Systematic Review Of Extraction Techniques And Environmental Future Prospects For The *Commiphora gileadensis* Medicinal Plant

Aiman A. Bin Mokaizh[1*], Abdurahman Hamid Nour[1,2*], Rosli Mohd Yunus[1], and Ahmed A. M. Elnour[2]

[1] *Faculty of Chemical and Process Engineering Technology, Universiti Malaysia Pahang Al-Sultan Abdullah, 26300 Gambang, Pahang, Malaysia*

[2] *Centre of Excellence for Advanced Research in Fluid Flow (CARIFF), Universiti Malaysia Pahang Al-Sultan Abdullah (UMPSA), 26300, Pahang, Malaysia*

[*] *Corresponding author. E-mail: ay.stmy@gmail.com; abrahman@umpsa.edu.my*

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Commiphora gileadensis is a significant medicinal plant with various therapeutic uses. The plant's phytoconstituents possess antioxidant, antibacterial, cytotoxic, anticancer, and antiviral properties, which recently attracted research interest. The objectives are as follows: (i) this study serves as the first Systematic Literature Review (SLR) on *C. gileadensis* that identified the used extraction methods to extract the bioactive components of *C. gileadensis*; (ii) outlined the literature study gap and stated the future trends' recommendations. The existing literature on *C. gileadensis* was searched on Scopus, PubMed, and Web of Science. This PRISMA-style article searches covered articles published between 2010 to 2022. The search was conducted using common terms like "*Commiphora gileadensis*," "*Balm of Gilead*," "*Balm of Judea*," "*Apharsemon*," "*Opobalsamum*," and "*Becham*". The search on the three databases yielded 156 documents, 55 of which were included. The SLR study found low extraction yields and phenolic contents of the phytochemical components of *C. gileadensis* due to ineffective extraction techniques and process parameters. More so, these might involve environmental implications for how resources are used, how much energy is consumed, and how much waste is produced throughout the extraction process. The SLR overcame the limitations of traditional extraction methods and boosted phenolic content recovery by using eco-friendly technique such as Microwave-Assisted Extraction (MAE). It also recommended researching how improved extraction methods affect the phytochemical composition and recovery yield of the extracts.

Keywords: Environmental implications; Traditional extraction methods; *C. gileadensis*; Systematic literature review; Green extraction methods.

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1. Introduction

Commiphora gileadensis is a one-to-three-meter-long tree that belongs to the Burseraceae family [1–4]; it originated from the southern Kingdom of Sheba in the Arabian Peninsula's [5–8] and has been distributed to other regions of the world, such as Yemen, Oman, Somalia, Sudan, Ethiopia, India, and Pakistan [9, 10]. The plant, which is also called balsam, produces an expensive perfume; its seeds, bark, sap, wood, and leaves contain phytochemicals of therapeutic importance [11, 12]. The aromatic plant, *C. gileadensis*, further known as *besham* or *becham* in the Middle East, is used for medicinal herbal remedies [1].

C. gileadensis is commonly used to treat a variety of illnesses as of ancient times and is still used in traditional medicine throughout many Middle Eastern countries today [6, 13, 14]. *C. gileadensis* could indeed treat a variety of ailments, including pain and inflammation, and it has a powerful anti-impact on cancer cell lines [1]. It also has medicinal properties for controlling diseases such as inflammatory disorders, stomach problems, liver problems, urinary retention, constipation, headache, and jaundice [11]. The phytochemical analysis of this plant's aerial parts revealed phenolic compounds, flavonoids, saponins, sterols, and triterpene [15, 16]. The plant is well for both its useful aromatic resin and its medicinal properties [17]. *C. gileadensis* has antibacterial properties and is employed to treat infections [14]. It many in numerous African and Arabic countries as a traditional medication to cure opportunistic infections, cancer analgesics, and diuretics [14, 18].

Bioactive compounds can be extracted from plants using green methods like supercritical fluid, enzyme-assisted, ionic liquids, ultrasound-assisted, pressurized liquid/fluid, and microwave-assisted methods [19] or traditional techniques such as decoction, percolation, hydro-distillation, maceration, immersion, and Soxhlet extraction [20]. Traditional extraction methods have lengthy extraction times, utilize large solvent volumes, produce waste, and consume energy, all impacting the environment [20, 21]. Modern extraction techniques address drawbacks by offering higher yields, shorter times, reduced solvent usage, and improved safety and environmental effects [20].

