Tropical Journal of Drug Research September 2025; 2 (9): 245 - 262
ISSN: 2476-8065 (Electronic)
Available online at http://www.tjdr.org
https://doi.org/10.26538/tjdr/v2i9.4

Original Research Article

Phytochemical Screening, Gas Chromatography-Mass Spectrometry Analysis and Invitro antioxidant Activities of the Seed, Leaf and Essential oils of *Petroselinum Crispum*, Parsley (Mill.) Nym. Ex A.W. Hill, *Apiaceae*)

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Sent for review: 12 September 2025 Revised accepted: 28 September 2025

Abstract

Purpose: This study investigated the phytochemistry and bioactive compounds in extracts of seed, leaf, and essential oils, as well as the in vitro antioxidant activity of *Petroselinum crispum*.
Methods: Preliminary phytochemical evaluations used standard methods, and Gas Chromatography-Mass Spectrometry (GC-MS) analyzed the bioactive compounds. The antioxidant activity was assessed by the 1, 1-diphenyl-2-picrylhydrazyl (DPPH) reduction test.
Results: The extracts contained major classes of phytochemicals, including flavonoids, alkaloids, terpenoids, and phenols; anthraquinones were absent in all extracts. Terpenoids were notably present in all extracts, with the highest in the seed essential oil (8.994 mg/g). GC–MS analysis identified 18 bioactive compounds in the aqueous seed extract and 26 in the ethanol seed extract, with Apiol making up 81.04% and 81.54%, respectively. For the leaf extract, 38 compounds in the aqueous form and 40 in the ethanol form were identified, with the highest percentages being 13.00% (Mono-Palmitin) and 17.58% (Palmitic acid). The GC–MS analysis of the essential oils revealed 30 compounds in the seed oil and 52 in the leaf oil, with Apiol at 88.93% and Oleic acid at 17.67%, respectively. The aqueous seed extract of *P. crispum* showed the strongest antioxidant activity, with an IC50 of 6.7 µg/mL, while all other extracts exhibited antioxidant activity lower than the standard ascorbic acid (IC50=7.1 µg/mL).
Conclusion: Overall the findings highlight numerous bioactive compounds in the seeds, leaves, and essential oil of *P. crispum*, with Apiol as the dominant compound in both the seed and essential oil. The presence of Apiol, along with other phenolics, volatile compounds, flavonoids, and terpenoids, contribute significantly to the plants' antioxidant potential. This property may offer valuable applications in culinary, pharmaceutical and therapeutic fields.

Keywords: Apiol, Gas Chromatography-Mass Spectroscopy, *Petroselinium crispum*, Phytochemical Constituent

Tropical Journal of Drug Research is indexed by Chemical Abstracts, Embase, Index Copernicus, EBSCO, African Index Medicus, JournalSeek, Directory of Open Access Journals
(DOAJ), African Journal Online, Bioline International, Open-J-Gate and Pharmacy Abstracts

INTRODUCTION

Aromatic and Medicinal plants play very important roles in the ethno-medical, food, cosmetic, and pharmaceutical industries. They represent an inexhaustible source of traditional and effective remedies due to bioactive compounds.[1] According to Gomathi, [2] bioactive molecules are compounds that occur in nature, part of the food chain, capable of interacting with one or more compounds of living tissue, exerting a synergistic effect on

human health. They play various roles within living organisms, such as serving as antioxidants, antimalarials, anticancer, antimicrobial agents, stimulants for the immune system, modifiers of detoxifying enzymes, contributors to anti-inflammatory processes, reducers of platelet activity, and facilitators of physiological functions including binding to pathogens. [3, 4, 5]

Petroselinum crispum (Mill) Nym. Ex A. Hill is a member of the carrot family, *Apiaceae*; an aromatic plant commonly known as garden parsley, used as a vegetable in soups, salads, meat, and sauces.[6] The unique aroma promotes its use as flavouring in food condiments, and also the seed is employed in the manufacturing of soaps, cosmetics, and perfumes.[7] Parsley is rich in biologically active compounds such as carotenoids, flavonoids, apiole, terpenoid compounds, phenylpropanoids, and furanocoumarins. The leaves and roots hold high content of Vitamins A, C, E, K, carotene, thiamine, niacin, folate, and minerals (Fe,Mg,Na,K,andZn).[6] There are two well-known species: *P. crispum* and *P. sativum*, which are commonly cultivated in Nigeria, and have been investigated for their nutritional and medicinal benefits.[8] The leaves, seeds and root of *P.crispum* are employed in traditional and folklore medicine, in many European, Mediterranean and Asian Countries of the World.[8,9] *P.crispum* has a wide range of traditional medicinal uses worldwide, including as a carminative, diuretic, and anti-inflammatory agent.[10] The plant has also been shown to have antioxidant, antibacterial, antifungal, antidiabetic, antihypertensive, antiplatelet, analgesic, anti-hyperuricemia, antihepatotoxic, anti-nephrotoxic, anticancer, wound healing, anti-obesity, and neuroprotective activities.[10,11] Recent studies in Nigeria have shown that the ethanol extract of *P.crispum* leaf has estrogenic properties. [12,13] All these biological functions and therapeutic potentials are due to the presence of the phytochemicals and bioactive components available for research and development.[11] Though with beneficial roles, some studies have shown *P.crispum* leaves and seeds to be phototoxic, abortifacient, nephrotoxic and hepatotoxic when the plant extracts are used at high concentrations.[3,14,15,16]

Essential oils are a mixture, typically comprising a diverse array of volatile compounds, including mono- and sesquiterpenes, as well as aromatic and aliphatic components derived from phenols extracted from parts of the plants.[17] Investigations on the essential oils of *P.crispum* show that the major compounds found include apiol, myristicin, limonene, and 1,3,8-p-menthatriene, accompanied by other components such as α and β-pinene, camphene, terpinolene, β-phellandrene, and myrcene.[18] In recent decades, interest has increased in the finding of naturally occurring antioxidants for food and medicinal materials, to replace synthetic antioxidants, which are being restricted due to their effects, such as carcinogenicity. [19] Natural antioxidants can protect the human body from free radicals and retard the progression of many chronic diseases, as well as retard lipid oxidative rancidity in foods.[19] There have been reports of essential oils' antioxidant properties, hence the use as a substitute for synthetic antioxidants.[20,21] The seeds, root, and leaves of *P.crispum* have been shown to yield a significant amount of essential oils, which are mostly employed as flavouring agents in the food, cosmetics, and hygiene industries.[21] Bioactive compounds can be extracted from plant materials by various scientific extraction methods. Most of which depend on the extraction power of the various solvents used, the application of heat, and mixing. Commonly used scientific methods include Soxhlet, maceration, reflux extraction, and hydro-distillation. [22] Gas Chromatography-Mass Spectrometry (GC-MS) is a highly effective and sensitive analytical technique most commonly used for the identification and quantification of biomolecules.[23]

Several studies have been conducted on *P.crispum* leaves; however, there is limited information on the constituents of the seeds and essential oils of *P.crispum*, especially for the specie grown in North Central Nigeria. This research will provide insight that can support its various beneficial roles in nutrition, pharmaceuticals, the cosmetic industry, and its potential therapeutic values, particularly in alternative medicine. Comparatively, the bioactive constituents and sources obtained via different solvent extractions will also enhance their medicinal applications for efficacious and standardized formulations. Therefore, this investigation aimed at analyzing the phytochemical constituents, in vitro-antioxidant potential of the aqueous and ethanol extracts of *P. crispum* seed, leaf, and essential oils; as well as identifying and quantifying the bioactive compounds present using GC-MS.

MATERIALS AND METHODS

Chemicals and Reagents

Ethanol (85%purity) 1,1-diphenyl-2-picrylhydrazyl (DPPH) Standard Ascorbic Acid) Sigma Aldrich USA. All other chemicals were of analytical grade.

Plant Collection and Identification

Fresh leaves and seeds of *P.crispum* were purchased from Gosa Market in Abuja Municipal Area Council, Abuja, North Central Nigeria, 900102 FCT, in February 2023. The plant's identification was done by a botanist in the department of Medicinal Plant Research (MPR) of the National Institute for Pharmaceutical Research and Traditional Medicine (NIPRD), Idu, Abuja. A Specimen Voucher number of NIPRD/H/7350 and NIPRD/H/7351 was deposited in the same unit for reference purposes.

