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Evaluation of soxhlet extraction parameters for the recovery of improved bioactive compounds from *Commiphora gileadensis* bark

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SUMMARY: Medicinal plants, valued for their natural therapeutic properties and minimal side effects, have been used safely for centuries, as many synthesized drugs often pose serious side effects and long-term health risks, thereby highlighting the importance of plant-based alternatives in modern medicine. The extraction of phenolic phytoconstituents and recovery yields from *Commiphora gileadensis* bark (*C. gileadensis)* via Soxhlet extraction (SE) were investigated using One-Factor-At-a-Time (OFAT) to study the influence of the SE variables (solvent concentration, solid: solvent ratio, and process time) on the recovery of phenolic compounds. The findings showed that optimal yields were achieved at 60 % v/v solvent concentration, and a solid-to-solvent ratio of 1:35 g/mL within 90 min of the extraction process. The optimum recoveries were: TFC = 23.12±1.62 mg QE/g d.w; Y_{Ex} = 26.70±0.31% w/w, and TPC = 77.21 ±1.59 mg GAE/g d.w. In addition, 20 phenolics with good biological activities were identified in the extracts.

KEY-WORDS: *GC-MS;* C. gileadensis *bark, FTIR; Soxhlet extraction; Phytochemical.*

RESUMEN: ***Evaluación de los parámetros de extracción en soxhlet para mejorar la recuperación de compuestos bioactivos de la corteza de*** **Commiphora gileadensis**. Las plantas medicinales, valoradas por sus propiedades terapéuticas naturales y sus mínimos efectos secundarios, se han utilizado de forma segura durante siglos, ya que muchos fármacos sintetizados suelen presentar graves efectos secundarios y riesgos para la salud a largo plazo, lo que resalta la importancia de las alternativas vegetales en la medicina moderna. Se investigó la extracción de fitoconstituyentes fenólicos y los rendimientos de recuperación de la corteza de *Commiphora gileadensis* (*C. gileadensis*) mediante extracción soxhlet (SE) utilizando el método de un factor a la vez (OFAT) para estudiar la influencia de las variables SE (concentración de disolvente, relación sólido:disolvente y tiempo de proceso) en la recuperación de compuestos fenólicos. Los resultados mostraron que los rendimientos óptimos se alcanzaron con una concentración de disolvente del 60 % v/v y una relación sólido-disolvente de 1:35 g/mL en los 90 min posteriores al proceso de extracción. Las recuperaciones óptimas fueron: TFC = 23,12 ± 1,62 mg QE/g p.s., YEx = 26,70 ± 0,31 % p/p, y TPC = 77,21 ± 1,59 mg GAE/g p.s. Además, se identificaron 20 compuestos fenólicos con buena actividad biológica en los extractos.

PALABRAS CLAVE: *Corteza de* C. gileadensis*; Extracción soxhlet; Fitoquímica FTIR. GC-MS.*

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1. INTRODUCTION

Developing countries worldwide have begun to trust that herbal remedies and medicinal plants can heal numerous diseases (Bin Mokaizh *et al.,* 2024a). The WHO reported that a greater percentage of the global population uses herbal items as alternative treatments for various illnesses or as dietary supplements (WHO, 2022). Although numerous plants are utilized as alternative medicine sources, many undiscovered medicinal plants must be identified to ensure sustainability (Bin Mokaizh *et al.,* 2023).

Commiphora gileadensis is a shrub that originally grew in the Arabian Peninsula's southern Kingdom of Sheba; it reaches a height of one to three meters and belongs to the Burseraceae family (Al-Abdallat *et al.,* 2023). *C. gileadensis* has anti-arthritic, anti-inflammatory aromatic properties, and is used in the Middle East, where it is known by the name besham or becham to make herbal treatments (Alsherif, 2019). In many Middle Eastern countries, *C. gileadensis* has been used as an alternative cure for various diseases in the past, and up to date (Alsherif, 2019). Its seeds, bark, sap, wood, and leaves contain phytochemicals of therapeutic importance (Khan *et al.,* 2019; Yehoshua *et al.,* 2015).

C. gileadensis could treat various diseases, and traditional medicine has manifested a high anti-cancer efficacy in many cervical cancer cell lines (Alsherif, 2019). Phytochemical analysis of the aerial parts of *C. gileadensis* showed the presence of phenolics, flavonoids, saponin, stearyl, and triterpenoid compounds (Almulaiky and Al-Farga, 2020). *C. gileadensis* is neatly suitable for its therapeutic profile and balsamic resinous (Abdallah *et al.,* 2022). Furthermore, this plant is used in traditional Arabic medicines of several African nations to treat diuretic and analgesic conditions; it also affects opportunistic infections (Almulaiky and Al-Farga, 2020; Mokaizh *et al.,* 2024a). However, the full utilization of the potential of any natural remedy is reliant on the complete recovery of its bioactive components using suitable extraction methods.