Nonetheless, no defined procedures or clear guidelines exist to assist researchers in increasing their chances of getting high-quality extracted bioactive constituents for medical use, particularly from *C. gileadensis*. Consequently, researchers are more frequently based on literature reviews to define subjective flaws in previous studies [22]. In essence, no SLR has reported the extraction methods and phytochemistry of *C. gileadensis*'s bioactive activities. Hence, this is the first SLR on *C. gileadensis* that investigated the extraction methods. This SLR adopted the "PRISMA method Preferred Reporting Items for Systematic Reviews and Meta-Analyses" [23, 24]. Therefore, the purpose of the SLR is to detailly review the existing articles on *C. gileadensis* and provide a clear summary of the investigations carried out between 2010 and 2022. Also, the SLR highlighted the limitations of the existing conventional extraction methods, as well as recommendations to overcome these issues, especially regarding their environmental impacts.

2. Review methodology

The existing research on *C. gileadensis* was reviewed in this study using the PRISMA method [23–27]. According to the PRISMA principles, the scoping approach was used to gather relevant publications on the sustainability criteria and evaluation of *C. gileadensis*. This technique revealed potential keywords and helped with the control of the aspects [23, 28, 29]. Because of the widespread use of *C. gileadensis*, a thorough literature research was conducted using several databases to find relevant articles and academic works. To find the pertinent publications published in the most recognized research databases (Web of Science, Scopus, and PubMed), many search term combinations were used. Each database was searched with the following keywords "*Commiphora gileadensis*", "*Balm of Judea*", "*Apharsemon*", "*Balm of Gilead*", "*Opobalsamum*" and "*Becham*" to locate the related articles. The data search was refined using predetermined inclusion and exclusion criteria as well as quality standards [30, 31]. The quality level was guaranteed by each filter; the measures for inclusion and exclusion are covered in the next section.

To guarantee that current sustainability measures were highlighted, the timeline of the literature search included the last decade (2010-2022). Fig. 1 demonstrates that the literature survey focused on academic research articles, book chapters, and peerreviewed publications, resulting in 156 records. Fifty (50) articles were not considered for this SLR because they were not published in the English language. Additional 35 articles were also excluded because they appeared twice in the three electronic databases. Based on the remaining exclusion and inclusion criteria, a total of 71 papers were determined to be appropriate for further evaluation. The SLR was then started after converting the data into an MS Excel file. Then, about 16 articles had been eliminated from the MS Excel since these articles' full contents were unrelated to the subject. This SLR article used the PRISMA framework, as depicted in Fig. 1.

2.1. Evaluation of Quality

To find the best outcomes and give a comprehensive summary of earlier data, the evaluation now looks at the original and review articles that have already been published. The results, conclusions, and abstracts were kept apart to keep the archives manageable. To improve the desired results, the records were double-checked for duplication, and irrelevant research articles were removed.

2.2. Inclusion and Eligibility

The following selection criteria applied to the identified published research to ensure a more precise collection; the study included only research articles written in the English language. Additionally, only articles published in the Scopus, Web of Science, or PubMed databases were considered during the search. These datasets are more reliable and organized than those produced by other search engines.