Preparation of Crude Extracts of *P.crispum*
Ethanol Extract of *P.crispum* Seed (Et.PS) and Leaf (Et.PL)

The leaves were dried in the shade for two weeks and then pulverized into a fine powder using a commercial blender. The pulverized leaves and seeds (300grams each) were placed in separate containers, and extraction was done by the Cold Maceration method as adopted by Enefe [16], using 1200mL of 85% ethanol for 48hours with intermittent shaking and then filtered through muslin cloth and Whatman filter paper Number 1. The filtrate was concentrated to dryness using a rotary evaporator (KNF RC Neuberger USA) under reduced pressure at 50 °C. The ethanol extract was stored in the fume cupboard to allow the residual ethanol in the extract to evaporate, and then air-dried to yield the crude aqueous extract of *P.crispum.* The crude extracts were then stored under refrigerated conditions until used.

Aqueous Extract of *P.crispum* Seed (Aq.PS) and Leaf (Aq.PL)

A modified method of Gnintoungbe [24] was adopted for the aqueous seed extraction. The finely ground dried parsley seeds and leaves, weighing 300g each, were placed in seperate containers and soaked in distilled water (One and a half Liters) at an optimal temperature for 10 minutes, heated at 70 °C for 10minutes (for the seed only), then left for 48hours with intermittent shaking. Subsequently, the mixture was filtered through muslin cloth and Whatman Number 1 filter paper to obtain the aqueous extract. The filtrate was dried using a water bath (HH-4-CHINA WATER) set at 50°C. The extract was stored in a freeze 4°Cfor furtheruse.

Extraction of *P.crispum* Seed and Leaf Essential Oils from the (PSEO/PLEO) (Simultaneous Hydro-distillation method)

The method, as described by Osibote and Olajide [25, 26] was adopted. Distilled water (Three Liters) was added to 100 grams of pulverized parsley leaf/seed in a 5L round-bottom flask. Hydro-distillation was employed to extract the essential oil, which was then collected in n-hexane. The extraction process lasted for 4 hours, and the resulting essential oil was transferred into a glass vial. Anhydrous sodium sulfate (Na2SO4) was used to remove water from the extract. The resulting colorless essential oil with a pleasant scent was then stored in a dark container in a freezer at 4 °C for further use. The percentage (%) yield was calculated using equation 1

$$The\ \%\ yield = \frac{Wgt\ of\ extract\ (g)}{Wgt\ of\ pulverized\ plant\ material\ (g)} \times 10 \quad 1$$

$$---------- Eq1$$

Preliminary Phytochemical Screening.

The qualitative phytochemical screening was conducted on both the aqueous and ethanol extracts of *P.crispum* leaves and seeds, as well as on the essential oils. This was carried out using a conventional protocol as described by Odebiyi and Sofowora. [27] for the detection of major phytochemical constituents, including analysis for steroids, terpenoids, alkaloids, saponnins, tannis, flavonoids, phenols, volatile oils, cardiac glycosides, and anthraquinones. The quantitative phytochemical analysis was conducted on both the aqueous and ethanol extracts of *P.crispum* leaves and seeds, as well as the essential oil extracts, by standard methods as described by Harborne.[28]

Evaluation of In Vitro Antioxidant Activity (DPPH ASSAY)

The Antioxidant free radical scavenging activity was assessed using the DPPH (1, 1-diphenyl-2-picrylhydrazyl) method, with ascorbic acid as a standard, as described by Okan.[29] A 0.1mM solution of DPPH (Sigma Aldrich USA) in methanol was prepared, and 1.5mL of this solution was added to 1.5mL of the standard (ascorbic acid) / sample (extracts) in methanol at different concentrations (0.1-0.9 mg/ mL). The mixture was shaken vigorously and then allowed to stand at room temperature for 30minutes. Free radical scavenging was visually indicated by a colourimetric shift from dark violet to bright yellow. A blank was also prepared containing methanol and DPPH; the absorbance was taken at 517nm using a UV-VIS Spectrophotometer (Cecil CE 7400, 7000 series). The DPPH radical scavenging capacity was expressed as percentage (%) inhibition, which was calculated using equation 2:

$$Percentage\ (\%) inhibition \quad \frac{(A0 - A1 \times 100)}{A0} \quad --$$

$$----- Eq\ 2$$

Where
A0 -the absorbance of control, A1 -Absorbance of standard /sample
All measurements of free radical scavenging activity were performed in triplicate, and the mean ± SD was calculated. The concentrations of the extracts/ascorbic acid that caused a 50% reduction in DPPH radicals (IC50 in ug/mL) were determined from the regression curve relating scavenging activity to concentrations

GC -MS Analysis of the Extracts of *P.crispum*
The crude extracts of *P.crispum* were all analyzed for the presence of different bioactive and volatile compounds by the Gas chromatographic technique (GC-MS-QP 2010), Agilent Technologies with flame ionization detectors. The gas chromatograph was equipped with a capillary column measuring 30 meters in length, 250 micrometers in diameter, and coated with a 0.25 micrometer film, packed with HP-5MS 5% (phenyl methyl siloxane). Helium served as the carrier gas, flowing at a rate of 1 mL/min. The leaf and seed extracts/ essential oil extract were injected into the gas chromatographic column to separate their components. The temperature program for the analysis commenced with the column set at 70°C for 3 minutes, gradually increasing to 250°C at a rate of 4°C/min, and held for 4 minutes. Each sample run took a total of 52 minutes to complete. The mass spectrometer was equipped with ChemStation control for programming and data processing. An ionization energy of 70 eV was utilized to record the mass spectra.[23, 25]

Identification of Bioactive Compounds
The spectrum of the unidentified compounds was matched against spectra stored in the National Institute of Standards and Technology (NIST 1990) and the Wiley9 library database to identify the components of the extract as well as to determine their names, molecular weights, and structures.[30, 31]

Statistical Analysis
Values were in triplicate, and data obtained from the quantitative analysis were represented as mean ± standard deviation (mean ± SD). Microsoft Excel version 2.1 was used. Differences in means were analysed using Graph Pad Prism Software version 8.0) values of $p < 0.05$ significantly different

RESULT AND DISCUSSION

Preliminary Phytochemical Screening of *P. crispum* Seed, Leaf, and Essential Oil Extracts
The percentage extraction yield from this investigation is presented in Table 1. The Aq. PS and Et. PS gave percentage yields of 23%w/w and 34.4%w/w, respectively, while the Aq.PL and Et.PL yielded 13.4%w/w and 26.5%w/w, respectively. From this result, it can be seen that ethanol the solvent yielded a higher yield than aqueous; this is in agreement with the wealth of literature on the nature of ethanol as a polar solvent that can extract a broader spectrum of polar and nonpolar compounds.[32] The extraction yield from this study is shown to vary with other studies conducted in other environments and countries; this could be attributed to the differences in the plant species, weather, cultivation conditions, environmental conditions, and extraction methods.[3] The PSEO and PLEO gave percentage yield of 2.1%v/w and 0.88% v/w (dry weight). This finding is in agreement with a study conducted to determine essential oils from different cultivars by the hydro distillation method, and this showed a range of percentage yield (0.08-9.63%v/w).[33, 34]
The differences in essential oil yield and composition were also attributed to factors such as different geographical conditions, collection season, genetics, and plant species.[34] Phytochemicals are natural chemical constituents found in plants, and they have the ability to positively or negatively impact health. Crude plant extracts are typically a mixture of both active and inactive ingredients.[34,35] The result of the phytochemical screening from this study revealed the presence of flavonoids, saponins, alkaloids, glycosides, volatile oils, and terpenoids in the extracts; while the cardiac glycosides, steroids, and tannins were found in trace amounts in the seeds. Anthraquinone was absent in all the extracts. Table 1. This result is in agreement with studies conducted on the P. crispum leaves. [36, 37, 38] According to some authors, [34, 38] *P.crispum* leaves contain flavonoids (apin, luteolin, and apigenin-glycosides); volatile compounds (myristicin, apiole). In some other studies, coumaroyl-derived compounds were also detected.[39] The composition varies according to the authors, the geographical location of the plant, and species.[34] The quantitative phytochemical analysis revealed the presence of the major phytochemicals, occurring in varying amounts in the extracts as shown in Table 2; from not quantifiable (0), trace amounts (0.0052 ± 0.001) mg /g of flavonoids in the PLEO, to the highest concentrations of the flavonoids (0.082 ± 0.02) mg / g in the Et PL; the lowest concentrations of phenols in the PLEO (0.021± 0.003) mg / g and the highest in the Aq.PS (0.060 ± 0.002) mg /g; there was also the of presence of significant amounts of terpenoids in the seed and leaf extracts (2.07-2.76 mg/g) as indicated in Table 2.