Extraction is a proper approach to the analysis of phenolic elements in a matrix of plant origin. Both traditional and non-traditional extraction methods have been developed and used in literature. Conventional methods such as Soxhlet, hydro-distillation, soaking, maceration, and boiling have been commonly employed for many years. However, extraction using Soxhlet is considered the most commonly employed technique for extracting phenolic chemicals, as it takes less time and solvent, is simple to practice, is effective for the overall recovery of an extract, can be performed faster than other traditional methods such as percolation or maceration, and is suitable for initial and bulk extraction (Alara *et al.*, 2018). Furthermore, SE is a well-known technique with excellent performance compared to other traditional extraction procedures; however, its application to any process requires an accurate understanding of the right combination of process parameters through an optimization study, otherwise, thermos-labile compounds may be lost during the process (Alara *et al.,* 2018). In addition, greater yields can be obtained using considerably less solvent when using this method as opposed to other traditional methods (Nayak *et al.,* 2015).

Despite the good phenolic and antioxidant contents in *C. gileadensis* extracts, there is still a lack of ability to obtain its extract via an appropriate extraction method and comprehensive analysis. Yields of phenolic compounds from *C. gileadensis* bark have been studied using different conventional extraction methods. For instance, *C. gileadensis* stem peel has been extracted with 80% methanol via solvent extraction and found to contain 34.98 mg GAE/g TPC and 10.49 mg CE/g TFC (Al-Mahbashi *et al.,* 2019). Although the methods for recovery of the phyto-constituents in *C. gileadensis* bark were traditional, it is thought that the low yields could be due to the improper selection and combination of the extraction parameters. Thus, the parameters of the Soxhlet extraction method were investigated using the OFAT experimental approach in obtaining the recovery yield and phenolic compounds from the bark of *C. gileadensis*. Also, a Fourier Transform Infrared Spectrometer (FTIR), and GC-MS were employed to identify the extracts' functional groups and phenolic constituents at optimal process conditions.

2. MATERIALS AND METHODS

2.1. Pre-treatment of sample

From October to December 2021, fresh *C. gileadensis* bark was obtained from Hadhramout, Yemen. After air drying at 50 °C for one day to obtain a stable weight, the bark was pulverized using a RETSCH-PM 100 grinding machine, sieved, and stored at 4 °C for later use.

2.2. Reagents and chemicals

Sigma Aldrich Sdn. Bhd. in Selangor was the source of analytical-grade ethanol, (EtOH) 99.5 wt%, gallic acid, aluminum chloride salt ($AlCl_3$), Folin-Ciocalteu phenol reagent, methanol (MeOH) 99.9 wt%, sodium carbonate anhydrous (Na_2CO_3), and Quercetin. Ultra-pure water was supplied by the Faculty of FTKKP, UMPSA, Malaysia.

2.3. Extraction process

Ten (10) grams of the powdered *C. gileadensis* bark sample were loaded into a thimble and placed in the Soxhlet extractor. The Soxhlet extractor was equipped with a 0.50-L round-bottom flask (attached to the condenser) that had been previously filled with a measured volume of the water-ethanol mixture. The flask was placed in a mantle for heating. The heating mantle heated the solvent as it flowed into the Soxhlet extractor and then into the condenser. Additionally, solvent condensate drips began to run into the Soxhlet extractor containing a thimble with plant material. The extract-containing solvent was refluxed into the heating round-bottom flask to complete a cycle. This process was repeated until the complete intended time of extraction had elapsed, and the extract solution was cooled before using a rotary evaporator to concentrate the extract; upon quantification, the TPC, Y_{Ex}, and TFC of the extract were determined.

2.4. TFC calculation

The TFC of the sample was calculated according to a previously described method (Bin Mokaizh *et al.,* 2024b). The extract (approximately 10 mg) was liquified in 1 mL ethanol to obtain a stock solution. To prepare the aluminum chloride solution, 2 g of $AlCl_3$ were added to 100 mL of ethanol and combined with the extract (1 mL) from each of the previously mentioned extracts in the amount of one: one, then 10 µl/ml of appropriate alternative were modified collectively. The absorbance change at 420 nm was determined using a spectrophotometer after completion of the reaction at room temperature for one hour. This curve was used to estimate the TFC concentration (50–500 mg/L) of the plant extract. The TFC was determined using Equation 1 and presented as mg QE/g d.w.

$$TFC = (c \times V) /m \quad (1)$$

Where
c = sample concentration (mg/L)
V = extraction solvent volume (L)
m = dried sample weight (g).

