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RESEARCH ARTICLE

COMPARATIVE PHYTOCHEMICAL, MINERAL, PROXIMATE AND ORGANIC COMPOUND STUDY OF FOLIAR EXTRACTS OF *CAPSICUM SPECIES* WITH THEIR ANTIMICROBIAL POTENTIALS

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ABSTRACT

Capsicum variants are significant spices in traditional diets because they provide nutritional and medicinal benefits and contain high levels of vitamins A and C. Determining the near-term, chemical, biochemical, and antibacterial potentials of foliar extracts of *Capsicum* annuum and *C. chinense* is the main goal of this work. The primary goal of this study was to examine the biochemical components of the extracts of *Capsicum* spp. in relation to their antibacterial potentials. Standard techniques were used to study the proximate and phytochemical analyses of these extracts, and Gas Chromatography-Mass Spectrometry (GCMS) was employed to assess the elemental and organic content of the leaves. By using the disc-diffusion method, the bioactive components and antibacterial efficacy of 7 bacterial and 3 fungus isolates were examined. The biochemical analyses showed that the leaves have a high crude protein content and low dry matter content. Studies on phytochemicals revealed that among the other phytochemicals found, *C. annuum* and *C. chinense* were rich in cardiac glycoside but low in tannin. In the extracts of the, it was discovered that Mn, Zn, Cu, Na, K, Mg, Ca, Fe, and P were among the different mineral elements present. There were found to be 16 different organic compounds in all, falling into five different chemical categories: esters, alkanoates, alkanoic acids, alkanols, and alkanes. The methanolic extracts of *C. annuum* and *C. chinense* exhibit notable effectiveness against all chosen bacterial and fungal isolates when used at a dosage range. These plant species' methanolic extracts were discovered to be full of chemical and biological components. As a result, these chemicals' synergistic actions are anticipated to have positive effects on nutrition and health. Therefore, it is advised to consume a lot of food that contains these components.

KEYWORDS

Capsicum, Proximate, Minerals, Phytochemical, Biochemical, Antimicrobial, Pepper

1. INTRODUCTION

Nature has given people medicinal plants, such as chilli (pepper), to help them live healthy lives free of illness. According to Al-Snafi (2013), they have a wide variety of pharmacological effects. The Solanaceae family contains the genus *Capsicum*, which includes the five species *Capsicum frutescens*, *Capsicum annuum*, *Capsicum chinense, Capsicum baccatum*, and *Capsicum pubescens*. Through Spanish and Portuguese traders, *Capsicum annuum* and *Capsicum frutescens* were rapidly dispersed from the New World to other continents in the 16th century, although the other species are scarcely found outside of South America (Andrews, 1995). *It is possible to eat cooked or raw Capsicum species. Varieties of the Capsicum frutescens and Capsicum annuum species are frequently used in cooking (Aziagba et al., 2013). The species of Capsicum annuum and Capsicum frutescens include a variety of nutritious ingredients as well as pharmacologically active metabolites. The little herb Capsicum annuum L. has a maximum height of 1 m. Oval, oblong-ovate, or ovate-lanceolate leaves are 4–13 cm long and 1.5–4 cm wide with an entire border. The flowers are tiny and have a purple or white tint. Fruits can be up to 15 cm long and are often red, although they can also be green, orange, or yellow, while seeds are discoid or reniform and pale yellow in color (Li, 2000; Abdul, 2003).*

The *Capsicum annuum*, *C. frutescens*, *C. baccatum*, *C. pubescens*, and *C. chinense* species are the ones that were first cultivated in Central and South America (Zimmer et al., 2012). These species continue to flourish in the wild today and spread fast throughout the subtropical areas. Because it requires a warm, humid climate to exist, the plant only grows in tropical climes (Anthony et al., 2013). The presence of bioactive chemicals in *Capsicum* and their significance as dietary antioxidants are largely responsible for the interest in its consumption. Peppers offer nutritional and nutraceutical value and can be consumed raw, dried, fermented, or as an oleoresin extract (Adepoju et al., 2019).

Capsicum is utilized as a source of pungency, a flavoring agent, and/or a colorant. The chemical family of alkaloid chemicals known as capsaicinoids (CAPS), which are made in the fruit, is the principal cause of peppers' pungency. The most prevalent CAPS is capsaicin (C18H27NO3, trans-8-methyl-N-vanillyl-6-nonenamide), which is followed by dihydrocapsaicin and contains only trace amounts of homocapsaicin, nordihydrocapsaicin, and homodihydrocapsaicin. Insoluble in water,

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odorless, and tasteless, capsaicin is a white, crystalline, fat-soluble molecule made from homovanillic acid (Andrews, 1995).

