Communication in Physical Sciences 2025, 12(4): 1370-1380

GC-MS Profiling of Bioactive Compounds in Methanol Extracts of Spices Used in Ibibio Postpartum Healthcare

Godwin Ndarake Enin, Itoro Joseph Archibong, Itoro Nyakno Willie and Ndifreke Ime Asuquo

Received: 11 February 2025/Accepted: 02 March 2025/Published: 08 March 2025
https://dx.doi.org/10.4314/cps.v12i4.16

Abstract: *Piper nigrum and Xylopia aethiopica are commonly used in postpartum health practices among the Ibibio people of Nigeria due to their reputed medicinal properties. This study aimed to investigate the phytochemical composition and identify bioactive compounds present in the methanol extracts of these spices. Qualitative phytochemical screening using a standard procedure revealed the presence of saponins, tannins, flavonoids, and cardiac glycosides in both extracts. Gas Chromatography-Mass Spectrometry (GC-MS) analysis identified 21 compounds in Piper nigrum and 47 compounds in Xylopia aethiopica. Major constituents in Piper nigrum included α-bisabolol (4.50%) decahydro-1,1,7-trimethyl-4-methylene-, [1ar-(1aα,4aα,7β,7bα)]- (6.73%), 1,6,10-Dodecatrien-3-ol, 3,7,11-trimethyl- (7.84%), 4H-Pyran-4-one, 2,3-dihydro-3,5-dihydroxy-6-methyl- (8.02%), apiol (10.69%), 1H-Cycloprop[e]azulen-7-ol, decahydro-1,1,7-trimethyl-4-methylene-, [1ar-(1aα,4aα,7β,7bα)]- (6.73%) and naphthalene, decahydro-1,1-dimethyl- (31.89%) while prominent compounds in Xylopia aethiopica were bicyclo[3.1.1]heptan-3-ol, 6,6-dimethyl-2-methylene- (33.97%), 9-[((1,3-benzodioxol-5-ylmethyl)amino]octahydro-2,5a-dimethyl- (11.11%), and 9-Octadecenoic acid (Z)-, methyl ester (8.76%). Several of these compounds are known for their antimicrobial, anti-inflammatory, and antioxidant activities. These findings support the traditional use of these spices in postpartum care and provide a scientific basis for their continued therapeutic application among the Ibibio people.*

Keywords: *Piper nigrum* and *Xylopia aethiopica*, spices, phytochemical composition, GC-MS analysis.

Godwin Ndarake Enin*
Department of Chemistry, Faculty of Physical Sciences, University of Uyo, Uyo, Nigeria
Email: gowinenin@uniuyo.edu.ng
Orcid id: 0000-0001-7611-722X

Itoro Joseph Archibong
Department of Animal and Environmental Biology, University of Uyo, Nigeria
Email: itoroarchibong@uniuyo.edu.ng

Itoro Nyakno Willie
Department of Chemistry, Faculty of Physical Sciences, Akwa Ibom State University, Ikot Akpaden, Nigeria
Email: itoro_willienyakno@yahoo.com

Ndifreke Ime Asuquo
Department of Chemistry, Faculty of Physical Sciences, University of Uyo, Uyo, Nigeria
Email: ndifrekeasuquo009@gmail.com

1.0 Introduction

Spices and herbs have long been integral to various cultures, not only for enhancing the taste and aroma of food but also for preserving it and offering medicinal benefits. Historically, different civilisations recognised their therapeutic value (Sachan *et al*., 2018; Gannenas *et al*., 2020). In the context of postpartum care, certain plants are known for their wide-ranging pharmacological effects, supporting recovery for new mothers and promoting the health of newborns. These plants are often used in dietary treatments, either alone or in combination and are sometimes categorized as bioenhancers and immunomodulators (Gidwani *et al*., 2022; Patil *et al*., 2022). Bioenhancers are agents that, while not pharmacologically active on their own, can boost the effectiveness of other drugs when used together.

Postpartum diet therapy often involves herbal preparations such as decoctions, infusions, and cold extracts (Fadzil *et al*., 2016; Sibeko, Johns and Cordeiro, 2021). These remedies are traditionally believed to help strengthen both body and mind, and to prevent common postpartum issues like depression, body pain, sleep disturbances, digestive problems, and oxidative stress (Kuroda *et al*., 2010; Jaber and Al-Zeidaneen, 2021). Additionally, this herbal nutrition supports the infant's growth and development, as active plant compounds can be transferred from mother to child through breastfeeding. In regions like South Southern Nigeria, some of these herbs are even used for contraceptive purposes and for managing postnatal complications in nursing mothers. Medicinal plants are frequently relied upon as the main source of therapeutic agents during the postpartum phase (Okafor and Rizzuto, 1994).

These herbs are credited with a variety of benefits, including expelling lochia, minimizing mild hemorrhages, contracting the uterus, aiding physical recovery, promoting lactation, boosting maternal strength, and treating infant illnesses (Mills *et al*., 2006; Sibeko and Johns, 2021). Feeding postpartum mothers with a variety of herbs is believed to be advantageous for both mother and baby. Scientific evidence suggests that bioactive compounds from such herbs can pass through breast milk without degrading (Bardanzellu *et al*., 2020; Sánchez *et al*., 2021). This transfer of herbal compounds to the infant has been validated through modern research as beneficial.