2.5. TPC calculation

TPC was determined using a slightly modified Folin Ciocalteu method (Bin Mokaizh *et al.,* 2024b). After redissolving 10 mg of the extract in aqueous ethanol (2 mL), 0.1 mL of FC reagent was mixed with 1 mL of the extract and left for 5 min at room temperature, after which Na_2CO_3 (0.5 mL) was added to the mixture and left for 20 min before reading the absorbance at 750 nm. TPC was estimated using Equation 2 and presented as mg GAE/g d.w.

$$TPC = (c \times V) /m \quad (2)$$

Where
c = sample concentration (mg/L)
V = extraction solvent volume (L)
m = dried sample weight (g).

2.6. Y_{Ex} calculation

Equation (3) was used to calculate the extraction yields and the results were given as (d.w.) (Bin Mokaizh *et al.,* 2024b).

$$Y_{Ex} = [(\text{Wt. of plant sample extract (g)}) / (\text{Wt. of dried plant powder (g)})] \times 100\% \quad (3)$$

2.7. FTIR characterization

A FTIR analysis was carried out to identify the peaks related to the existing functional groups in the bark extract of *C. gileadensis* at the best OFAT condition. Gas Permeation FTIR spectroscopy (Nicolet iS5 iD7 ATR; Thermo Scientific, Germany) equipped with "OMNIC software" was used for the identification process. The peaks were scanned within the infrared (IR) spectra within the 4000-500 cm^{-1} range at 4 cm^{-1} resolution (Bin Mokaizh *et al.,* 2024b). Peaks were identified by comparing the peaks found in the sample with a database of expected bands of absorbance for the different groups and bonds of the molecules.

2.8. GC-MS characterization

The compounds in the bark extract of *C. gileadensis* at the best OFAT condition were identified and their total concentration was determined by employing the method mentioned earlier (Almulaiky and Al-Farga, 2020). The extracts were analyzed using GC-MS (Thermo-Fisher Scientific, Waltham, Massachusetts, USA) fitted with an Elite-5-MS 0.25 x 30 x 0.25 m column. The column temperature was set to increase at a rate of 4 °C/min from 40 – 220 °C. The carrier gas was Helium at a flow rate of 20 mL/min. The injector and transfer temperatures of 250 and 280 °C, respectively, were maintained at an injection volume of 1 µL. EI mode was employed; the scan range was set to 50–600 Da, and the ionization voltage and ion source temperature were kept at 70 eV and 180 °C, respectively.

2.9. Statistical analysis

ANOVA using MS Excel was conducted to analyze the mean values at a probability value of less than 0.05. The data are presented as mean ± SD. Responses in the triplicate experiments were also subjected to the ANOVA test, which used the t-test to confirm the existence of significant differences at $p < 0.05$, to verify the validity of the study.

3. RESULTS AND DISCUSSION

Figures 1, 2, and 3 show how the SE parameters, including the ethanol concentration (20–100 % v/v), process time (30–150 min), and solid/solvent ratio (1:20–1:50 g/mL), were used to study the recovery of TFC, Y_{Ex}, and TPC of extracts. The influence of SE variables was evaluated in an OFAT experiment. Here, we discuss how each factor influences recovery yields.

3.1. Influence of extraction time

The extraction time must be considered in order to minimize cost and energy use (Alara *et al.,* 2018) as it is a critical factor affecting the recovery of phenolic compounds from plant matrices. The major reason is that excess heating of the samples leads to the destruction of phenolic chemicals (Brglez Mojzer *et al.,* 2016). Therefore, there should be an appropriate choice of extraction period for good recovery. Consequently, the impact of the extraction time was studied using SE and Figure 1 shows the impact of extraction time on the TPC, Y_{Ex}, and TFC recovered from the bark extract. The experiment examined the influence of various extraction times (150, 120, 90, 60, and 30 min), keeping the solid/solvent ratio constant at 1:20 g/mL and the ethanol content at 20 % v/v. After extraction for 30 to 90 min, the greatest recovery yields were observed; the highest recoveries were obtained at 90 minutes as 23.60 ± 0.10% w/w, 63.09 ± 1.24 mg GAE/g d.w., and 19.80 ± 1.79 mg QE/g d.w. Figure 1 illustrates declines in the yield, TPC, and TFC after 90 min because the extension of the extraction time beyond 90 min caused a decline in the phenolic chemical recovery due to potential degradation by heating of the plant material. As such, yields typically decrease once optimal equilibrium has been achieved. This could be due to a process of overheating during the preparation of samples, leaving some phenolic compounds to be degraded (Dahmoune *et al.,* 2014). So, if an ideal equilibrium is obtained, then, perhaps, the yield will be lower (Alara *et al.,* 2018). These results are similar to prior work on extracting tanshinones from *Salvia miltiorrhiza bunge* using SE, in which the extraction

recovery of the obtained product increased from 30 to 90 min and then decreased after 90 min (Bin Mokaizh *et al.,* 2024c). Overall, the SE period significantly influenced the efficiency of total phenolic compounds from *C. gileadensis* bark and its impact on the recovery yield. Hence, 90 min was considered for subsequent OFAT for assessing the influence of the solid/solvent ratio.