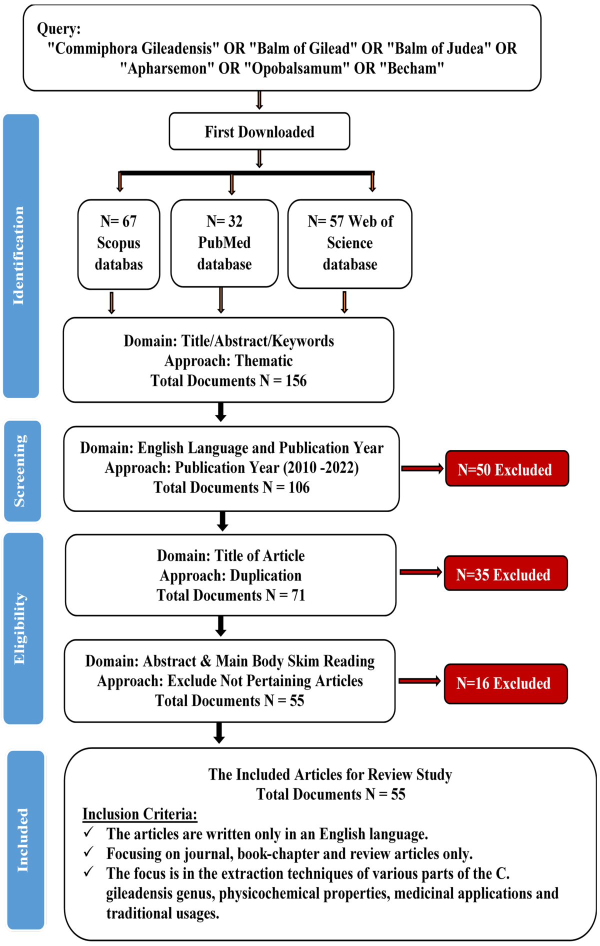

Fig. 1. The flow diagram of using the PRISMA framework for SLR article

2.3. Qualitative Synthesis Included Studies

After the articles were chosen, a two-step technique was used to check the accuracy of the analysis done on the chosen papers. An illustrative study of the literature on *C. gileadensis*, including the qualitative and quantitative studies performed globally, was performed by importing the sustained meta-data into MS Excel. The next step was to do a comprehensive content analysis, classifying and analyzing key inquiry flows, reporting the most recent evidence study, and highlighting significant obstacles and research opportunities. A study method called content analysis allows for reproducible and reliable implications of texts by characterizing and evaluating the clear content regarding predetermined groupings systematically.

3. Overview of extraction methods

Pharmaceutical extraction separates active components from plant or animal tissues using selective solvents [32]. After an extraction process, some of the initially obtained extracts may be suitable for use as tinctures or fluid extracts, while others require additional processing [20]. The extraction of bioactive compounds from plant matrices can be achieved through traditional techniques such as decoction, percolation, hydro-distillation, maceration, immersion, and Soxhlet extraction; these methods require a long extraction time and a large volume of solvents. Bioactive compounds can also be extracted using modern extraction methods as supercritical fluid, enzymeassisted, ionic liquids, ultrasound-assisted, pressurized liquid/fluid, and microwaveassisted methods. Modern extraction techniques improve upon traditional techniques by offering higher recovery yields, shorter extraction times, reduced solvent usage, improved safety, and environmental effects [20, 21].

In the process of extracting plants, choosing the right extraction technique is crucial. The benefits and drawbacks of different extraction techniques generally depend on variables, including the extraction yield, the time required for extraction, the safety, and quality of the extract, as well as the cost of extraction. Therefore, it is crucial to use the right procedures to extract the bioactive compounds from the plant matrix. Additionally, the extraction methods used, and the extraction solvent, affect the quantity and quality of the extracted bioactive compounds. Chemical compounds are extracted from plant matrix using either contemporary or antiquated techniques using water or organic solvents like ethanol, methanol, hexane, or other solvents [19].

3.1. Traditional Extraction Methods

Traditional extraction methods involve separating the desired components from a mixture using physical and/or chemical processes. Some of the most used traditional extraction methods include decoction, immersion, maceration, percolation, Soxhlet extraction, and hydro-distillation [20, 32]. Conventional extraction methods are impractical due to their high solvent usage and low recovery yields [33]. Fig. 2 showed the drawbacks of the traditional extraction methodologies on the environment and economy.

3.2. Green/Advanced Extraction Methods

Green (advanced) extraction methods are the latest approaches to extracting bioactive compounds from natural resources; they aim to minimize the environmental impact of extraction processes and improve the extraction efficiency. These methods utilize less harmful solvents like water, ethanol, and various extraction techniques such as supercritical fluid, enzyme-assisted, ionic liquids, ultrasound-assisted, pressured liquid/fluid, and microwave-assisted [7, 34, 35]. These methods optimize compound yield, expe-