Table 1: Qualitative Phytochemical Screening of Extracts of *P.crispum*

S/N	Extracts (Yield)	Aq.PS 23%w/w	Et.PS 34.4%w/w	Aq. PL 13.4% w/w	Et.PL 26.5% w/w	PSEO 2.1%v/w	PLEO 0.88%v/w
	Parameters						
1	Tannins	-	-	+	+	-	+
2	Steroids	+	-	+	-	+	-
3	Flavonoids	+	+	+	+	+	+
4	Saponins	+	+	+	+	+	+
5	Anthraquinones	-	-	-	-	-	-
6	Phenol	+	+	+	+	+	+
7	Alkaloids	+	+	+	+	+	+
8	Volatile oil	+	+	+	+	+	+
9	Terpenoids	+	+	+	+	+	+
10	Cardiac glycoside	+	+	+	-	-	-

Foot note: - absent, + present, (Aq.PS: Aqueous *P.crispum* Seed, Et.PS: Ethanol *P.crispum* Seed, Aq.PL: Aqueous *P.crispum* Leaf, Et.PL: Ethanol *P.crispum* Leaf, PSEO/PLEO: *P.crispum* Seed /Leaf Essential oil. Extraction yield in (%)

Table 2: Quantitative Phytochemical Screening of Different Solvent Extracts of the Seed, Leaf and Essential oils of *P.crispum*

S/N	Extracts	Aq.PS	Et.PS	Aq. PL	Et.PL	PSEO	PLEO
	Parameters						
1	Tannins (mg /g)	0	0	0.022 ± 0.001	0.099± 0.010	0	0.098±.002
2	Steroids (mg/g)	0.019 ±0.013	0	0.029± 0.0200	0	0.012 ±0.001	0
3	Flavonoids (mg/ g)	0.014 ± 0.001	0.063 ±0.001	0.078 ± 0.012	0.082 ±0.020	0.011± 0.001	0.005± 0.001
4	Saponins (mg/g)	0.028 ± 0.003	0.030± 0.002	0.018 ±0.010	0.0188±0.010	0.030± 0.020	0.010± 0.001
5	Phenol (mg/g)	0.060 ± 0.002	0.045 ±0.010	0.010 ± 0.030	0.046 ± 0.030	0.054± 0.020	0.021± 0.020
6	Alkaloids (mg/g)	0.051 ± 0.02	0.053± 0.001	0.057 ± 0.003	0.067± 0.001	0.051±0.020	0.063± 0.034
7	Terpenoids (mg/g)	2.100± 0.400	2.079± 0.330	2.760 ± 0.300	2.694 ± 0.300	*8.994± 0.350	4.855± 0.10

Values expressed as mean ± SD, Values in triplicates, 0 -not quantifiable * significantly different at $p<.0.05$

This finding agrees with the findings of Bakkali [40] in which terpenoids were also detected in significant amounts (2.100 mg/g) in the leaves. On the contrary, Farzei, 37 reported that the secondary metabolites of parsley leaves phytochemistry are the flavonoids, especially the flavones, flavanols, andglycosides.

In the present study, the essential oil extracts from both the seed and leaf revealed the presence of steroids, saponins, alkaloids, volatile oils, terpenoids, phenols, and flavonoids with a significant amount of terpenoids (8.994± 0.350) mg/g occurring in the PSEO. (Table 2.). This result is in agreement with another study, which found terpenoids to be the main constituent of the seed essential oil.[41] Terpenoid, a primary component of *P.crispum* essential oil, plays a role in the aromatic attributes and potential therapeutic benefits of P.crispum.[6] In plants, terpenoids serve as pigments (carotenoids), food preservatives, fragrances, and defence compounds against pathogens. They exhibit biological activities such as anticancer, antimicrobial, antimalarial, anti-inflammatory, antioxidant, and anti-allergic.[41, 42] From the present study, the high amounts of terpenoids (carotenoids, camphor, menthol, terpenes) and apiol investigated, especially confined in the seeds of *P.crispum*, give credence to the strong aromatic odour exhibited by the seeds; hence the application of the seed essential oils as a potential in natural food preservatives, cosmetics industry, and chemotherapy. The phytochemical constituent saponin was found to be highest in the Et PS extract (0.0302 mg/ g), followed by the PSEO extract (0.0300 mg/g) and then the Aq.PS (0.0278 mg/g) extract (Table 2). This is indicative of the potential use of *P.crispum* seed and oils as surfactants in the cosmetics

industry.[43] Saponin has been shown to possess potential foaming and emulsifying properties; thus, it contributes to the essential oil composition.[43,44] Saponins provide various health advantages, including anti-inflammatory, immune-boosting, and cholesterol-lowering effects.[45] Tannins were found in the Aq.PL (0.0218 mg/g) and Et.PL (0.099mg/g) and PLEO (0.098 mg/g), with the highest occurring in the leaves. Tannins are recognized for their potential health benefits, including antioxidant, anti-inflammatory, antimicrobial, and cardio-protective properties.[46] In the Aq.PS and Aq.PL, small quantities of steroids (0.0187 mg/g, 0.0288 mg/g) were found. Steroids, including phytosterols, are linked to anti-inflammatory properties and the reduction of cholesterol levels, as reported by Nattagh [47]. Alkaloids were detected in all the extracts, with higher concentrations found in the Et.PL (0.0674 mg/g) and PLEO (0.0630 mg/g). Alkaloids in *P.crispum* may exhibit a range of pharmacological effects, thereby increasing the therapeutic importance of the plant.[48] The phytochemical screening results from this study, revealed that the ethanol extracts had higher concentrations of flavonoids and alkaloids than the aqueous extracts, as indicated in Table 2 .The aqueous extracts showed a higher concentration of phenols and terpenoids when compared to the ethanol extracts. Table 2. It is known from the wealth of literature that ethanol solvent can extract a broader range of polar compounds.[23, 32] this could imply that ethanol solvent would be a better solvent for the extraction of flavonoids and alkaloids from *P.crispum*, while aqueous solution would be a better solvent for the extraction of phenolics and terpenoids from *P.crispum*. Further comparison of the phytochemical constituents of the seed and leaf revealed that the seed contained more saponins and phenols, while the leaf contained a higher concentration of flavonoids, tannins, alkaloids, and terpenoids. This property could also be harnessed for therapeutic purposes.

In vitro antioxidant Activity of *P. crispum* Seed, Leaf, and Essential oil extracts.