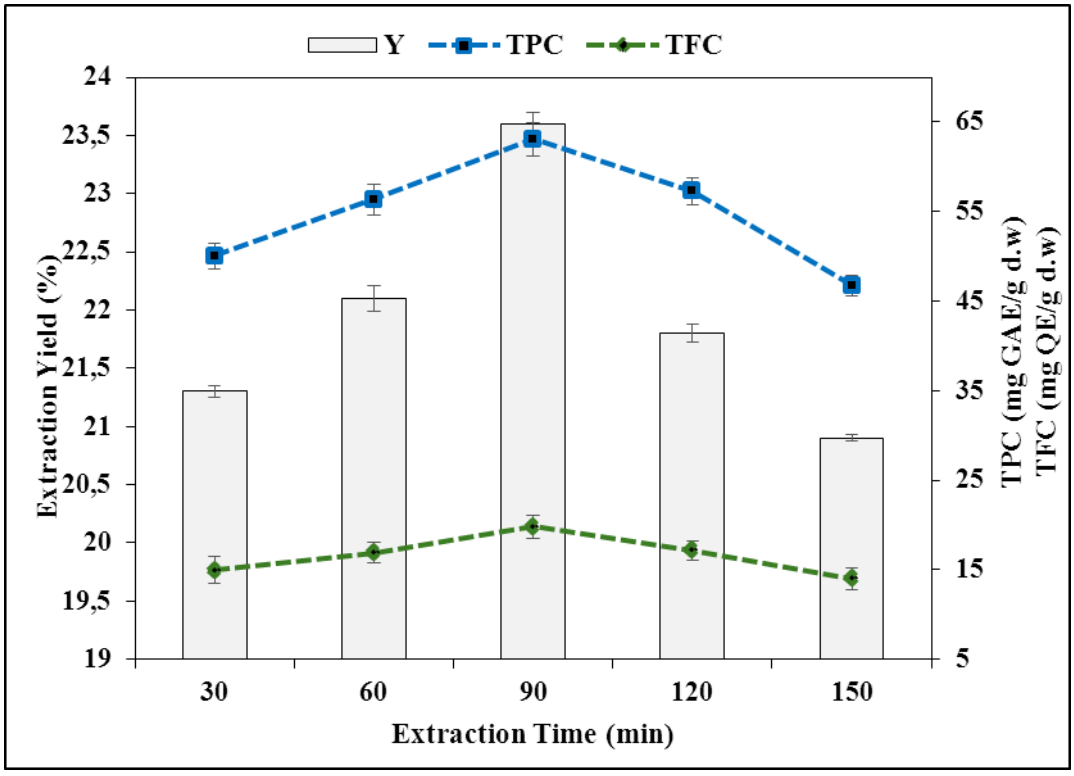

FIGURE 1. The Influence of extraction time (min) of SE on the Y_{Ex}, TPC, and TFC of *Commiphora. gileadensis* bark extract.
*The results were provided as the means ± SD of the observed values. The means of triplicate trials were used (n=3)
*TPC= Total Phenolic Content.
*TFC= Total Flavonoid Content.
*Y= Extraction Yield.
*mg GAE/g d.w= milligrams of gallic acid equivalents per gram dried sample weight.
*mg QE/g d.w= milligrams of quercetin equivalents per gram dried sample weight.

3.2. Influence of feed-to-solvent ratio

It is crucial to remember that suitable impregnation by the solvent must be made during the extraction phase to allow recovery. An increase in the amount of solvent used in the extraction technique yields positive extraction outcomes (Brglez Mojzer *et al.,* 2016). A test was carried out with a view to determining the relationship between the proportion of the solvent/feed in the extracts of the *C. gileadensis* bark and that of phenolic recovery yield. The solid/solvent ratio was adjusted between 1:20 and 1:50 g/mL of extract in the solvent, with 20% (v/v) ethanol and an extraction time of 90 minutes. Figure 2 shows that when the solvent-to-feed ratio increased from 20:1 to 35:1 mL/g, the phenolic constituents and extraction yield increased. The recovery yields declined as the solid/solvent ratio rose above 1:35 g/mL, which was also reported to yield maximum extraction recoveries (Conde-Hernández *et al.,* 2021). Thus, at a solid/solvent ratio of 1:35 g/mL, the ultimate recovery yields, TFC, and TPC were obtained as 24.8 ± 0.34 % w/w, 20.97 ± 1.23 mg QE/g d.w., and 70.04 ± 1.52 mg GAE/g d.w., respectively. Hence, the 1:35 g/mL solid/solvent ratio was used in the next study.