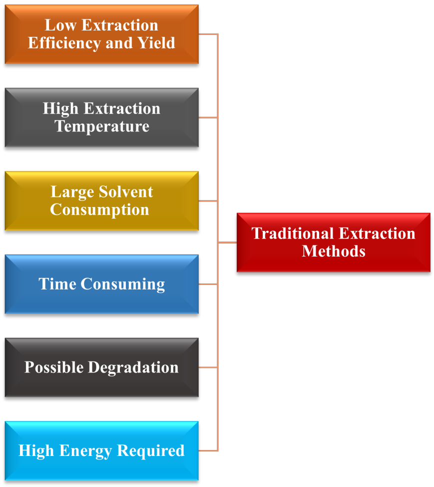

Fig. 2. The overall drawbacks of the traditional extraction methods

dite extraction, and minimize toxic solvent usage, resulting in a afer, eco-friendly final product. They are acquiring popularity in various industries, such as pharmaceuticals, cosmetics, and food, due to their sustainability and ecofriendliness [36, 37]. In general, traditional extraction techniques' limitations are overcome by using the green extraction techniques that have been discussed previously. Fig. 3 presents the overall advantages of the unconventional extraction methods.

Fig. 3. The advantages of the unconventional extraction methods

4. Extraction of *C. gileadensis*

The current SLR was conducted to study comprehensively the extraction methods that had been used to extract the bioactive compounds from different parts of *C. gileadensis*. Table 1 summarizes the extraction methods for recovering bioactive compounds from different parts of *C. gileadensis* (2010-2022).

4.1. Observations on the used extraction methods

The overall observations from 2010 to 2022, based on Table 1's extraction techniques, are as follows:

- The conventional extraction methods have been the most used technique for the extraction of bioactive compounds from different parts of *C. gileadensis*. As previously discussed, the cons of conventional extraction methods have environmental implications.
- Investigation of the therapeutic use of *C. gileadensis* has mostly focused on its traditional use.
- Scientific studies on *C. gileadensis* from the engineering perspective are yet to be reported.
- Fewer characterization studies had been conducted on *C. gileadensis*.

5. Literature gap

Previous studies have highlighted many recommendations for future studies on *C. gileadensis* to address some of the identified gap in knowledge. A summary of these recommendations based on previous studies is presented in Table 2.

6. Challenges and recommendations

Traditional extraction processes have limitations impacting quality, yield, and the environment. One challenge is the lack of standardization in the extraction process. Traditional extraction methods can vary depending on the plant species, the part of the plant being extracted, and the geographical location. This can lead to variations in the quality and quantity of the extracted compounds, making it difficult to achieve consistent results. Another challenge is the potential for contamination or impurities in the extracted compounds. Traditional extraction methods may use solvents or other materials that can leave behind residues or impurities in the final extract. This can affect the purity and safety of the extract, particularly if it is intended for medicinal or dietary use. In addition, traditional extraction methods can be time-consuming and labor-intensive. They may require a significant amount of plant material, and