The scavenging ability of the standard ascorbic acid/ extract of parsley against DPPH is presented in Figure 1A-C, expressed in Concentration (µg/ mL) and (%inhibition). The IC50 is the concentration of the sample or standard that can scavenge 50% DPPH. The IC50 were determined from the equations obtained on each correlation curve plotted using Excel. (As adopted by Orisakeye[49])

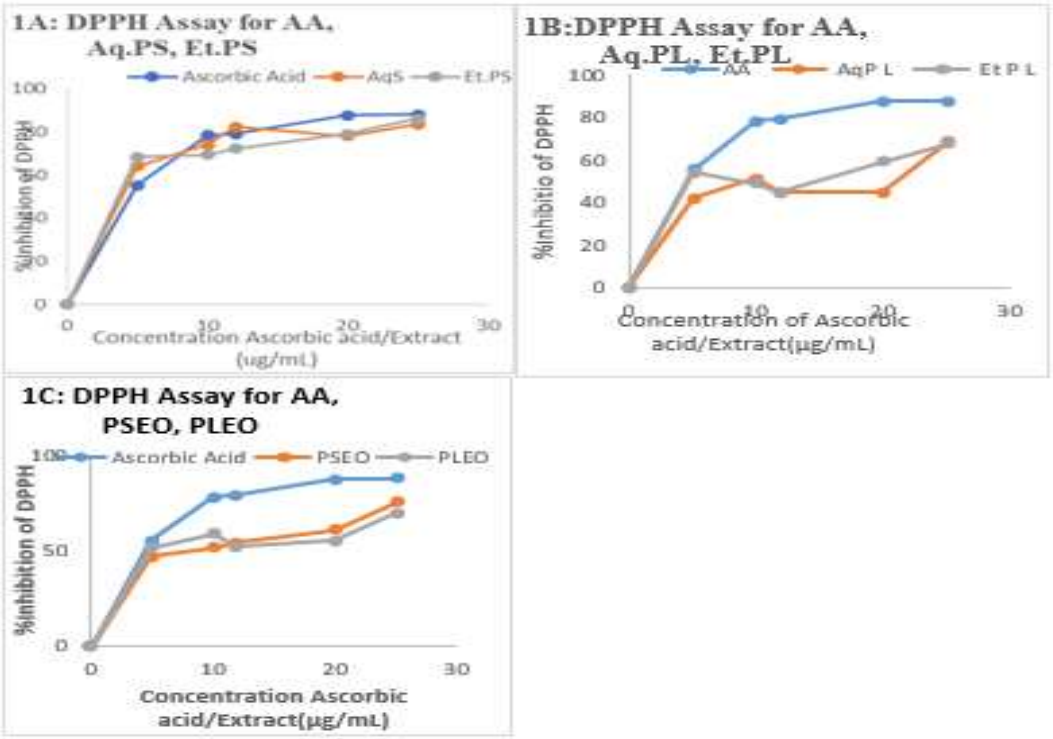

Figure 1A-C: Antioxidant Scavenging Activities of Ascorbic acid (AA), Seed (Aq.PS) (EPS) /leaf (Aq.PL) (Et.PL) and Essential oils of *P.crispum* -PSEO, PLEO on DPPH radical

The result revealed that Aq.PS exhibited the highest antioxidant activity (IC50=6.7 µg/mL) when compared to the other extracts and the standard ascorbic acid, though all other extracts, showed lesser antioxidant activities than the standard ascorbic acid AA; as indicated from the activities occurring in the order as follows: (Aq.PS > AA > Et.PS > PSEO > PLEO > Et.PL > Aq.PL); since a lower IC50 indicates a stronger antioxidant activity. Thus, the range of IC50 for the extracts is (6.7 – 16.1 µg /mL). IC50: (AA =7.1 µg/mL), Aq.PS (6.7 µg/mL), Et.PS (7.4 µg/mL), Aq.PL (16.1 µg/mL) Et.PL (14.1 µg/mL), PSEO (12.7 µg/mL), PLEO (12.9µg/mL). It is important to recall that a lower IC50 value indicates a stronger antioxidant activity; thus, a smaller concentration is needed to achieve 50% Inhibition. From this study, the Aq.PS extract exhibited the highest antioxidant activity (IC50=6.7 µg/mL), which correlates with the high content of phenolics and terpenoids identified in the seed extract. Tables 2 and 3. The PSEO (IC50 =12.7 µg/mL) also exhibited high content of terpenoids as well as phenolic compounds, thus showing antioxidant activity higher than the leaf oil, although lower than the standard ascorbic acid AA (IC50 =7.1 µg/mL). In accordance, several reports have established a correlation between the polypropenes, phenol, and flavonoid content of *P.crispum* leaves, seeds, stem and their antioxidant properties. 24,49,51,52 The lower antioxidant activities exhibited by some of the extracts (Et.PS, Et.PL, Aq.PL PSEO and PLEO) when compared to the standard ascorbic acid is shown to agreement with another study conducted using a similar method.24 They revealed that the antioxidant activity of aqueous parsley leaf extract, IC50 =63.66 µg/mL) to be lower when compared to the standard ascorbic acid IC50 (0.111µg/mL). In another study by Stitou, 51, the antioxidant power of methanolic and ethanolic extracts of *P.crispum* leaves was found to be high, with the IC50 values being 359 µg/mL and 19 µg/mL, respectively, by the DPPH radical inhibition method. Hinneburg [53] was also found by the same method, with an IC50 of 12000.0 µg/mL, which was lower than that of the standard ascorbic acid AA, as well as those of the present study. These differences in antioxidant abilities obtained by the authors could be due to variations in the composition of the plant resulting from different geographical locations, species and environmental and cultivation conditions.[53, 54] Wong and Kitts [54] also investigated the in vitro antioxidant effects of different vegetative organs of *P.crispum*, and they showed that the essential oils play a significant role in the scavenging effect. They attributed the antioxidant activity to the presence of polyphenolic compounds identified from the phytochemical screening (terpenoids, tannins, flavonoids, and phenols, in addition to their content of volatile and fixed oils. [20] Thus, we can conclude from the present study that the antioxidant power of *P. crispum* seed, leaf, and essential oils is due to the synergy between the volatile terpenoids, the high content of polypropenes, and flavonoid constituents.

GC-MS Analysis of *P crispum* Seed, Leaf, and Essential Oil Extracts

In this study, the GC-MS analysis of the extracts revealed varying numbers of bioactive compounds with predominant peaks and percentage abundances as indicated in the chromatograms (Figs 2-4), obtained at the end of fifty two minutes The active principles with their retention time (RT), Chemical Class (CC), Chemical formular(CF) Molecular Weight (MW) and percentage(%) abundances are presented in Tables 3-6.

The GC-MS analysis of Aq.PS and Et.PS extracts revealed the presence of 18 and 26 bioactive compounds, respectively, with the most abundant bioactive compound in the seed extract being Apiol (81.04% and 81.54%). While the GC-MS of the Aq.PL and Et.PL extracts revealed the presence of 38 and 40 bioactive compounds, respectively, with the predominant compounds being Monopalmitin (13.00%) and 9,7 Octadecenal (Z) (17.58%), respectively. The GC-MS analysis of the extracts also revealed the presence of phenylpropanoids (Apiol, myristicin), phenolics, fatty acids, esters, and hydrocarbons as the predominant chemical classes of compounds in *P. crispum* seed, leaf, and essential oils. Table 3-6.

Table 3: GC-MS of Bioactive compounds present in the aqueous extract of *P.crispum* seed (Aq.PS)

RT (min)	Chemical Name of Compounds	CC	CF	Mwt (g/mol)	% Abundance
3.799	3, 5-Dihydroxybenzoic acid.	Phenolic acid	$C_7H_6O_4$	496	0.19
6.039	1,3 Benzodioxole 4 methoxy 6-2 propenyl (Myristicin)	Phenylpropanoid	$C_{11}H_{12}O_3$	192	1.03
6.159	Benzene, 1,2,3-trimethoxy-5-(2-propenyl benzene (Elemicin)	Phenylpropanoid	$C_{12}H_{16}O_3$	180	0.40
.377	4-Methyl-2,5-dimethoxybenzaldehyde	Phenolics	$C_{10}H_{12}O_3$	180	0.25
7.160	Apiol	Phenylpropanoid	$C_{12}H_{14}O_4$	222	81.04
7.828	Octadecanoic acid (Stearic acid)	Fatty acid	$C_{19}H_{36}O_2$	24	0.27
8.177	Benzoic acid, 4-hydroxy-3,5-dimeth oxy-, hydrazide	Phenolics	$C_9H_{12}N_2O_4$	212	0.26
8.657	Hexadecenoic acid, methyl ester	Fatty acid ester	$C_{17}H_{34}O_2$	270	0.44
8.971	n-Hexadecenoic acid (Palmitic acid)	Fatty acid	$C_{16}H_{32}O_2$	256	5.38
8.971	9-Octadecenoic acid, methyl ester E (Methyl stearate)	Fatty acid ester	$C_{19}H_{36}O_2$	296	5.38
9.754	Oleic Acid	Fatty acid	$C_{18}H_{34}O_2$	282	3.19
10.143	9-Octadecenoic acid, (E)-	Fatty acid	$C_{18}H_{34}O_2$	298	0.53
10.840	Glycidyl palmitate	Fatty acid ester	$C_{19}H_{36}O_3$	312	0.91
0.886	p-(Dimethylamine)styryl phenyl ketone	Phenol compound	$C_{17}H_{17}NO$	251	0.33
11.795	Glycidyl oleate	Ester	$C_{21}H_{38}O_3$	338	1.52
11.920	1-Nonadecene	Unsaturated H/C	C_9H_{38}	266	0.36
12.069	Hexadecenoic acid, 1-(hydroxymethyl)-1,2-ethanediyl ester	Fatty acid ester	$C_{19}H_{38}O_4$	330	1.42
13.041	9-Octadecenoic acid (Z)-, 2,3-dihy droxypropyl ester	Fatty acid ester	$C_{21}H_{40}O_4$	356	1.05