These herbs and spices are rich in organic compounds that have specific physiological effects on the human body. These bioactive substances include tannins, alkaloids, carbohydrates, triterpenoids, steroids, and flavonoids. Collectively, they are known as phytochemicals compounds. Apart from their therapeutic role, phytochemicals serve vital functions in plants, such as protecting the plant from disease, environmental stressors, and against pathogens, and they also contribute to the plants' colour, taste, and fragrance. Broadly, phytochemicals safeguard plant cells against environmental challenges such as pollution, stress, drought, ultraviolet radiation, and microbial attacks (Saleem *et al*., 2022). Although these spices have long been used in traditional Ibibio postpartum practices, there is still limited understanding of their bioactive components. This knowledge gap highlights the need to investigate their active constituents. Therefore, this study aims to identify and profile the bioactive compounds present in the methanol extracts of *Piper nigrum* and *Xylopia aethiopica*.

2.0 Materials and Methods

2.1 Plant Collection and Identification

Two commonly used spices, *Xylopia aethiopica* (African pepper) and *Piper nigrum* (Black pepper), were procured from Urua Afaha market in Uyo, Akwa Ibom State, Nigeria, in July 2023. The plant materials were identified and authenticated at the Department of Botany and Ecological Studies, University of Uyo, Nigeria. Voucher specimens were deposited for future reference.

2.2 Preparation of Extracts

The spice samples were thoroughly washed with distilled water to remove surface contaminants, shade-dried for five days, and then ground into fine powder using a laboratory mill. Sixty grams (60 g) of each powdered sample were soaked in 300 mL of methanol for 48 hours at room temperature with occasional stirring. The mixtures were filtered using Whatman No. 1 filter paper, and the filtrates were concentrated under reduced pressure using a rotary evaporator at 40 °C to obtain the crude methanol extracts.

The dry extracts were weighed, and the percentage yield was calculated using the formula:
{Yield (%)} = {{Weight of extract (g)}} \ {Weight of plant sample (g)}} × 100.

2.3 Phytochemical Screening

Preliminary phytochemical screening was conducted to detect the presence of flavonoids, alkaloids, saponins, tannins, and cardiac glycosides using standard procedures (Ouandaogo *et al*., 2023).

2.3.1 Test for Flavonoids

To 0.2 g of the extract, 2 mL of distilled water was added and filtered. One milliliter (1 mL) of 5% sodium hydroxide solution was then added. A color change from dark green to yellow indicated the presence of flavonoids.

2.3.2 Test for Saponins

To 0.2 g of the extract in a test tube, 5 mL of distilled water was added. The mixture was shaken vigorously for 60 seconds and allowed to stand for 15 minutes. Persistent frothing indicated the presence of saponins.

2.3.3 Test for Alkaloids

To 0.2 g of the extract dissolved in ethanol, 5 mL of 1% hydrochloric acid was added, warmed, and filtered. Dragendorff's reagent was added to 2 mL of the filtrate. The appearance of a reddish precipitate indicated the presence of alkaloids.

2.3.4 Test for Tannins

To 0.2 g of the extract, 5 mL of distilled water was added and filtered. Two drops of 1% ferric chloride solution were added to 2 mL of the filtrate. A blue-black or greenish-black coloration indicated the presence of tannins.

2.3.5 Test for Cardiac Glycosides

To 0.2 g of the extract dissolved in chloroform, 1 mL of concentrated sulfuric acid (H_2SO_4) was carefully added down the side of the test tube. The formation of a reddish-brown ring at the interface indicated the presence of the steroidal nucleus characteristic of cardiac glycosides.\

2.4 GC-MS Analysis

Gas Chromatography-Mass Spectrometry (GC-MS) analysis was conducted using a Shimadzu QP2010SE GC-MS system equipped with an Rtx-5MS capillary column (30 m × 0.25 mm ID × 0.25 µm film thickness). Helium was used as the carrier gas at a constant flow rate of 1.0 mL/min. One microliter (1 µL) of the methanolic extract was injected in split mode at a split ratio of 10:1.
The oven temperature was initially set at 60 °C, then increased at a rate of 5 °C/min to 180 °C, followed by a ramp of 20 °C/min to 250 °C. The ion source temperature was maintained at 230 °C, and electron ionization was performed at 70 eV. Mass spectra were recorded over the 40–550 m/z range. Compounds were identified by comparing their mass spectra with those in the National Institute of Standards and Technology (NIST) library (Kadhim *et al*., 2016).

3.0 Results and Discussion

The chemical composition of *Piper nigrum* and *Xylopia aethiopica* extracts was determined using Gas Chromatography-Mass Spectrometry (GC-MS). This analytical method is widely used for the identification of bioactive compounds in complex plant matrices due to its sensitivity, accuracy, and ability to separate volatile and semi-volatile organic compounds. The GC-MS profiles of these two medicinal plants reveal the presence of diverse chemical constituents, many of which are known to exhibit pharmacological and therapeutic properties. Below is the detailed interpretation and discussion of the bioactive compounds identified in each plant species.

3.1 Bioactive Compounds Identified in Piper nigrum

The GC-MS analysis of *Piper nigrum* revealed the presence of 21 bioactive compounds. These compounds were identified based on their retention time (RT), molecular formula (MF), molecular weight (MW), and relative abundance (Area %). Table 1 presents the list of these constituents, including their respective chemical identities.