Table 1. Comparison of extraction methods of *C. gileadensis* genus

C. gileadensis Specie/part	Extraction Method	Solvent	Application/ Investigation	Remarkable Findings	Year	Ref.
Stem	Hydrodistillaion	Trichloromethane	Methanol	Cream for wound healing The cream is effective in wound treatment and management treatment of wounds	2022	[38]
C. gileadensis parts	Solvent extract	Aqueous solutions	Ethno-botanical and phytochemical	TFC = 1.67 μg R/mg dry weight; TPC = 23.54 μg GA/mg dry weight	2022	[39]
C. gileadensis	Methanol extract	Methanol	Phytochemical analysis	Identified one novel triterpenoid and four previously identified constituents	2022	[17]
Fresh stem	Solvent extraction	Methanol	Antibacterial compounds from the stem	The isolated compounds exhibited excellent wound-healing potential	2022	[40]
Leaves and fallen branches	Maceration	Methanol	Antimicrobial activity	The extracts served as excellent fever and pain relievers; they also showed good anti-hypertensive and anti-inflammatory properties	2022	[41]
Stem	Solvent extraction	Autoclave water	Anticancer activity	*C. gileadensis*-based nanoparticles should be studied as possible novel therapeutic agents for cancer treatment	2022	[42]
Aerial parts	Solvent extraction	Methanol	Toxicological profile	The acute and chronic toxicity profile of *C. opobalsamum* was discovered in rats	2021	[43]
Myrrh resin (*C. opobalsamum*)	Solvent extraction	Methanol	Anti-inflammatory activity evaluation	Some of the identified compounds exhibited anti-inflammatory activity	2021	[44]
Leaf and twig	Maceration	Distilled water	Anti-diabetic, hypolipidaemic, and antioxidant activities	*C. gileadensis* leaf and twig aqueous extracts exhibited antidiabetic, antioxidant, and hypolipidemic activities in a hypercholesterolemic, diabetic male rat model	2020	[45]
Leaves and disgraced branches	Maceration	Methanol	Antibacterial activity against MRSA	The extract had good antibacterial activity against MRSA	2020	[46]
Stem peel and Leaf	Solvent extraction	Methanol, ethanol, and acetone	Antioxidant and antibacterial effects	Better antioxidant and antibacterial activities were observed with the 80% methanol extract {TPC of methanol stem extract = 34.98 mg GAE/g; TPC of methanol leaf extract = 20.97 mg GAE/g; TFC of methanol stem extract = 10.49 mg CE/g; TFC of methanol leaf extract = 6.90 mg CE/g; Leaf [ABTS: EC_{50} = 0.690; DPPH: EC_{50} = 3.390] Peroxide scavenging activity, leaf (EC_{50} = 2.430) Stem [ABTS: EC_{50} = 0.550; DPPH: EC_{50} = 1.060] Peroxide scavenging activity, stem (EC_{50} = 1.280]	2020	[15]

C. gileadensis Specie/part	Extraction Method	Solvent	Application/ Investigation	Remarkable Findings	Year	Ref.
leaf and stem peel	Maceration	Ethanol	Biological activity and phytochemical analysis	Leaf [ABTS: EC_{50} = 0.690; DPPH: EC_{50} = 3.390] Stem [ABTS: EC_{50} = 0.550; DPPH: EC_{50} = 1.060] TPC leaf = 20.970 mg GAE/g TPC stem = 34.980 mg GAE/g TFC leaf = 6.900 mg GAE/g TFC stem = 10.490 mg GAE/g	2019	[47]
The aerial parts (including fruits, leaves, and resin)	Hydro-distillation	Ethanol	Biological activity and phytochemical analysis	TPC = 0.23 μg GA/mg	2019	[2]
Stem peels	Solvent extraction	Tris–HCl buffer	The chances of extracting a peroxidase	The immobilized peroxidase can be used industrially for many purposes	2019	[48]
Leaf	Maceration	Methanol	Antiviral activity	Isomers of guggulsterone in *C. gileadensis* leaf extract was first reported. The compound also had good anti-viral activity	2019	[49]
Stem bark, leaves, and fruits	Hydrodistillation	Dichloromethane	Monoterpene monoterpenoids oils	The extracted essential oil contained mostly oxygenated monoterpenoids and monoterpene hydrocarbons	2017	[50]
Stem bark	Solvent extraction	Ethanol	Flavonoids	The total extract showed an IC50 value of 15 mg/mL against the MCF-7 cell line and 19 mg/mL against the HepG-2 cell line. The chloroform extract was the most potent fraction with IC50 values of 14 mg/mL against MCF-7 cells and 17 mg/mL against HepG-2	2017	[51]
Resin of *C. opobalsamum*	Solvent extraction	Dichloromethane	Novel sesquiterpenes	The cytotoxicity of the novel sesquiterpenes, as well , as the antibacterial analgesic, antioxidant, antifungal, and anti-inflammatory activities, were validated	2015	[52]
C. gileadensis sap	Solvent extraction	Ethanol	Anti-cancer activity	The cytotoxicity of the sap extract of *C. gileadensis* was demonstrated on skin tissues and human epidermal cells	2015	[53]
Stem wood	Soxhlet	Hexane, Methanol, dichloromethane (DCM), and acetone	Flavonoids in c comparison to the existing data	The presence of 6 compounds was determined, including two novel prenylated flavonoids and other known flavonols and flavanonols. The extract of this plant species contains all previously unreported isolated flavonoids except quercetin	2015	[54]
Bark	Maceration	Methanolic	Cytotoxicity and antimicrobial activity	The cytotoxicity, antimicrobial activity, and LD50 value were determined in addition to the phytochemical analysis	2015	[55]