Footnote: Retention time (RT), Chemical Class (CC), Chemical formular(CF) Molecular Weight (MW) and percentages(%) abundances

Table 4: GC-MS of Bioactive compounds present in the ethanol extract of *P.crispum* seed (Et.PS)

RT (min)	Chemical Name of Compounds	CC	CF	Mwt (g/mol)	%Abundance
3.508	2,6-Dihydroxybenzoic acid,	Phenolic acid	$C_7H_6O_4$	496	0.30
5.268	Cyclodisilazane-2,2,4,4-tetramine, N, N, N', N'-tetramethyl-1,3-bis[tris(methylamino)silyl]-	Amine	$C_{10}H_{40}N_{12}Si_{14}$	440	0.10
6.039	1,3-Benzodioxole, 4-methoxy-6-(2-propenyl)-(Myristicin)	Phenylpropanoid	$C_{11}H_{12}O_3$	192	1.03
6.159	Benzene, 1,2,3-trimethoxy-5-(2-pro phenyl)-(Elemicin)	Phenylpropanoid	$C_{10}H_{12}O_3$	180	0.40
6.377	4-Methyl-2,5-dimethoxybenzaldehyde	Phenolics	$C_{12}H_{16}O_3$	180	0.25
6.662	Cyclopentanemethanamine, 2-amino-	Amine	$C_6H_{14}N_2$	114	0.08
7.040	Methyl 4, 6-ethylidene-. Alpha. -d-Galactopyranoside	Glycoside	$C_9H_{16}O_6$	220	0.07
7.160	Apiol	Phenylpropanoid	$C_{12}H_{14}O_4$	222	81.54
7.691	Octadecanoic acid (Stearic acid)	Fatty acid	$C_{18}H_{36}O_2$	284	0.27
7.828	Benzoic acid, 4-hydroxy-3,5-dimethoxy-, hydrazide	Phenolic	$C_9H_{14}N_2O_4$	212	0.26
8.177	Cyclopentane carboxylic acid, butenyl)-2-oxo-, ethyl ester, (Z)-	Acid ester	$C_{12}H_{18}O_3$	210	0.12
8.657	Hexadecenoic acid, methyl ester (Palmitic acid ester)	Fatty acid ester	$C_{17}H_{34}O_2$	270	0.27
8.874	Palmitoleic acid	Fatty acid	$C_{16}H_{30}O_2$	254	5.3

8.971	n-Hexadecenoic acid (Palmitic acid)	Fatty acid	$C_{16}H_{32}O_2$	256	5.3
9.720	9-Octadecenoic acid, methyl ester, (E)-	Fatty acid	$C_{19}H_{36}O_2$	296	0.13
9.863	Heptadecanoic acid, 14-methyl-, methyl ester	Fatty acid	$C_{19}H_{38}O_2$	282	0.14
10.040	Oleic Acid	Fatty acid	$C_{18}H_{34}O_2$	298	3.19
10.143	9-Octadecenoic acid, (E)-	Fatty acid	$C_{19}H_{36}O_2$	282	0.53
10.840	Glycidyl palmitate	Fatty acid ester	$C_{19}H_{36}O_3$	312	0.91
10.886	p. Dimethylamine) styryl phenol ketone	Phenol compound	$C_{17}H_{17}NO$	251	0.33
11.795	Glycidyl Oleate	Fatty acid	$C_{21}H_{38}0_3$	338	1.52
11.920	Nonadecene	Unsaturated H/C	C_9H_{38}	266	0.36
12.069	Glycerol 1- Palmitate	Monoacylglycerol	$C_{19}H_{38}O_4$	330	1.42
12.269	2 Deoxyadenosine 3TMS derivative	Purine nucleoside	$C_{19}H_{37}N_5O_3Si_3$	467	0.07
12.663	Imidazole -2-methanol dodecyl	Aromatic compound	$C_{14}H_{26}N_2O$	238	0.13
13.041	9 Octadecenoic acid Z 2,3 dihydroxy propyl ester	Fatty acid ester	$C_{21}H_{40}O_4$	356	1.05

Table 5: GC-MS of Bioactive compounds present in the Aqueous Extract of *P.crispum* Leaf (Aq.PL)

RT (min)	**Chemical Name of Compounds**	**CC**	**CF**	**Mwt (g/mol)**	**% Abundance**
3.610	Carbamic acid,	Organic Carbonic Acids	$C_7H_{14}N_2O_3$	174	0.71
3.902	Endo-3-Methylenetricyclo [3.2.1.0(2,4)] oct-6-ene	Polyclic Alkene	C_9H_{10}	118	0.95
6.342	7-Ethyl-5-methyl-6,8-dioxabicyclo [3.2.1] oct-3-ene	Bicyclo Alkene	$C_9H_{14}O_2$	154	0.50
6.497	2-Heptanol, 5-ethyl-	Alcohols	$C9H_{20}O$	144	0.45
6.674	1H-Pyrazole, 1,3,5-trimethyl	Hydrogenated pyridines	$C_6H_{10}N_2$	110	0.46
7.045	3Cyclopentylpropionic acid, but-3 -yn-2-yl ester	Cyclic ester	$C_{12}H_{18}O_2$	194	0.51
7.148	3-(1-Methylhept-1-enyl)-5-methyl-2 5-dihydrofuran-2-one	Cyclic ester	$C_{13}H_{20}O_2$	208	0.96
7.554	Methyl 8,11,14-heptadecatrienoate	PUFA methyl ester	$C_{18}H_{30}O$	278	0.48
8.040	3-(3-Fluoroanilino)-1-(3-nitrophenyl) -1-propanone	Aromatic ketone	$C_{15}H_{13}FN_2O_3$	288	2.51
8.680	Palmitic acid, methyl ester	Fatty acid ester	$C_{17}H_{34}O_2$	270	0.45
8.846	Fluoro-3-nitrobenzyl alcohol	Phenol	$C_7H_6FNO_3$	171	0.55
8.988	n-Hexadecanoic acid (Palmitic acid)	Fatty acid	$C_{16}H_{32}O_2$	256	2.10
10.057	9-Octadecenoic acid, (E)-	Fatty acid	$C_{18}H_{34}O_2$	282	1.68
10.200	2-Butyl-5-methyl-3-(2-methylprop-2enyl) cyclohexanone	Aromatic Ketone	$C_{15}H_{26}O$	222	0.47
10.297	Palmitamide	Fatty acid amide	$C_{16}H_{33}NO$	255	3.71
10.360	Dimethylphenylphosphine	Organophosphorus	$C_8H_{11}P$	136	2.48
10.600	15-Hydroxypentadecanoic acid	PUFA	$C_{15}H_{30}O_3$	256	1.10
10.692	2,14-Dioxocyclotetradecyl) acetic acid methyl ester	Ester	$C_{17}H_{28}O_4$	296	1.55
10.760	5 Dodecanoyl acetate	Acid ester	$C_{14}H_{28}O_2$	228	0.98
10.852	Glycidyl palmitate	Fatty acid	$C_{19}H_{36}O_3$	312	11.74
10.949	5-Methyl-2-(1-methylethylidene) cyclohexan-1-one oxime	Ketoxime	$C_{10}H_{17}NO$	167	2.31
11.149	Z, Z-10,12-Hexadecadien-1-ol acetate	Acid	$C_{18}H_{32}O_2$	280	4.98
11.292	Oleic acid amide	Fatty acid amide	$C_{18}H_{35}NO$	281	9.51