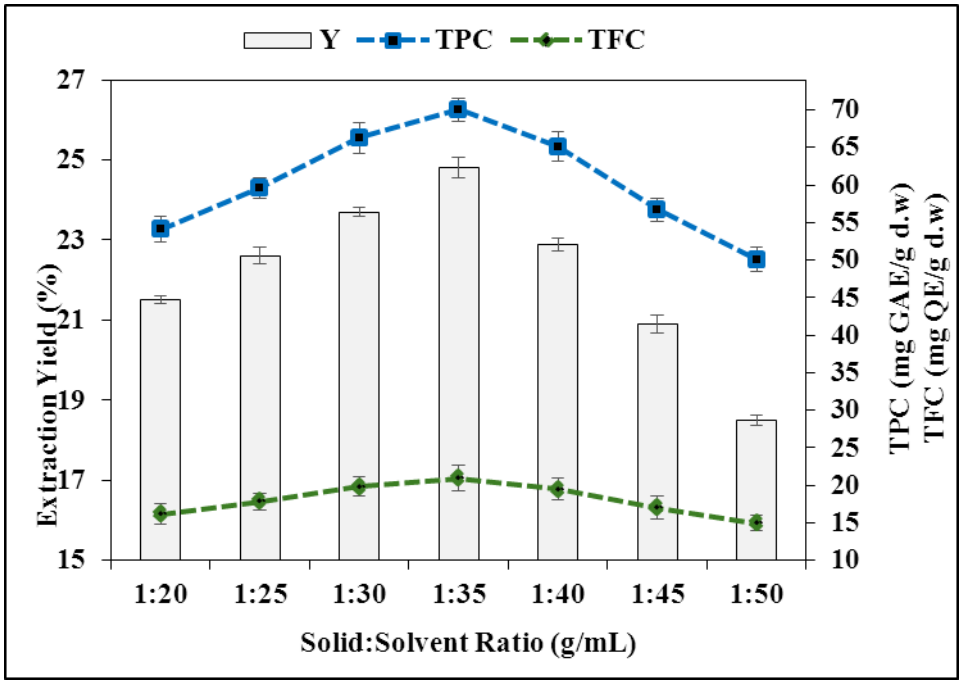

FIGURE 2. The Influence of solid/solvent ratio of (g/mL) of SE on the Y_{Ex}, TPC, and TFC of *Commiphora. gileadensis* bark extract.
*The results were provided as the means ± SD of the observed values. The means of triplicate trials were used (n=3)
*TPC= Total Phenolic Content.
*TFC= Total Flavonoid Content.
*Y= Extraction Yield.
*mg GAE/g d.w= milligrams of gallic acid equivalents per gram dried sample weight.
*mg QE/g d.w= milligrams of quercetin equivalents per gram dried sample weight.

3.3. Influence of ethanol concentration

Ethanol is also used for the recovery of phenolic constituents from plant matrices and has been seen as an environmentally-friendly solvent owing to its nontoxic characteristics (Zhang *et al.,* 2007). For TPC, YEx, and TFC from the bark extract, the ethanol concentrations were varied in the ranges of 20–100% v/v (see Figure 3), while the solid-to-solvent ratio and process time were kept at 1:35 g/mL and 90 min, respectively. Evidently, the TPC, Y_{Ex}, and TFC of the extracts progressively increased with the ethanol concentration from 20 to 60% v/v but after this ethanol concentration of 60%, the TPC, Y_{Ex}, and TFC started to significantly decline, possibly due to the compound's solubility, which is a function of the solvent polarity and chemical nature of the sample (Wong *et al.,* 2014). So, the greatest TFC, Y_{Ex}, and TPC from the bark of *C. gileadensis* were therefore (as seen in Figure 3) obtained at 60% v/v ethanol concentration and the values were 26.70 ± 0.31% w/w, 77.21 ± 1.59 mg GAE/g d.w., and 23.12 ± 1.62 mg QE/g d.w. This finding is consistent with the results of phenolic component extraction from *Vernonia cinerea* (L.) leaves at an optimum concentration of 60% v/v (Alara *et al.,* 2018).