C. gileadensis Specie/part	Extraction Method	Solvent	Application/ Investigation	Remarkable Findings	Year	Ref.
Stem	Solvent extraction	Methanol and warm water	Antibacterial activity	The MIC of the methanol extract ranged between 50 and 100 g/ml	2014	[56]
Resin of *C. gileadensis*	Solvent extraction	Ethanol	Isolation of diterpenes	Two diterpenes were identified from the bio-assay-guided approach using isolated rat pulmonary artery rings	2014	[57]
Resin of *C. gileadensis*	Solvent extraction	Ethyl acetate	Isolation of sesquiterpenoids	Identified 8 known phytochemicals and two novel germacrene-type sesquiterpenoids. The cytotoxic properties of the compounds were also established against DU145 and PC3 cell lines	2014	[58]
Stem and leaf	Solvent extraction	Ethanol	Anti-inflammatory activity	The presence of apoptosis inducers in the extract was confirmed; these inducers had selective effects on the tumor cell lines	2013	[59]
Stem	Solvent extraction	Ethanol	Cytotoxicity effect	The presence of apoptosis inducers in the extract was confirmed; these inducers had selective effects on the tumor cell lines	2012	[60]
Resin of *C. gileadensis*	Solvent extraction	Ethanol	Isolation and identification of sesquiterpenoids and triterpenoids	The extract contained phytochemicals that exhibited cytotoxicity against HeLa (IC50 = 15.4 lM) and HepG2 (IC50 = 8.7 lM) cell lines	2012	[61]
Exuded liquid sap	Exudation	-	Antimicrobial activities	The antibacterial and wound-healing activities of *C. gileadensis* xudate were demonstrated	2010	[14, 62]

the extraction process itself can take several hours or even days. This can make it difficult to produce large quantities of high-quality extract in a timely and cost-effective manner. Finally, traditional extraction methods may not be suitable for many compounds or plant materials. Some compounds may be difficult to extract using traditional methods or may require specialized equipment or techniques to achieve optimal yields and purity. While traditional extraction methods have their benefits, they also have their challenges and limitations. Hence, modern extraction techniques have been developed to offer better results in terms of efficiency, yield, purity, and eco-friendly, particularly for complex or difficult to extract compounds.

The recommendations to address the literature research gap based on the observation of Table 1 and Table 2 of previously conducted research are as follows:

- Application of green extraction methodologies during the extraction of *C. gileadensis* to improve recovery yields and considering the 3E 's issues (Environment, Economic, and Engineering).
- More characterizations to investigate the detailed properties and medicinal activities of *C. gileadensis* extracts.
- Initiation of more studies on *C. gileadensis* extracts from the scientific and engineering perspectives.
- Conduction of more in-vitro and in-vivo animal trials on the biological activities of *C. gileadensis* extracts.

7. Proposed approach

Due to the above findings and recommendations, the proposed approach section is to validate that the innovative extraction technique and the extracts of the medicinal plant; C. *gileadensis*; is eco-friendly.

Several important variables support the extraction process's environmental friendliness. Firstly, ethanol and other green solvents are used in eco-friendly extraction process; these solvents are known to have less of an adverse effect on the environment than traditional organic solvents [65] . These solvents are made from renewable resources, biodegrade naturally, and are not harmful. Green solvents, such as ethanol, are preferred for sustainable extraction operations because of their much smaller environmental footprints, as demonstrated by a study conducted by Alara et al. [19] and Fomo et al. [66]. Secondly, green extraction procedure uses a significant fraction of the energy in comparison to conventional techniques. As an example, using microwave-assisted extraction (MAE), which contributes to overall sustainability by reducing energy usage and extraction times [41, 67, 68]. Third, by improving the use of solvents and recycling capabilities, MAE technique reduces waste creation. This is in line with green engineering's guiding principles, which place a strong emphasis on minimizing waste and creating effective yet ecologically friendly processes [69]. Another study had emphasized the importance of waste reduction and improved solvent recovery techniques in environmentally friendly extraction procedures [70]. In comparison with conventional approaches, MAE extraction procedure executes quickly, demonstrating its efficiency. The time it takes to extract materially decreases with the use of MAE [71]. In a fraction of the time needed by traditional methods, like Soxhlet extraction or maceration, microwave-assisted extraction, for instance, can finish the extraction process [72]. Furthermore, MAE extraction process's improved parameters enable high-throughput operations, enabling quicker sample processing without sacrificing yield or quality. This is especially helpful in industrial settings where productivity and cost-effectiveness are closely correlated with time efficiency [73]. The present empirical evidence aligns with findings from previous studies that indicate comparable increases in extraction speed through the use of sophisticated approaches. In the final analysis, both theoretical precepts and actual data solidly support the eco-friendliness and rapidity of MAE extraction procedure [74]. Its sustainability is enhanced by reduced waste creation, energyefficient methods, and the utilization of green solvents.