The most abundant compound in *Piper nigrum* was Naphthalene, decahydro-1,1-dimethyl-, which had a peak area of 31.98% at a retention time of 21.941 minutes. This compound is a saturated polycyclic hydrocarbon derivative that may contribute to the insecticidal and antimicrobial properties of the plant (Pandey et at., 2018)

Table 1. Bioactive Compounds in GC-MS of *Piper nigrum*

Peak	Name	MF	RT	MW	Area %
1	2-Furanmethanol	$C_5H_6O_2$	8.234	98	1.77
2	4-Cyclopentene-1,3-dione	$C_5H_4O_2$	8.880	96	2.86
3	Cyclohexanone	$C_6H_{10}O$	9.437	98	1.79
4	4H-Pyran-4-one, 2,3-dihydro-3,5-dihydroxy-6-methyl-	$C_6H_8O_4$	12.842	144	8.02
5	5-Hydroxymethylfurfural	$C_6H_6O_3$	14.018	126	4.05
6	Cis-β-Farnesene	$C_{15}H_{24}$	16.079	204	1.16
7	β-Bisabolene	$C_{15}H_{24}$	16.953	204	3.37
8	1,6,10-Dodecatrien-3-ol, 3,7,11-trimethyl-,	$C_{15}H_{26}O$	17.445	222	7.84
9	3,7-Cyclodecadiene-1-methanol, alpha, alpha, 4,8-tetramethyl-, [s-(Z,Z)]	$C_{15}H_{26}O$	17.736	222	2.21
10	1,2-Cyclohexanediol, 1-methyl-4-(1-methylethenyl)-	$C_{10}H_{18}O_2$	17.843	170	1.11
11	Cubenol	$C_{15}H_{26}O$	18.295	222	1.58
12	Caryophyllene oxide	$C_{15}H_{24}O$	18.400	220	1.28
13	Apiol	$C_{12}H_{14}O_4$	18.533	222	10.69
14	1H-Cycloprop[e]azulen-7-ol, decahydro-1,1,7-trimethyl-4-methylene-, [1ar-(1aα,4aα,7β,7bα)]-	$C_{15}H_{24}O$	18.811	220	6.73
15	α-Bisabolol	$C_{15}H_{26}O$	19.166	222	4.50
	2-Naphathalenemethanol, decahydro-α,α,4a-trimetyl-8-methylene-, [2R-(2α,4aα,8aβ)]-	$C_{15}H_{26}O$	19.223	222	2.83
17	Naphthalene, decahydro-1,1-dimethyl-	$C_{12}H_{22}$	21.941	166	31.98
18	Naphthalene, decahydro-1,1-dimethyl-	$C_{12}H_{22}$	23.222	166	1.21
19	Cyclopropane, 1-heptanoyl-3-methylene-2-pentyl-	$C_{16}H_{28}O$	24.485	236	1.71
20	N-(1-Cyclohexen-1-yl)piperdine	$C_{11}H_{19}N$	24.556	165	2.40
21	Pyrimidin-4-ol, 6-methyl-2-(1-piperidyl)-	$C_{10}H_{15}N_3O$	24.848	193	1.46

Another significant compound was Apiol (Area: 10.69%; RT: 18.533 min), a phenylpropanoid with known antioxidant, anti-inflammatory, and uterotonic properties (Guidi & Landi, 2014). The high abundance of apiol in *Piper nigrum* suggests a potential role in traditional medicine, particularly in treating menstrual disorders and inflammation (Salehi *et al.*, 2019). Also notable is 4H-Pyran-4-one, 2,3-dihydro-3,5-dihydroxy-6-methyl- (Area: 8.02%), a derivative of maltol known for its antioxidant and flavor-enhancing properties. The presence of this compound supports the use of *Piper nigrum* as a flavoring and preservative agent (Abdulazeez *et al*., 2016).

1,6,10-Dodecatrien-3-ol, 3,7,11-trimethyl- (Area: 7.84%) and α-Bisabolol (Area: 4.50%) are sesquiterpenoids with strong anti-inflammatory, antimicrobial, and wound-healing activities (Schepetkin *et al*., 2022). These compounds may explain the wide medicinal use of *Piper nigrum* in treating skin infections and inflammation.

Other minor but pharmacologically important compounds include Caryophyllene oxide (1.28%) and β-Bisabolene (3.37%), both of which are known to exert antifungal and anticancer activities (Banik & Das, 2023; Yeo *et al*., 2016).

Overall, the diversity of compounds, particularly terpenoids, phenols, and alkaloid derivatives, indicates that *Piper nigrum* is a rich source of natural products with therapeutic potential.