In summary, the study showed that the SE method for extracting the bark of *C. gileadensis* yielded higher extraction yields at 60% v/v ethanol concentration, 90 min of extraction, and a solid-to-solvent of 1:35 g/mL; the TPC of 77.21 ± 1.59 mg GAE/g d.w., Y_{Ex} of 26.70 ± 0.31% w/w, and TFC of 23.12 ± 1.62 mg QE/g d.w. were obtained at this optimized SE process condition. The outcomes were noticeably superior to those achieved with other traditional techniques, including the solvent extraction approach (Almulaiky and Al-Farga, 2020), where the TFC yield of 10.49 mg QE/g d.w., and TPC from the same plant bark was only 34.98 mg GAE/g d.w. This demonstrates that employing the SE process at the optimized conditions generates higher recovery yields from *C. gileadensis* bark compared to other traditional techniques such as the solvent extraction method. Hence, the *C. gileadensis* bark extract under the above-mentioned conditions was further characterized in detail in the following subsection (4.1 and 4.2).

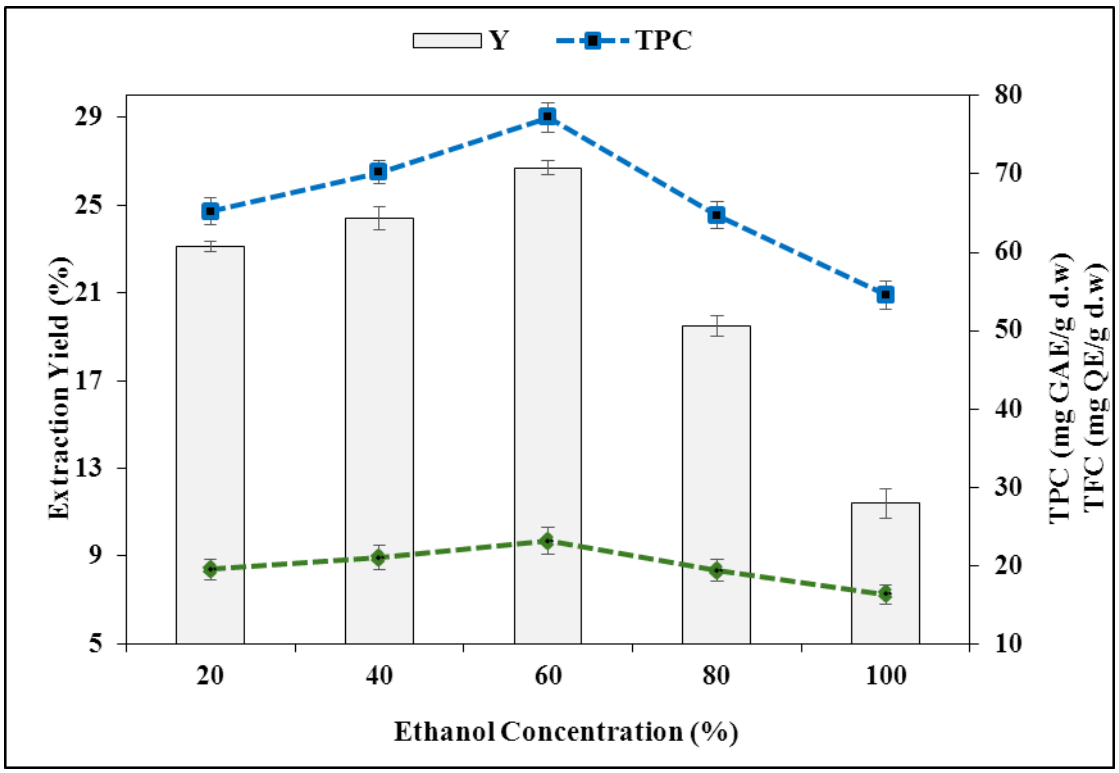

FIGURE 3. The Influence of ethanol concentration (v/v %); of SE on the Y_{Ex}, TPC, and TFC of *Commiphora. gileadensis* bark extract.
*The results were provided as the means ± SD of the observed values. The means of triplicate trials were used (n=3)
*TPC= Total Phenolic Content.
*TFC= Total Flavonoid Content.
*Y= Extraction Yield.
*mg GAE/g d.w= milligrams of gallic acid equivalents per gram dried sample weight.
*mg QE/g d.w= milligrams of quercetin equivalents per gram dried sample weight.

3.4. Characterization

3.4.1. FTIR analysis

This analysis revealed the presence of many compounds as evidenced by their apparent peaks (Figure 4). The bands at 2976.85, 2896.56, and 2119.36 cm^{-1} were mostly attributed to stretching *vs*(CH_2) and *vas*(CH_2), which exhibited the presence of lipid-carbohydrate molecules. The bands at 1647.29, 1450.21, 1381.75, and 1324.38 cm^{-1} reveal the presence of phosphodiester stretching to confirm the existence of nucleic acid, vas > P=O, bending of carboxylic acid, C=O stretching, and N-H bending, indicating the presence of tannins, saponins, glycosides, and flavonoids (Duygu, 2012). The band at 1270.68 cm^{-1} reflects an abundance of the C-O group in polyols, including hydroxy-flavonoids (Oliveira *et al.,* 2016). The peaks that appeared at 1043.74 cm^{-1} and 1085.16 cm^{-1} were assigned to the ester group or secondary alcohols, while the peak at 877.68 cm^{-1} can be assigned to the aromatic ring vibration. Accordingly, the elevated fingerprints obtained from the extract prepared using the Soxhlet method developed characteristics which are typical of the presence of flavonoids and polyphenols from *C. gileadensis* bark.

