. Yusoff, "Rutin extraction from female Carica papaya Linn. using ultrasound and microwave-assisted extractive methods: Optimization and extraction efficiencies," *Heliyon*, vol. 9, no. 10, p. e20260, 2023, doi: 10.1016/j.heliyon.2023.e20260.

[50] F. Chemat *et al.*, "Review of Green Food Processing techniques. Preservation, transformation, and extraction," *Innov. Food Sci. Emerg. Technol.*, vol. 41, no. November 2016, pp. 357–377, 2017, doi: 10.1016/j.ifset.2017.04.016.