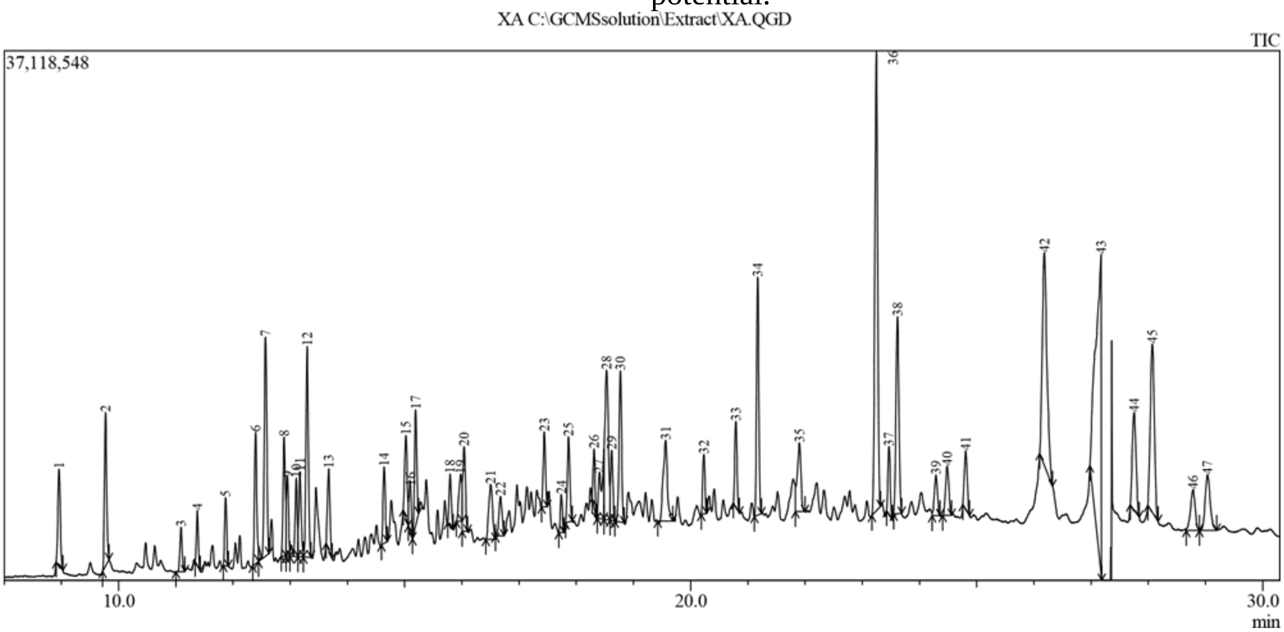

Fig. 1. GC-MS Chromatogram of *Xylopia aethiopica*

3.2 Bioactive Compounds Identified in Xylopia aethiopica

The GC-MS chromatographic analysis of *Xylopia aethiopica* revealed a total of 47 bioactive compounds. These compounds span various classes, including monoterpenes, sesquiterpenes, diterpenoids, fatty acid esters, and alcohols. The identification and quantification of these constituents are presented in Table 2 below.

Table 2. Bioactive Compounds Identified in *Xylopia aethiopica* via GC-MS

Peak	Name	MF	MW	RT	Area %
1.	Bicyclo[3.1.0]hex-2-ene, 2-methyl-5-(1-methylethyl)	$C_{10}H_{16}$	136	8.959	1.55
2.	Bicyclo[3.1.0]hexane, 4-methyl-1-(1-methylethyl)-	$C_{10}H_{16}$	136	9.771	2.33
3.	γ-Terpinene	$C_{10}H_{16}$	136	11.091	0.69
4.	Bicyclo[3.1.0]hexan-2-ol, 2-methyl-5-(1-methylethyl)-, 1α, 2β, 5α	$C_{10}H_{18}O$	154	11.376	0.68

5.	Bicyclo[3.1.0]hexan-2-ol, 2-methyl-5-(1-methylethyl)-, 1α, 2β, 5α	$C_{10}H_{18}O$	154	11.871	0.90
6.	Spiro[bicyclo[3.1.1]heptane-2,2’-oxirane], 6,6-dimethy-	$C_{10}H_{16}O$	152	12.395	2.01
7.	Bicyclo[3.1.1]heptan-3-ol, 6,6-dimethy-2-methylene- [1S-(1α, 3α, 5α)]-	$C_{10}H_{16}O$	152	12.568	3.97
8.	3-Dodecyne	$C_{12}H_{22}$	166	12.893	1.82
9.	Pinocarvone	$C_{10}H_{14}O$	150	12.955	1.13
10.	3-Cyclohexen-1-ol, 4-methyl-1-(1-methylethyl)-, (R)-	$C_{10}H_{18}O$	154	13.105	1.24
11.	1,5-Cyclohexandiene-1-methanol, 4-(1-methylethyl)-	$C_{10}H_{16}O$	152	13.169	1.38
12.	Bicyclo[3.1.1]hept-2-ene-2-methanol, 6,6-dimethy-	$C_{10}H_{16}O$	152	13.296	3.44
13.	Bicyclo[3.1.1]hept-3-en-2-one, 4, 6,6-trimethy-	$C_{10}H_{14}O$	150	13.673	1.36
14.	p-Cymen-7-ol	$C_{10}H_{14}O$	150	14.641	1.15
15.	2H-Pyran, 2-ethenyltetrahydro-2,6,6-trimethyl	$C_{10}H_{18}O$	154	15.022	1.39
16.	α-Cubebene	$C_{15}H_{24}$	204	15.105	0.71
17.	2H-Pyran, tetrahydro-4-methyl-2-(2-methyl-1-propenyl)-	$C_{10}H_{18}O$	154	15.192	1.79
18.	4(axial)-n-Propyl-trans-3-oxabicyclo[4.4.0]decane	$C_{12}H_{22}O$	182	15.795	0.78
19.	Cyclohexene, 3-acetoxy-4-(1-hydroxy-1-methylethyl)-1-methyl-	$C_{12}H_{20}O_3$	212	15.979	0.95
20.	Bicyclo[3.1.1]heptan-2,6,6-trimethyl-, [1S-(1α, 2β, 5α)]	$C_{10}H_{18}$	138	16.041	1.50
21.	α-Campholenal	$C_{10}H_{16}O$	152	16.506	1.43
22.	α-Campholenal	$C_{10}H_{16}O$	152	16.675	0.83
23.	Cubedol	$C_{15}H_{26}O$	222	17.442	1.13
24.	3,7-Cyclodecadiene-1-methanol, α, α, 4,8-tetramethyl-, [s-(Z,Z)]	$C_{15}H_{26}O$	222	17.738	0.53
25.	Andrographolide	$C_{20}H_{30}O_5$	350	17.865	1.44
26.	(-)-Spathulenol	$C_{15}H_{24}O$	220	18.311	0.73
27.	Caryophyllene oxide	$C_{15}H_{24}O$	220	18.400	1.48
28.	Tricyclo[3.3.1.1(3,7)]decane, 2-bromo-	$C_{10}H_{15}Br$	214	18.531	3.45
29.	Andrographolide	$C_{20}H_{30}O_5$	350	18.620	1.06
30.	(-)-Spathulenol	$C_{15}H_{24}O$	220	18.772	2.56
31.	6-Isopropenyl-4,8a-dimethyl-1,2,3,5,6,7,8,8a-octahydro-naphthalen-2ol	$C_{15}H_{24}O$	220	189.564	2.32
32.	9,10-Dimethyltricyclo[4.2.1.1(2,5)]decan-9,10-diol	$C_{12}H_{20}O_2$	196	20.230	0.90
33.	1-Hexadecanol	$C_{16}H_{34}O$	242	20.790	1.32
34.	Hexadecanoic acid, methyl ester	$C_{17}H_{34}O_2$	270	21.172	3.63
35.	1-Heptatiacotanol	$C_{37}H_{76}O$	536	21.901	1.70
36.	9-Octadecenoic acid (Z)-, methyl ester	$C_{19}H_{36}O_2$	296	23.246	8.76