11.555	Cyclooctane acetic acid, 2-oxo-		Cyclic Alkane	$C_{10}H_{16}O_3$	184	0.79
11.669	2-Propenamide, N-dodecyl-3-phenyl-cinnayl cinnamate		Phenolic acid	$C_{12}H_{33}NO$	315	1.73
11.755	1,2,3,4-Tetrahydronaphthalen-1-ylmethamine		Alkyl Amine	$C_{13}H_{11}F_5O_2$	294	2.45
11.800	9-Octadecenal, (Z)-		Fatty acid	$C_{18}H_{34}O$	266	8.56
11.926	1-Cyano-4-(5-hexenyl) benzene		Aromatic Nitrile	$C_{13}H_{15}N$	185	2.70
12.063	Hexadecenoic acid, 2-hydroxy-1-(hydroxymethyl)ethyl ester (MonoPalmitin)		Monoacylglycerol	$C_{19}H_{36}O_4$	330	13.00
12.263	15 Hydro squalene		Triterpenoid	$C_{33}H_{46}O_5$	522	0.53
12.360	Silane, dimethyl(2-methoxyethoxy) octadecycloxy		Inorganic Compound	$C_{23}H_{50}O_3Si$	402	2.17
12.532	Phosphorousdichloride (trichloro methyl)-		Inorganic Compound	CCL_5P	218	0.69
12.464	2-Propenamide, N-dodecyl-3-phenyl-cinnamate	Cinnamyl	Phenolic acid	$C_{21}H_{33}NO$	315	2.62
12.772	1H-Indole, 5-methyl-		Alkaloid	C_9H_9N	131	1.44
13.018	2,3-Dihydroxypropyl elaidate		Ester	$C_{21}H_{40}O_4$	356	8.87
13.235	9,12,15-Octadecatrienoic acid		Fatty acid	$C_{24}H_{40}O_4$	392	0.50
13.445	Carvacrol TBDMS		Terpenoid	$C_{16}H_{28}OSi$	264	0.68
13.915	Methyl-7-phenylindole		Alkaloid	$C_{17}H_{13}N$	207	0.72

Table 6: GC-MS of Bioactive compounds present in the Ethanol Extract of *P.crispum*_Leaf (Et.PL)

RT (min)	Chemical Name of Compounds	CC	CF	Mwt (g/mol)	%Abundance
3.891	1-Hexacosanol, TBDMS derivative	Fatty Alcohol	$C_{26}H_{54}O$	496	0.29
4.376	2-Buten-1-amine, N-butyl-,	Alkyl Amines	$C_8H_{17}N$	127	0.42
5.182	Silane, diethyloctadecyloxy (trans 4-methylcyclohexyloxy)	Organosilicon	$C_{29}H_{60}O_2Si$	468	0.56
5.245	Protocatechuic acid, 3TBDMS derivative	Phenolic acid	$C_{25}H_{48}O_2Si$	496	0.24
5.977	2,6-Dihydroxybenzoic acid,3TDMS derivative	Phenolic acid	$C_{25}H_{48}O_2Si$	496	0.53
7.126	Apiol	Phenylpropanoid	$C_{12}H_{14}O_4$	222	4.47
7.331	Pyroquilon	Hydro quinolones	$C_{11}H_{11}NO$	173	1.26
7.686	4-Benzothiazol-2-yl-2,5-diphenyl-3 trifluoromethyl-3,4-dihydro-2H-py razol-3-ol	Hydrogenated pyridines	$C_{23}H_{16}F_3N_3OS$	493	0.53
7.794	Ethyl cyclohexane propionate	Ester	$C_{11}H_{20}O_2$	184	0.31
8.006	Succinic acid, 2,2-dichloroethyl-methoxyphenyl ester	Succinic acid Ester	$C_{13}H_{14}Cl_2O_5$	320	0.32
8.063	Neophytadiene	Sesquiterpenes	$C_{20}H_{38}$	278	6.38
8.126	2-Pentadecanone, 6,10,14-trimethyl	Sesquiterpenes	$C_{18}H_{36}O$	268	0.78
8.223	1-Phenyloxycarbonyl-7-pentyl-7-aza bicyclo [4.1.0] heptane	Alcohol Ether	$C_{17}H_{31}NO_2$	281	0.27
8.343	1-Methoxy-3-(2-hydroxyethyl) nonane	Alcohol nonane	$C_{12}H_{26}O_2$	202	0.28
8.846	Tricyclo [6.3.3.0] tetradec-4-ene,10,13-dioxo-		$C_{14}H_{18}O_2$	218	0.66
8.977	n-Hexadecanoic acid (Palmitic acid)	Fatty acid	$C_{16}H_{32}O_2$	256	16.53

9.063	Hexadecanoic acid, ethyl ester (Ethyl Palmitate)	Fatty acid ester	$C_{17}H_{34}O_2$	270	7.44
9.629	11,13-Dimethyl-12-tetradecen-1-ol acetate	Acetate Ester	C18H34O2	282	0.35
9.777	Phytol	Diterpene alcohol	$C_{40}H_{40}O$	296	9.28
10.052	9,17-Octadecadienal, (Z)-	Fatty aldehyde	$C_{18}H_{36}O_2$	264	17.58
10.149	Octadecanoic acid (Stearic acid)	Fatty acid	$C_{18}H_{36}O_2$	284	0.76
10.229	Stearic acid ethyl ester	Fatty acid ester	$C_{20}H_{40}O_2$	312	1.85
10.658	Heptacos-1-ene	Alkene	$C_{27}H_{54}$	378	0.51
10.829	15-Hydroxypentadecanoic acid	Fatty acid	$C_{15}H_{30}O_3$	258	1.10
10.995	6-Octadecenoic acid, (Z)- Petroselinic acid	Fatty acid	$C_{18}H_{34}O_2$	282	0.29
11.149	9-Octadecenoic acid, (E)-	Fatty acid	$C_{18}H_{34}O_2$	282	4.75
11.309	Methyl 19-methyl-eicosanoate	Fatty acid Ester	$C_{22}H_{44}O_2$	340	1.12
11.841	Carbonic acid, but-3-en-1-yl decyl ester	Ester	$C_{19}H_{36}O_3$	312	1.08
12.064	Hexadecenoic acid, 2-hydroxy-1-(hydroxymethyl) ethyl ester (Monopalmitin)	Monoacylglycerol	$C_{19}H_{38}O_4$	330	3.31
12.349	3-Cyclopentylpropionic acid, ethyl	Ester	$C_{10}H_{18}O_2$	170	0.64
12.561	2-(3-Cyano-6,7-dimethylquinolin-2-ylsulfanyl)-N-(2-methoxyphenyl) acetamide	Acetamide	$C_{19}H_{19}N_3O_3S$	377	0.27
12.915	13-Tetradecen-1-ol acetate (Eicosanol)	Ester	$C_{16}H_{30}O_2$	254	1.22
13.372	3'-Chlorooxanilic acid N'-(3-ethox y-4-hydroxybenzylidene) hydrazide	Hydrazide	$C_{17}H_{16}ClN_3O_4$	361	0.64
13.635	alpha. -Tocospiro B (α tocopheroid)	Benzopyranoid	$C_{29}H_{50}O_4$	462	0.67
13.744	5-Hexenoic acid, 6- [p-chlorophenyl	Fatty acid	$C_{14}H_{13}ClO_4$	280	0.73
14.007	(1H) Pyrrole-3-carboxylic acid, 5- [cyano(4-morpholinyl) methyl]-1-(methoxymethyl)-, methyl ester	Heterocyclic Organic Compound	$C_{14}H_{19}N_3O_4$	293	1.34
14.990	Benzo[h]quinoline, 2,4-dimethyl-	Benzo quinolone	C15H13N	207	0.25
15.590	1H-Thiopyrano[3,4-c] pyridine-5-carbonitrile, 6-isobutylsulfanyl-3,3-dimethyl-8-morpholin-4-yl-3,4-dihydro-	Heterocyclic Organic Compound	C19H27N3OS	377	0.75
16.630	2,3,4-Trimethoxyphenylacetonitrile	Nitrile	C11H13NO3	207	9.17
17.282	Tantalum, tetra ethoxide (2,4-pentanedionato-O, O')-	Metal Alkoxide	$C_9H17Cl2O4Ta$	440	1.05