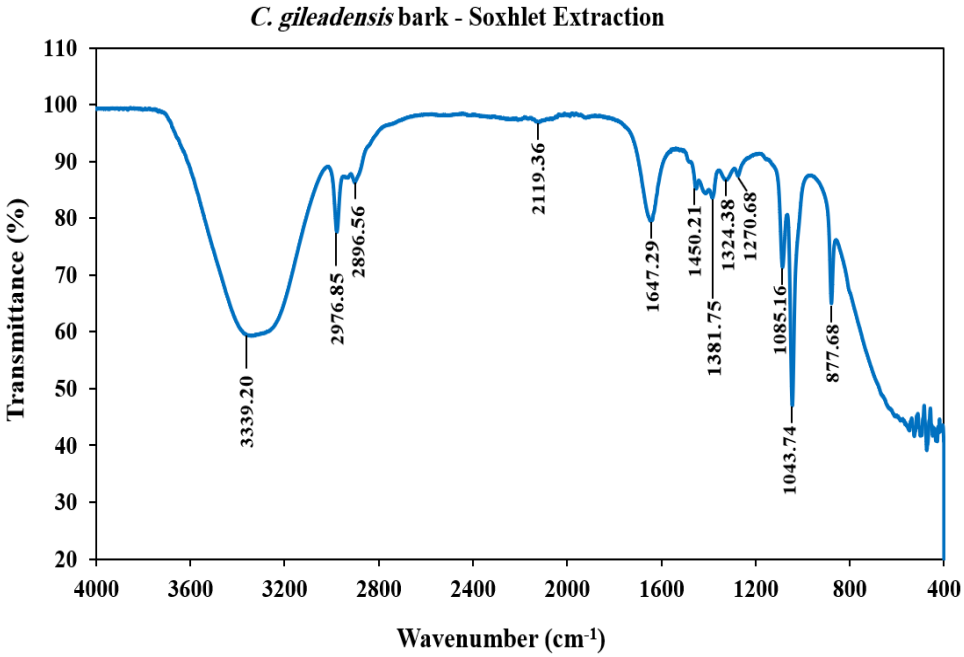

FIGURE 4. The infrared spectra of bark extract from *C. gileadensis* obtained using the SE method.

3.4.2. GC-MS analysis

The GC-MS analysis of the obtained extracts at the optimized SE process showed the presence of many chemical constituents in the bark extract of *C. gileadensis.* Table 1 lists 20 recognized phytoconstituents from the extracts which are comprised of fatty acids, alcohols, hydrocarbons, and esters.

The most abundant are cycloheptasiloxane (8.34 %), with reported anticancer and antimicrobial activity; heptasiloxane (10.81 %), with reported antioxidant, antimicrobial, antifungal, antiarthritic, anti-inflammatory, diuretic, and antiasthma properties (Febronia and Santhi, 2017); and cyclohexasiloxane (12.52 %), with reported anti-spasmodic, anti-rheumatic, and hepatoprotective activities (Ferdosi *et al.,* 2021). Furthermore, 3-Isopropoxy-1,1,1,7,7,7-hexamethyl-3,5,5-tris(trimethylsiloxy)tetrasiloxane (11.55 %) was reported to have antimicrobial activity (Singh *et al.,* 2021), and phenol, 2,4-bis(1, 1-dimethyl ethyl) (14.97 %), has anti-inflammatory, antioxidant, insecticidal, cytotoxic, antiviral, nematocidal, phytotoxic, antifungal, and antibacterial properties (Ferdosi *et al.,* 2022). Interestingly, the phytochemicals in the bark extracts of *C. gileadensis* extracted using SE contained a diversity of bioactive substances which possess strong antioxidant activity.

It is a recent fact that the face of lifestyle has changed significantly, owing to changing aspects of the nutritional value of food intake, and a question has been raised as to what kind of impact industrial manufactured commodities would have on human health (Weisz *et al.,* 2015). Most commodities are made from synthetically prepared substances that are said to harm human health (Momtaz *et al.,* 2023). A substitute seeks to obtain raw elements from nature instead of synthetically produced ones (Gurib-Fakim, 2006). This indicates that extracts are more in demand than artificial additives because they are regularly used in traditional medicine or as food (Gurib-Fakim, 2006).