37.	Methyl stearate	$C_{19}H_{38}O_2$	298	23.468	1.04
38.	1H-Naphtho[2, 1-b]pyran, 3-ethenyldodecahydro-3, 4a, 7, 7, 10a-pentamethyl-, [3R-(3α, 4aβ, 6aα, 10aβ, 10bα)]-	$C_{20}H_{34}O$	290	23.615	3.89
39.	(-)-Isolongifolol, acetate	$C_{17}H_{28}O_2$	264	24.288	0.84
40.	Kaur-16-ene, (8β, 13β)-	$C_{20}H_{32}$	272	24.484	1.11
41.	Epibolin	$C_{20}H_{32}OS$	320	24.808	1.10
42..	1-Cyclopropene-1-pentanol, α, epsilon, epsilon, 2-tetramethyl—(1-methyethenyl)-	$C_{15}H_{26}O$	222	26.183	6.60
43.	2H-Benzo(f)oxireno[2,3-E]benzofuran-8(9H)-one, 9-[((1,3-benzodioxol-5-ylmethyl)amino]octahydro-2,5a-dimethyl-	$C_{23}H_{29}NO_5$	339	27.173	11.22
44.	Napthalene, decahydro-1,1,4a-trimethyl-6-methylene-5-(3-methyl-2,4-pentadienyl)-, [4As-(4aα, 5α, 8β)]	$C_{20}H_{32}$	272	27.751	2.45
45.	Kaur-16-ene	$C_{20}H_{32}$	272	28.070	4.55
46.	Androstan-17-one, ethyl-3-hydroxy-, (5α)-	$C_{21}H_{34}O_2$	318	28.784	1.27
47.	4,8,1-Cyclotetradecatriene-1,3-diol, 1,5,9-trimethyl-12-(1-methylethyl)-	$C_{20}H_{34}O_2$	306	29.034	1.88

Among the identified compounds, 9-Octadecenoic acid (Z)-, methyl ester (oleic acid methyl ester) exhibited the highest relative abundance with an area of 8.76% at a retention time of 23.246 min. Oleic acid esters are known for their anti-inflammatory, hypocholesterolemic, and antioxidant effects, which support the use of *Xylopia aethiopica* in cardiovascular and metabolic health management (Oge *et al*., 2020; Ayodele *et al*., 2021).

(-)-Spathulenol appeared twice in the spectrum (RT: 18.311 and 18.772 min) with a combined area of 3.29%, indicating its significant contribution. This compound is a sesquiterpene alcohol with potent antimicrobial, anti-inflammatory, and antitumor properties (Chan *et al*., 2016; do Nascimento *et al*., 2018).

Andrographolide, a diterpenoid lactone with known anticancer, antiviral, and hepatoprotective effects (Gupta *et al*., 2017; Sharma *et al*., 2017), was identified at two retention times (17.865 and 18.620 min), totaling an area of 2.50%. Its presence further emphasizes the therapeutic relevance of this plant in traditional medicine.

Another major compound was Hexadecanoic acid, methyl ester (Area: 3.63%), a saturated fatty acid ester known to have antimicrobial and antioxidant effects (Davoodbasha *et al*., 2018).

Unique compounds such as Tricyclo[3.3.1.1(3,7)]decane, 2-bromo- (Area: 3.45%) suggest that halogenated compounds may also contribute to the plant's bioactivity.