The extraction of *C. gileadensis*, a medicinal plant, is considered eco-friendly due to several reasons. For instance, the use of plant extracts for synthesizing silver nanoparticles is a green and eco-friendly process [42]. This method eliminates the need for harsh chemicals and toxic solvents, which are typically used in traditional synthesis methods [42, 75]. The green synthesis process is low-cost and nontoxic, making it an attractive alternative to traditional methods. This approach also reduces the environmental impact of nanoparticle synthesis [42, 75, 76]. *C. gileadensis* is a renewable resource, as it can be sustainably harvested and replenished. This ensures that the extraction process does not deplete natural resources or harm the environment. The plant extracts used in the synthesis process are biodegradable, which means they can easily decompose without harming the environment [16]. This reduces the risk of environmental pollution and toxicity. The green synthesis process generates minimal waste, which reduces the environmental impact of the extraction process. This approach also promotes sustainable waste management practices. Ultimately, the use of plant extracts in the synthesis process is energy-efficient, as it eliminates the need for

Table 2. Recommendations of the previously conducted research

No.	Recommendations of Previous Research	Reference
1.	The study recommends conducting further research on Commiphora species utilizing cutting-edge approaches and educating the public about the importance of these plants	[39]
2.	The antibacterial activity of the isolated components supports the plant's historical uses for treating infected wounds	[40]
3.	To determine this compound's effectiveness against dengue major envelope protein, additional in-vitro research is required	[63]
4.	*C. gileadensis*-derived nanoparticles should indeed be investigated as potential novel therapeutic agents for cancer treatment	[42]
5.	Future research will focus on isolating, purifying, and discovering physiologically active chemicals from *C. gileadensis* that can be used as an antibacterial agent, particularly in infected wounds, to prevent bacterial infection	[9]
6.	*C. gileadensis* contains a variety of bioactive chemicals, and more investigation is needed to evaluate their biological and pharmacological properties	[15] [15]
7.	A new study determines the active component of *C. gileadensis* and compares its effect on the entire extract	[9]
8.	To analyze and verify these preliminary findings, more samples need to be examined in greater numbers	[64]

high-temperature and high-pressure conditions typically required in traditional methods. This reduces the energy consumption and carbon footprint of the extraction process. In essence, the extraction of *C. gileadensis* can be considered as eco-friendly due to the use of green synthesis, low-cost and non-toxic methods, renewable resources, biodegradable materials, minimal waste generation, and energy efficiency. These factors contribute to a more sustainable and environmentally friendly extraction process.

8. Conclusion

The review explores the previous extraction techniques used to extract bioactive compounds from *C. gileadensis* based on the analysis of the published literature from 2010 to 2022. The SLR showed that solvent extraction and maceration were the two classic extraction methods most frequently employed to obtain *C. gileadensis* extract or resins. Future work recommendations have also been made in the literature, which included the following: (i) employing advanced extraction techniques; (ii) concentrating on the separation, purification, identification, and characterization of biologically active compounds; and (iii) conducting additional in-vivo and in-vitro studies to determine the range of the extracted compounds' potency. Therefore, innovative green extraction methods, such as MAE, can be applied in future studies to address the shortcomings of conventional extraction procedures, for instance overall recovery yields and environmental issues. Moreover, more phytochemical research is needed to emphasize the impact of extraction methods on the extracted bioactive components; the extract needs to be further characterized to get detailed information about the composition of the extract obtained using specific extraction methods. Non-traditional extraction methods should be compared to traditional methods as well to assess their impact on the quality and quantity of bioactive components.

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