TABLE 1. List of chemicals in *Commiphora gileadensis* bark detected by GC-MS.

No.	Name of Compound	Area of Peak (%)	Formula	M.W of Compounds	R.T (min)
1.	Ethanol, 2-(trimethylsilyl)-	0.78	$C_5H_{14}OSi$	118	3.762
2.	2,3-Pyridiendicarboxylic anhydride	6.71	$C_7H_3NO_3$	149	3.031
3.	2H-1,4-benzodiazepin-2-one, 7-chloro-1,3-dihydro-5-phenyl-1-(trimethylsilyl)-3-[(trimethylsilyl)oxy]-	0.64	$C_{20}H_{29}C1N_2O_2S_{i2}$	430	18.120
4.	7-Tetradecene, (E)-	0.92	$C_{14}H_{28}$	196	14.142
5.	Phenol, 2,4-bis(1, 1-dimethylethyl)-	14.97	$C_{14}H_{22}O$	206	24.671
6.	1-Dodecene	0.68	$C_{12}H_{24}$	168	21.015
7.	Cycloheptasiloxane, tetradecamethyl-	8.34	$C_{14}H_{42}O_7Si_7$	518	23.575
8.	1-Dodecanol	2.54	$C_{12}H_{26}O$	186	23.708
9.	2-Naphthalenemethanol, decahydro- α,α,4a-trimethyl-8-methylene-	1.15	$C_{15}H_{26}O$	222	18.983
10.	Lauryl acetate	0.64	$C_{14}H_{28}O_2$	228	27.833
11.	Cyclooctasiloxane, hexadecamethyl-	11.95	$C_{16}H_{48}O_8Si_8$	592	28.504
12.	3-Isopropoxy-1,1,1,7,7,7-hexamethyl-3,5,5-tris(trimethylsiloxy)tetrasiloxane	11.55	$C_{18}H_{52}O_7Si_7$	576	36.611
13.	1-Tetradecanol	0.82	$C_{14}H_{30}O$	214	29.816
14.	Ethanol, 2-(dodecyloxy)-	1.07	$C_{14}H_{30}O_2$	230	30.868
15.	Cyclohexasiloxane, dodecamethyl-	12.52	$C_{12}H_{36}O_6Si_6$	444	32.971
16.	Dodecyloxyethanol acetate (ester)	0.57	$C_{16}H_{32}O_3$	272	35.191
17.	Pentadecanoic acid	1.25	$C_{15}H_{30}O_2$	242	37.400
18.	Hexadecanoic acid	0.51	$C_{18}H_{36}O_2$	284	38.237
19.	Heptasiloxane, hexadecamethyl-	10.81	$C_{16}H_{48}O_6Si_7$	532	40.108
20.	Cyclooctasiloxane, octadecamethyl-	11.59	$C_{18}H_{54}O_9Si_9$	666	43.295

4. CONCLUSIONS

The OFAT technique was used in this study to investigate the influence of SE parameters on the recovery of phenolic compounds from *C. gileadensis* bark. Following the extraction study, the optimum TPC, Y_{Ex}, and TFC were achieved under the following process condition: process time = 90 minutes, solid-to-solvent = 1:35 g/mL, and solvent concentration = 60 % v/v; the yield, TFC, and TPC were achieved as Y_{Ex} =26.70±0.31% w/w, TFC =23.12±1.62 mg QE/g d.w, and TPC =77.21±1.59 mg GAE/g d.w. In addition, GC-MS investigation tentatively identified the existence of 20 phytoconstituents in the extract and among the most abundant were Cycloheptasiloxane (8.34%), Heptasiloxane (10.81 %), 3-Isopropoxy-1,1,1,7,7,7-hexamethyl-3,5,5-tris(trimethylsiloxy)tetrasiloxane (11.55 %), Phenol, 2,4-bis (1, 1-dimethyl ethyl) (14.97%), and cyclohexasiloxane (12.52 %). The extract from the bark of *C. gileadensis* is therefore said to contain bioactive compounds with potent biological functions. Therefore, they serve as natural alternatives for synthetic food additives and in the pharmaceutical industries.

RESEARCH DATA POLICY

DATA AVAILABILITY

The data used is confidential.

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DECLARATION OF COMPETING INTEREST

The authors declare no conflicting interest regarding the publication of this work.

AUTHORSHIP CONTRIBUTION STATEMENT

A. A. Bin Mokaizh: Conceptualization, Formal analysis, Funding acquisition, Investigation, Methodology, Writing – original draft, Writing – review & editing.

A. H. Nour: Conceptualization, Funding acquisition, Methodology, Project administration, Writing – original draft, Writing – review & editing.

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