The presence of various bicyclic terpenes, including α-Cubebene, Cubedol, and Caryophyllene oxide, suggests that *Xylopia aethiopica* may exert broad-spectrum antimicrobial, analgesic, and anti-inflammatory effects. These compounds are known to modulate inflammatory cytokines and disrupt microbial membranes (Milenković *et al*., 2023). Notably, the plant also contained high-molecular-weight alcohols such as 1-Heptatiacotanol (MW = 536; Area: 1.70%), which are important in cosmetic and pharmaceutical formulations for their emollient and stabilizing properties (Arsana *et al*., 2024). The complexity and diversity of the phytochemicals in *Xylopia aethiopica* support its widespread traditional usage for treating infections, pain, and inflammation.

Comparing the chemical profiles of *Piper nigrum* and *Xylopia aethiopica*, (Table 3) it is evident that both plants possess a rich reservoir of pharmacologically relevant secondary metabolites. *Piper nigrum* is dominated by aromatic compounds and sesquiterpenes like apiol and naphthalene derivatives, whereas *Xylopia aethiopica* is richer in monoterpenes, diterpenes (andrographolide), and fatty acid esters.

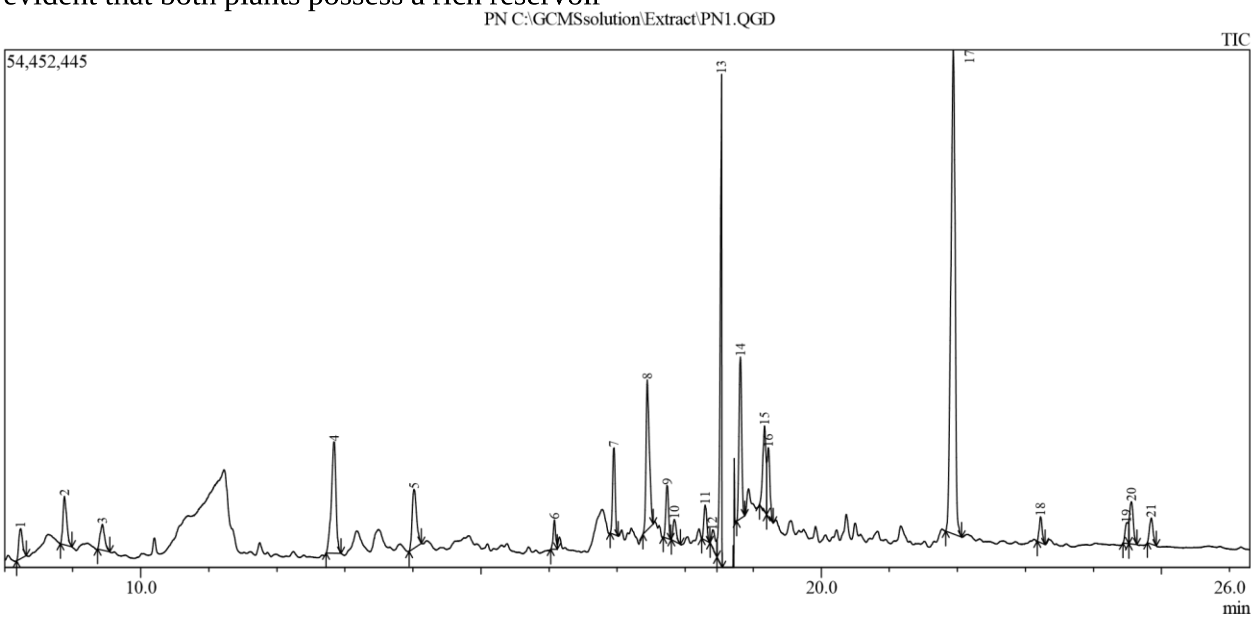

Fig 2. GC-MS Chromatogram of Piper nigrum

The higher abundance of oleic acid derivatives and sesquiterpenes in *Xylopia aethiopica* may explain its stronger traditional use in treating metabolic and inflammatory disorders, while the presence of potent aromatic compounds and terpenoids in *Piper nigrum* highlights its antimicrobial and flavoring potential. As shown in Table 3, both plants also contain Caryophyllene oxide, a shared bioactive compound known for its broad biological activities, including analgesic and anticancer properties. This suggests potential complementary or synergistic applications if both plants are used in polyherbal formulations.

Table 3: Comparative Summary of Phytochemical Profiles and Bioactivities of *Piper nigrum* and *Xylopia aethiopica* Based on GC-MS Analysis

Feature	*Piper nigrum*	*Xylopia aethiopica*
No. of compounds detected	21	>45
Major chemical classes	Hydrocarbons, esters	Terpenes, oxygenated terpenes
Notable compounds	Naphthalene, Apiol	Spathulenol, γ-Terpinene
Dominant biological activity	Antimicrobial, antioxidant	Antioxidant, anti-inflammatory

4.0 Conclusion

The study conducted a comparative phytochemical analysis of *Piper nigrum* and *Xylopia aethiopica* using Gas Chromatography-Mass Spectrometry (GC-MS), revealing significant differences in the number and types of compounds present in both plant species. *Piper nigrum* was found to contain 21 identifiable compounds, predominantly hydrocarbons and esters, with notable compounds such as naphthalene and apiol. In contrast, *Xylopia aethiopica* exhibited a much more complex chemical profile with over 45 compounds detected, primarily terpenes and oxygenated terpenes, including spathulenol and γ-terpinene. The biological activities associated with these compounds also differed, with *Piper nigrum* showing dominant antimicrobial and antioxidant properties, while *Xylopia aethiopica* exhibited stronger antioxidant and anti-inflammatory activities.