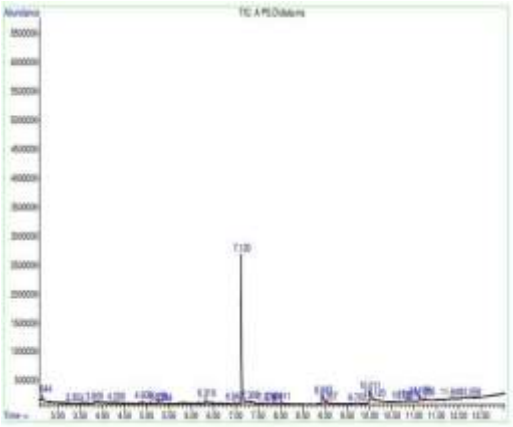

Figure 2: Chromatogram (GC-MS) for Aqueous Extract of *P.crispum* Seed.

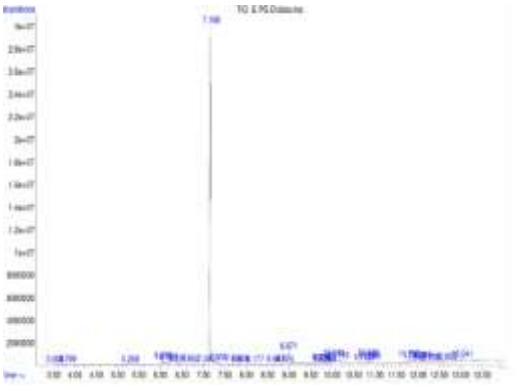

Figure 3: Chromatogram for Ethanol Extract of *P.crispum* Seed**.** Sample Name Et. PS

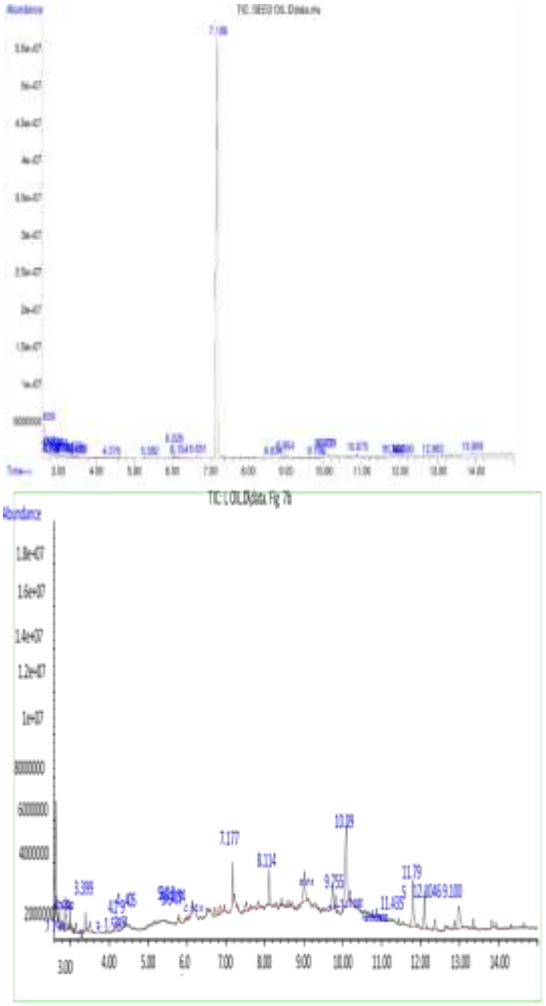

Figure 4: Chromatogram (GC-MS) of the Essential oil Extract from *P.crispum* Seed Essential Oil (PSEO)a and Leaf Essential Oil (PLEO)b]

It also showed the presence of a high percentage of the bioactive compound Apiol, in the seed extracts (Aq.PS (81.04%), Et.PS (81.54%) and PSEO (88.93%) when compared to the leaf extracts (Aq.PL (0) Et.PL (4.47%) PLEO (2.71%). The GC-MS of the essential oils for the seed and leaf extracts identified 30 and 52 bioactive compounds, respectively, with the predominant compounds and percentage abundances identified to be (88.93%) for Apiol and (17.67%) for Oleic acid, respectively. (Table 7) Some other classes of the major compounds identified include: the fatty acids (Palmitic acid, 6 Octadecenoic acid (Petroselinic acid) and 8 Octadecenoic acid methyl ester); Phenyl propanoids (myristicin, elemicin). Major bioactive compounds identified in the seed and leaf oils along with their respective percentage abundances, Chemical class (CC), Chemical formula (CF), and Molecular weight (Mwt) are indicated in Table 6. In the present study, the PSEO showed the principal compounds to be total apiol (88.93%), Myristicin (1.56%), Oleic acid (3.95%), and elemicin (0.24%). This finding is in agreement with some other studies conducted on parsley seed and leaf oils, [17, 18,34,54,56], where Apiol was identified as the principal compound, although it was present in alower percentage compared to the present study. The dominant compounds identified by the authors were apiol(23.5%), α-pinene (19%) and Myristicin(17.2%).[34] Other findings included Apiol (15.28%), Myristicin (13.70%) and α-pinene (11.08%).[18] Additionally they were also found to be present in percentages of Apiol (49.05%), Myristicin (21.01%).17 and Apiol (14.21%), myristicin (12.69%) [54] On the other hand, myristicin was identified as the predominant compound in the leaf extract and seed oils by yet some other authors; they are (Myristicin 36%-42%),[55]; myristicin (41.45%)[34], myristicin (36.15 %), Apiole (20.97%)[56] These variations, have been attributed to the differences in species, genetics, weather, environmental conditions and extraction methods.[56].

Figure 7a showed the chromatogram for the seed and leaf essential oils, with a predominant peak at RT 7.186 minutes for the bioactive compound Apiol (81.93%) in the seed, and the same compound Apiol (2.76%) was identified in the PLEO at RT of 7.17 minutes. Figure 7b. The highest peak for the PLEO identified at RT 8.114 minutes was Oleic acid with a percentage of 17.67%

Clearly, the bioactive compound Apiol (1 allyl 2,5 dimethoxy3,4 methylenedioxybenzene), a phenylpropanoid, was found to be mostly concentrated in the seed and seed oil (88.93%) of P.crispum and much lower in the leaves and leaf oil(2.76%) (Table 7). *P. crispum* apiol, in another study conducted by Mirmohammadmakki, [56] was also found to be higher in the seed oil (11.3–67.5%) than in the leaf oil (0.2–5.2%). Apiol is a key constituent responsible for *P. crispum's* unique aroma, characterized by a potent, spicy scent; hence, it is frequently utilized as a flavour enhancer in various food and beverage products.[56] Apiol, along with carotol, offers a range of health benefits, including antimicrobial, anti-inflammatory, digestive, antioxidant and natural diuretic properties as well as anticancer, and support for respiratory health and skincare.[6,62] However, considering the potential toxicity of Apiol, especially at high doses, it is important to proceed with caution in the use of Apiol or any herbal remedy containing Apiol for medicinal purposes. In addition, a study has reported that the

bioactive compound, Apiol, is responsible for the plant exhibiting abortifacient properties Tisserand and Young.[58] 9-Octadecenoic acid methyl ester, a fatty acid ester, was also identified in higher percentages in the leaf than in the seeds essential oils, as indicated in Table 7.Other bioactive compounds identified in the extracts include compounds of the chemical class of fatty acids and esters, terpenes, (di, tri and sesquiterpenes), alcohols, aldehyde esters, ether, epoxides, ketones, amines and phenolics; Tables 3-6 All these chemical classes possessing one or more biological activities including, Antioxidant and Antimicrobial[17], pesticide, nematicide inhibitor, anti-inflammatory, antiandrogenic and anticancer properties[64], as well as being beneficial in culinary, cosmetic, pharmaceutical industry, and in ethnomedicine.[11]