In the past, people have utilized *Capsicum* annum to treat toothaches. The fruits are utilized to stimulate blood circulation and stomach activity. Additionally, it is a stimulant, a carminative, and is applied locally to treat rheumatism and neuralgia. Soup made from the fruit is used to relieve childbirth-related uterine pain. *Capsicum* annuum was approved by the Commission to treat excruciating muscle spasms in the shoulder, arm, and spine regions. According to Blumenthal et al. (2000), treatments exist for arthritic pain, neuralgia, lumbago, and chilblains. According to Tesfaye (2000), capsaicin and its analogues were applied topically to treat musculoskeletal pain, osteoarthritis, rheumatoid arthritis, post-herpetic neuralgia, and diabetic neuropathy.

According to Fusco and Giacovazzo (1997), topical application of capsaicin induces burning pain, neurogenic inflammation (vasodilatation and plasma extravasation), and hyperalgesia to heat and mechanical stimulation. The pharmacological effects of capsaicin include antimicrobial (Shayan and Saeidi, 2013), insecticidal and antiheminthic (Oni, 2011), antioxidant (Govindarajan, 1986), cytotoxic (Motohashi et al., 2003), immuno-modulatory (Beltran et al., 2007), anti-inflammatory (Khabade et al., 2012), cardiovascular (Kwon et al. There is no published work that compares the chemical makeup of these two Nigerian species with their antibacterial efficacy. Investigating prospective pharmacological compounds is crucial, especially in light of the prevalence of microbial resistance to medications that have been in use for a while. This research work compares the antimicrobial potencies of the foliar extracts of these two types of *Capsicum* to their proximate, phytochemical, mineral element, and organic component contents.

2. Materials and Methods

2.1 Plant Sample Collection

Fresh leaves of *Capsicum annuim* and *Capsicum chinense* were collected into sterile polythene bags and transported to the laboratory for identification at the Biology Laboratory Complex, Ladoke Akintola University of Technology, Ogbomoso, Nigeria. The harvested leaves were cleaned under clean borehole water, air-dried for about four weeks. The dried leaves were crushed using porcelain mortar and pestle, sieved to attain powder of same size and the resulting powders were kept in air-tight containers placed in a cool and dry environment.

2.2 Extraction Process

10 g of the granules were extracted by soaking them in 100 ml of 100% methanol in clean, clearly marked conical flasks before corking them. The soaked leaf powder was extracted after seven days of soaking in methanol, and concentrate was prepared using a rotary evaporator on the decanted solutions. In preparation for analysis, the dried extracts were kept in a refrigerator. The dried leaf samples were used for analyses of biochemical compositions and mineral compositions, while the leaf extracts, which were also used for antimicrobial testing, were used for GC-MS analyses of phytochemical compositions and organic chemical compositions (Sukhdev et al., 2008).

2.3 Collection, Growth and Maintenance of Test Isolates

Test organisms used for this study were collected from the microbial gene bank of Pure and Applied Biology Department, LAUTECH, Ogbomoso, Nigeria. The bacterial cultures include *Escherichia coli, Pseudomonas aeruginosa, Pseudomonas putida, Staphylococcus aureus, Bacillus cereus, Bacillus subtilis* and *Klebsiella pneumoniae* maintained on nutrient agar at 37°C; then, fungal cultures of *Aspergillus niger, Aspergillus flavus* and *Candida albicans* and maintained on potato dextrose agar at 25°C. The microbes so selected for this work are the causative organisms/parasites which are responsible for common diseases in humans. This in vitro experiment was carried out with the hope to find solution to the challenge of microbial resistance to the drugs already in use.

2.4 Preparation of Inoculums

Two loopfuls of a bacterial colony that had developed overnight and had a similar morphology were injected into 5 ml of sterile nutrient broth, where they were cultured for 2 hours at 37°C and measured for turbidity using a 0.5 BaSO4 standard. 0.2 g of yeast extract and 1 g of sugar were combined with 100 ml of distilled water to create fungus inoculums. Test tubes containing 5 ml were pipetted and sterilized at 121°C for 15 minutes. Two loopfuls of test fungus were added to the medium after cooling, and after 2 hours of incubation, the suspensions were kept at 4°C for further use.