These findings highlight the chemical diversity and therapeutic potential of both spices, suggesting that *Xylopia aethiopica* may possess a broader range of bioactivities due to its higher chemical complexity. The presence of terpenes and oxygenated derivatives in *Xylopia aethiopica* is particularly significant, as these classes of compounds are well-documented for their pharmacological effects, including inflammation modulation and free radical scavenging. The dominance of hydrocarbons and esters in *Piper nigrum*, while less chemically diverse, still contributes substantially to its antimicrobial efficacy, which supports its traditional use in preserving food and treating microbial infections.

In conclusion, the study establishes a scientific basis for the traditional uses of both *Piper nigrum* and *Xylopia aethiopica*, while also identifying potential compounds that could be isolated and developed for pharmaceutical applications. It is recommended that further studies be carried out to isolate and characterize the individual bioactive constituents in both plants. Additionally, in vitro and in vivo biological assays are necessary to validate the therapeutic potentials of the identified compounds and to understand the mechanisms underlying their activities. The broader use of *Xylopia aethiopica* in functional foods and herbal medicine should be encouraged, while *Piper nigrum* remains a valuable spice with notable antimicrobial benefits.

Acknowledgments

The authors are grateful to the University of Uyo, Uyo for granting the laboratory space, and to Dr. Paul Sunday Thomas from the Department of Pharmacology and Natural Medicine for his technical support.

5.0 References

Abdulazeez, M. A., Sani, I., James, B. D. & Abdullahi, A.S., (2016). Black pepper (Piper nigrum L.) oils. In: *Essential oils in food preservation, flavor and safety* (pp. 277-285). Academic Press.

Arsana, I. N., Juliasih, N. K. A. & Widyantari, A. A. A. S. S., (2024). GC–MS Analysis of Bioactive Compounds in Lime Leaf Ethanol Extract (Citrus amblycarpa (Hassk.) Ochse), and Its Potential as a Traditional Medicine Agents. *Journal Penelitian Pendidikan IPA*, 10(4), pp.1994-2006.

Ayodele, P. F., Ibukun Akinloye, D., Akamo, A. J., Adejare Agboola, D. & Akinloye, O. A., (2021). Effect of Ethanolic Extract of Xylopia aethiopica Fruit on Cadmium-induced Inflammatory Changes and Dyslipidemic Rats. *Asian Journal of Research in Biochemistry*, 9(4), pp. 9-17.

Banik, B. K. & Das, A., (2023). *Natural Products as Anticancer Agents*. Elsevier

Bardanzellu, F., Peroni, D. G. & Fanos, V., (2020). Human breast milk: bioactive components, from stem cells to health outcomes. *Current nutrition reports*, 9: 1-13.

Chan, W. K., Tan, L. T. H., Chan, K. G., Lee, L. H. & Goh, B.H. (2016) Nerolidol: a sesquiterpene alcohol with multi-faceted pharmacological and biological activities. *Molecules*, 21(5): pp. 529.

Davoodbasha, M., Edachery, B., Nooruddin, T., Lee, S. Y. & Kim, J. W., (2018). An evidence of C16 fatty acid methyl esters extracted from microalga for effective antimicrobial and antioxidant property. *Microbial Pathogenesis*, 115, pp. 233-238.

do Nascimento, K. F., Moreira, F. M. F., Santos, J. A., Kassuya, C. A. L., Croda, J. H. R., Cardoso, C. A. L., do Carmo Vieira, M., Ruiz, A. L. T. G., Foglio, M. A., de Carvalho, J. E. & Formagio, A. S. N., (2018). Antioxidant, anti-inflammatory, antiproliferative and antimycobacterial activities of the essential oil of Psidium guineense Sw. and spathulenol. *Journal of ethnopharmacology*, 210, pp. 351-358.

Fadzil, F., Shamsuddin, K. & Wan Puteh, S.E., (2016). Traditional postpartum practices among Malaysian mothers: a review. *The Journal of Alternative and Complementary Medicine*, 22,7, pp. 503-508.

Gannenas, I., Sidiropoulou, E., Bonos, E., Christaki, E. & Florou-Paneri, P. (2020). The history of herbs, medicinal and aromatic plants, and their extracts: Past, current situation and future perspectives. In *Feed additives*, Academic Press. pp 1-8.

Gidwani, B., Bhattacharya, R., Shukla, S. S. & Pandey, R. K. (2022). Indian spices: past, present and future challenges as the engine for bio-enhancement of drugs: impact of COVID-19. *Journal of the Science of Food and Agriculture*, 102,8, pp. 3065-3077.

Guidi, L. & Landi, M., (2014). Aromatic Plants: use and nutraceutical properties. *Novel Plant Bioresources: Applications in Food, Medicine and Cosmetics*, pp. 303-345.

Gupta, S., Mishra, K. P. & Ganju, L., (2017). Broad-spectrum antiviral properties of andrographolide. *Archives of virology*, 162(3), pp. 611-623.

Jaber, D. & Al-Zeidaneen, S. (2021). Women's opinions, beliefs, and practices towards using different medicinal plants for postpartum health problems care. *Jordan Journal of Pharmaceutical Sciences*, 14,3, pp.309-322.

Kadhim, M. J., Mohammed, G. J. & Hussein, H., (2016). Analysis of bioactive metabolites from Candida albicans using (GC-MS) and evaluation of antibacterial activity. *International Journal of Pharmaceutical & Clinical Research* 8,7, pp. 655-670.