Table 7: GC-MS of Major Bioactive compounds present in extracts of *P.crispum* Seed Essential Oil (PSEO) and Leaf Essential Oil (PLEO)

RT (min)	Chemical Name of Compounds	CC	CF	Mwt (g/mol)	PSEO %Abundance	PLEO %Abundance
2.639	Undecane	Fatty acid	$C_{11}H_{24}$	156	2.16	7.28
2.725	Benzene, 1,3-diethyl-5-methyl-	Aromatic H/C	$C_{11}H_{16}$	148	0.20	2.06
2.879	trans-Decalin, 2-methyl-	Bicyclic H/C	$C_{11}H_{20}$	152	0.98	3.21
6.028	1,3- Benzodioxole, 4-methoxy-6-(2-propenyl) (Myristicin)	Phenylpropanoid	$C_{11}H_{12}O_3$	192	1.56	-
6.154	Benzene, 1,2,3-trimethoxy-5-(2-propenyl benzene (Elemicin)	Phenylpropanoid	$C_{12}H_{16}O_3$	208	0.24	-
6.651	Carotol	Sesquiterpenoids	$C_{15}H_{26}O$	222	0.24	-
7.188	Apiol	Phenylpropanoid	$C_{12}H_{14}O_4$	222	88.93	2.76
8.114	Neophytadiene	Diterpene	$C_{20}H_{38}$	280	-	2.98
8.954	n-Hexadecanoic (Palmitic acid)	Saturated Fatty acid	$C_{16}H_{32}O_2$	256	0.75	5.21
8.114	Oleic Acid	Unsaturated Fatty acid	$C_{18}H_{34}O_2$	298	3.95	17.67
9.755	9- Octadecenoic acid, Z methyl ester	Fatty acid ester	$C_{19}H_{36}O_2$	297	-	3.84
11.80	8 Octadecenoic acid methyl ester	Fatty acid ester	$C_{19}H_{36}O_2$	297	-	6.98
12.984	6Octadecenoic acid (Petroselinic acid)	Fatty acid	$C_{18}H_{34}O_2$	282	-	5.17

Footnote: Retention time (RT), Chemical Class (CC), Chemical formular (CF) Molecular Weight (MW) and percentage (%) abundances

Myristicin (1,3-benzodioxole-4-methoxy-6-(2-propenyl), another notable constituent found in the seed and seed oil in this present study, has also been shown to be present as the principal compound in some other studies, as previuosly discussed.[34, 55, 56] Myristicin is known for its antimicrobial properties,[18] as well as contributing to the overall medicinal potential of *P. crispum* seed, leaf, and essential oil.[18,61] Palmitic acid (Hexadecanoic acid), another dominant compound, was found to be present in all the extracts, with the highest occurring in the Et.PL extract (16.53%). Hexadecanoic acid is a saturated fatty acid with many biological activities, including as a hypocholesterolemic agent, antioxidant, nematicide, pesticide[62,63] [64], antibacterial and antifungal properties, as well as the ability to alter immunological responses directly on T-cells.[65] Table 8 showed the Comparison of the bioactive compounds identified in the extracts, the GC-MS analysis revealed the seed extracts to contain higher percentages of phenylpropanoids and fatty acid compounds while the leaf extracts showed a higher percentages of the fatty acids, esters and the terpene compound table 8.

Table 8: Comparism of the percentage (%) abundances of the dominant Bioactive Compounds identified in all the Extracts. (Chemical Classes CC, total number of compounds identified in each extract in parenthesis)

			Extracts					
S/N	**Predominant Compounds Identified**	**CC**	**Aq.PS (18)**	**Et.PS (26)**	**Aq.PL (38)**	**Et. PL (40)**	**PSEO (30)**	**PLEO (52)**
1.	Apiol C12H14O4	Phenylpropanoid	81.04**%**	81.54**%**	-	4.47%	88.93 %	2.76%
2	1,3 Benzodioxole 4 methoxy 6-2 propenyl (Myristicin)$C_{11}H_{12}O_3$	Phenylpropanoid	1.03%	1.03%	-	-	1.56%	-
3	n-Hexadecenoic acid (Palmitic acid) $C_{16}H_{32}O_2$	Fatty acid	5.38%	5.3%	2.10%	16.53%	0.75%	5.21%
4	n-Hexadecenoic acid methyl ester (Palmitic acid methyl ester $C_{17}H_{34}O_2$	Fatty acid ester	0.44%	0.27%	0.45%	-	-	-
5	9-Octadecenoic acid, methyl ester (E)-$C_{19}H_{36}O_2$	Fatty acid ester	5.38%	5.38%	-	-	0.73%	6.98**%**
6	Oleic Acid $C_{18}H_{34}O_2$	Fatty acid	2.99%	3.19%	-	-	3.95%	17.67 %
7	Hexadecenoic acid, 2-hydroxy-1-(hydroxymethyl) ethyl ester (MonoPalmitin) $C_{19}H_{38}O_4$	Fatty acid ester	-	-	13.00%	3.31%	-	-
8	Glycidyl palmitate $C_{19}H_{36}O_3$	Fatty acid ester	0.91%	0.91%	11.74%	-	-	-
9	Neophytadiene $C_{20}H_{38}$	Sesquiterpene	-	-	-	6.38%	-	2.98%
10.	Phytol $C_{21}H_{33}NO$	Diterpene alcohol	-	-	-	9.28%	-	1.14%
11	Hydroxy Elaidate $C_{18}H_{33}O_3$	Esters	-	-	8.87%	-	-	-
12	Cinnamyl Cinnamate$C_{21}H_{33}NO$	Phenolics	-	-	1.73%	1.73%	-	-
13	9-Octadecenoic acid, methyl ester (Z) $C_{19}H_{36}0_2$	Fatty acid ester	-	-	-	-	-	3.84%
14	6-Octadecenoic acid (Petroselinic acid) $C_{18}H_{34}O_2$	Fatty acid	-	-	-	-	-	5.17%
15	9-Octadecanel$C_{18}H_{34}O$	Fatty Aldehyde	-	-	8.75%	-	-	-

Legend: Total number of Bioactive Compounds Identified in extracts in parentheses ( ), - compound not detected Chemical Class (CC), and percentage abundances (%)

CONCLUSION

This study revealed a high content of terpenoids in the seeds, leaves, and essential oils of *P. crispum*. Apiol was found to be the most abundant bioactive compound in the seed extracts of *P. crispum* as well as in the essential oils of the seed, which accounts for the distinctive aromatic scent. *P. crispum* seed species from North Central Nigeria revealed a very high percentage of the bioactive compound Apiol, in comparison with most other studies conducted on *P. crispum* outside Nigeria.

The presence of this bioactive compound, together with other phenolic compounds, volatile compounds, flavonoids, and terpenoids, confers good antioxidant properties to the plant; this property could be harnessed by various industries. The diverse array of phytochemicals and bioactive constituents identified through the GC-MS analysis of *P. crispum* extracts suggests potential health advantages, thereby enhancing the understanding of the possible therapeutic, pharmaceutical, and nutritional benefits, as well as their applications in ethno medicine. Further research could be conducted to isolate and separate the predominant bioactive compounds thereby harnessing their anticancer potential.

CONFLICT OF INTEREST

The authors declare no conflict of interest.

AUTHORS DECLARATION

The authors hereby declare that the works presented in this article are original and that any liability for claims relating to the content of this article will be borne by them.

ACKNOWLEDGMENTS

The Authors are grateful to the staff of the EBIC Integrated Laboratory, Port Harcourt, Rivers State, Nigeria, for their support in the GC-MS analysis, and to Mr. Lateef Akeem Adeyanju of NIPRD Abuja, for his contributions to the identification of the plants.

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