2.5 Proximate Analysis

Using conventional analytical techniques, the proximate components of the dried leaf samples were identified. All samples under investigation underwent biochemical analysis in duplicate using established protocols to determine their moisture and ash levels, crude fiber, protein, fat, and carbohydrate concentrations (Arithmetic Difference Method, that is, %CHO = 100 - (% fat + % ash + % fiber + % protein) (Association of Official Analytical Chemist, 1995; James, 1995; Pearson, 1976; Onwuka, 2005).

2.6 Phytochemical Analysis of Leaf Extracts

The two species of *Capsicum* were chemically analyzed with an emphasis on phlobatannins, alkaloids, tannins, cardiac glycosides, saponins, flavonoids, terpenoids, and phenols, both qualitatively and quantitatively. The qualitative screening was conducted using Trease and Evans' (1989) methodology. The spectrophotometric approach published by (Brunner, 1984) was used to determine saponin as part of the quantitative screening. Alkaloids and flavonoids were identified using the procedure described by (Harbone, 1984). Tannin was determined by spectrophotometric means in accordance with the method published by Makkar et al. (1993), total phenols, cardiac gylcosides, and the use of Buljet's reagent in accordance with El-Olemy et al. (1994).

2.7 Analysis of Organic Compounds in The Plant Extracts using Gas Chromatography Mass Spectrometry (GC-MS)

On an Agilent 19091S, the GC-MS analyses of the leaf extracts were performed at the Chemical Engineering Department of the University of Ilorin. The following circumstances were employed with a gas chromatograph (GC) interfaced to a mass spectrometer (MS) 433HP-5MS instrument: a silica capillary column fused with 100% phenyl methyl silox (length: 30m x 250m; film thickness: 0.25m). An electron ionization device with an ionization energy of 70eV was employed for GC-MS detection. The carrier gas, helium gas (99.999%), was used at a constant flow rate of 1.5 ml/min, with an injection volume of 1 l (50:1), injector temperature of 300 oC, and an average velocity of 45.67 cm/sec. The oven temperature was set to climb by 4°C/min from 100°C (isothermal for 4 min.) to 240°C. The GC ran for 49 minutes in total. By comparing each component's average peak area to the sum of all areas, the relative percentage quantity of each component was computed. Turbomass was the program used to manage mass spectra and chromatograms. The NIST Ver. 2.0 year 2009 library was used for the detection (Paranthaman et al., 2012). The identification of the components found using their spectra came after the GCMS's operation.

2.8 Identification of the Chemical Components

The database of the National Institute of Standard and Technology (NIST), which contains more than 62,000 patterns, was used to interpret the mass spectrum of the GC-MS. The NIST library's spectrum of the known components and the mass spectra of the unknown components were compared. Using information from the library as well as the fragmentation patterns the test materials' constituent parts' names, molecular weights, and structures were also determined.

2.9 Antimicrobial Activities of Foliar Extracts on Test Organisms

Using the disc diffusion method, the antibacterial activity of foliar extracts of *C. annuum* and C. Chinese was evaluated against 7 bacterial and 3 fungus isolates. For bacteria and fungi, 20ml of sterile nutritional agar and potato dextrose broth, respectively, were prepared in petri dishes. Each petri plate's bottom was divided into segments marked 5, 25, 50, 100, and 250, with the control in the middle. The solidified sterile media was swabbed with the test organism. Perforated filter paper (4mm) was placed on the designated region after being dipped into the extract at various concentrations of 0.25, 0.1, 0.005, and 0.0005M. The control experiment was set up using methanol. For bacteria and fungi, plates were incubated for 24 hours at 37°C and 48 hours at 25°C, respectively. The results were compared with those obtained using standard antibiotics (gentamycin/augmentin). The zones of inhibition's (clearance's) sizes were measured in millimeters.

2.10 Statistical Analysis

The collected data were examined using IBM SPSS version 20 software, submitted to a one-way ANOVA to see whether there were significant differences between groups, and then expressed in mean and standard deviation (SDEV) using Microsoft Office Excel version 2007.