Kuroda, Y., Goto, A., Koyama, Y., Hosoya, M., Fujimori, K., Yasumura, S., Nishigori, H., Kuse, M., Kyozuka, H., Sato, A., Ogata, Y., Hashimoto, K., & Japan Environment and Children's Study (JECS). (2021). Antenatal and postnatal association of maternal bonding and mental health in Fukushima after the Great East Japan Earthquake of 2011: The Japan Environment and Children's Study (JECS). *Journal of Affective Disorders, 278*, 244–251. https://doi.org/10.1016/j.jad.2020.09.021

Milenković, A. N., Stanojević, J. S., Troter, D. Z., Pejčić, M. G., Stojanović-Radić, Z. Z., Cvetković, D. J. & Stanojević, L. P., (2023). Chemical composition, antimicrobial and antioxidant activities of essential oils isolated from black (Piper nigrum L.) and cubeb pepper (*Piper cubeba* L.) fruits from the Serbian market. *Journal of Essential Oil Research*, 35(3), pp. 262-273.

Mills, E., Dugoua, J.J., Perri, D. & Koren, G., (2006). *Herbal medicines in pregnancy and lactation: an evidence-based approach*. London; New York: Taylor & Francis, pp. 176-177.

Oge, E. N., Obese, E., Biney, R. P., Adakudugu, E., Agbenyeku, M., Osei, S.A., Cassera, M. B., Valenciano, A. L., Merino, E. F., Boampong, J. N. & Woode, E., (2020). A review of pharmacological effects of xylopic acid. *International Journal of Basic & Clinical Pharmacology*, 9(5), pp. 813-818.

Okafor, C.B. & Rizzuto, R.R., 1994. Women's and health-care providers' views of maternal practices and services in rural Nigeria. *Studies in family planning*, pp. 353-361.

Ouandaogo, H.S., Diallo, S., Odari, E. & Kinyua, J., 2023. Phytochemical screening and GC-MS analysis of methanolic and aqueous extracts of Ocimum kilimandscharicum leaves. *ACS omega*, 8, 50, pp. 47560-47572.

Pandey, S., Kushwaha, G. R., Singh, A. & Singh, A., (2018). Chemical composition and medicinal uses of Anacyclus pyrethrum. *Pharma science monitor*, *9*(1), pp. 551-560.

Patil, R., Aher, P., Bagad, P. & Ekhande, S., 2022. Herbal bioenhancers in veterinary phytomedicine. *Drug Deliv Technol Herb Bioenhancers Pharm*, pp. *325*.

Sachan, A.K., Kumar, S., Kumari, K. & Singh, D., 2018. Medicinal uses of spices used in our traditional culture: Worldwide. *Journal of Medicinal Plants Studies*, 6,3, pp. 116-122.

Saleem, S., Ul Mushtaq, N., Shah, W.H., Rasool, A., Hakeem, K.R. & Ul Rehman, R., (2022). Beneficial role of phytochemicals in oxidative stress mitigation in plants. In *Antioxidant defense in plants: molecular basis of regulation*. Singapore: Springer Nature Singapore, pp. 435-451.

Salehi, B., Zakaria, Z. A., Gyawali, R., Ibrahim, S. A., Rajkovic, J., Shinwari, Z.K., Khan, T., Sharifi-Rad, J., Ozleyen, A., Turkdonmez, E. & Valussi, M., (2019). Piper species: A comprehensive review on their phytochemistry, biological activities and applications. *Molecules*, 24(7), pp. 1364.

Sánchez, C., Franco, L., Regal, P., Lamas, A., Cepeda, A. & Fente, C. (2021). Breast milk: A source of functional compounds with potential application in nutrition and therapy. *Nutrients*, 13(3), pp. 1026.

Sharma, V., Sharma, T., Kaul, S., Kapoor, K. K. & Dhar, M. K., (2017). Anticancer potential of labdane diterpenoid lactone "andrographolide" and its derivatives: a semi-synthetic approach. *Phytochemistry Reviews*, 16, pp. 513-526.

Schepetkin, I. A., Özek, G., Özek, T., Kirpotina, L. N., Kokorina, P. I., Khlebnikov, A. I. & Quinn, M. T., (2022). Neutrophil Immunomodulatory activity of nerolidol, a major component of essential oils from Populus balsamifera buds and propolis. *Plants*, 11(23), p. 3399.

Sibeko, L., Johns, T. & Cordeiro, L.S., 2021. Traditional plant use during lactation and postpartum recovery: Infant development and maternal health roles. *Journal of Ethnopharmacology*, 279, pp. 114377

Sibeko, L. & Johns, T., (2021). Global survey of medicinal plants during lactation and postpartum recovery: Evolutionary perspectives and contemporary health implications. *Journal of Ethnopharmacology*, 270, 113812, doi:10.10 16/j.jep.2021.113812

Yeo, S. K., Ali, A. Y., Hayward, O. A., Turnham, D., Jackson, T., Bowen, I. D. & Clarkson, R., (2016). β-Bisabolene, a sesquiterpene from the essential oil extract of opoponax (Commiphora guidottii), exhibits cytotoxicity in breast cancer cell lines. *Phytotherapy Research*, 30(3), pp. 418-425.

Declaration

Consent for publication

Not applicable

Availability of data

Data shall be made available on demand.

Competing interests

The authors declared no conflict of interest

Ethical Consideration

Not applicable

Funding

There is no source of external funding.

Authors' contributions

All authors participated in all components of the work.