3. Results and Discussion

The results of the percentage biochemical composition of the two plant

leaves studied are shown in Table 1 while the phytochemical compound contents are presented in Table 2. The leaves of all the plants were significantly rich in essential biomolecules that are important in nutrition. Of all the nutrients detected, the leaves were particularly high (37-38%) in moisture content followed by protein (32%), but low (2.1-2.37%) in dry matter content as illustrated in Table 1. The quantities of the proximate contents (%) of the *Capsicum* species studied can be listed from the highest to the lowest as moisture> protein> crude fibre> total ash> crude carbohydrate> crude fat> dry matter. A total of eight secondary metabolites were detected in the leaves of the Nigerian species of *Capsicum* studied. These included alkaloids, saponin, phenols, tannins, flavonoids, terpenoids, cardiac glycosides and phlobatannins. Of these eight, the quantities of only two, i.e. cardiac glycosides and phlobatannins, did not show significant differences among the taxa studied. Cardiac glycoside were found highest (0.92 and 0.91) and lowest were phenols (0.14 and 0.13) for *C. annum* and *C. chinense,* respectively.

Table 1: Percentage proximate composition of two species of *Capsicum* studied

	% Cr. Fibre	% Cr. CHO	% Dry Matter	% Cr. Fat	% Moisture Content	% Cr. Protein	% Total Ash
ANN	16.21b ± 0.12	6.20b ± 0.03	2.37a ± 0.02	12.121b ± 0.23	38.009a ± 0.22	32.004b ± 0.47	15.720b ± 0.22
CHI	17.20a ± 0.23	7.22a± 0.11	2.10a ±0.02	12.506a ± 0.23	37.200b ± 0.25	32.100a ± 0.21	16.001a ± 0.12

ANN= *C. annuum* and CHI= *C. chinense*). Cr= crude; CHO= Carbohydrate *Mean values in columns with different superscripts of alphabets are significantly different at P≤0.05 while those with the same alphabets are not significantly different at P≤0.05

Table 2: Quantitative Phytochemical Contents of the *Capsicum* plants studied.

	Alkaloid	Saponin	Phenol	Tannin	Flavonoid	Terpenoid	Card. Glycos	Phlobatannin
ANN	0.71a ± 0.09	0.65b ± 0.001	0.14a ± 0.001	0.32b ± 0.015	0.49b ± 0.001	0.73a ± 0.001	0.92a ±0.022	0.39a ± 0.003
CHI	0.64b ± 0.003	0.71a ± 0.002	0.13a ± 0.001	0.40a ± 0.002	0.55a ± 0.017	0.70a ± 0.002	0.91a ±0.024	0.36ab ± 0.003

ANN= *C. annuum* and CHI= *C. chinense*. * Mean values in columns with different superscripts of alphabets are significantly different at P≤0.05 while those without alphabets are not significantly different at P≤0.05

The leaf proximate composition of the plants recorded in Table 1 has some notable implications for their use as leafy vegetables and as medicinal herbs. Previous studies showed that chilli is a highly nutritive fruit possessing carbohydrate, protein, fat and minerals (Ismail et al., 2011). Crude fiber makes stools bulkier and speeds up digestion. In both humans and animals, it is not digested, but it helps the intestinal tract operate normally. A study found that fiber contributes to sustaining human health and that it helps the body's cholesterol levels drop (Bello et al., 2008). According to recent study, diets deficient in fiber have been linked to an increased risk of heart disease, colon and rectum cancer, varicose veins, phlebitis, obesity, appendicitis, diabetes, and even constipation (Lajide et al., 2008).

The existence of phytochemicals in the foliar extracts of the Capsicum cultivars under investigation suggests that they may have therapeutic potential (AOAC, 1990). The two species contained steroidal glycosides, phlobatannins, and saponins. Recent studies claim that these chemicals are effective against bacteria that might cause gastrointestinal infections and other potentially serious illnesses (Owolabi et al., 2007). Saponins have also been reported in *Senna alata* and *Cajanus cajan*, and also in *Lophira lanceolata* seeds (Lawal et al., 2014). Saponins tend to kill or prevent the growth of cancer cells without negatively affecting healthy body cells, in addition to having anti-hypercholesterol, anti-inflammatory, and cardiac health-improving characteristics (Harborne, 1984; Okwu, 2001). Phlobatannins were reported by as inhibitors of growth in many microorganisms like bacteria, fungi and viruses, and they were detected in the leaves of *Senna alata* and *Cajanus cajan* (Asquith and Butter, 1986). According to other studies, tannins are plant polyphenols which can form complexes with metals ions and with macro-molecules such as polysaccharides and proteins (De-Bruyne et al., 1999; Dei et al., 2007). Also have claimed that tannins can adversely affect protein digestibility (Sathe and Salunkhe, 1984). It has been established that tannins usually form insoluble complexes with proteins, thereby interfering with their bioavailability, while associated poor palatability to high tannin content in diets (Mehansho et al., 1987).

The mineral elements of the two species of *Capsicum* studied are illustrated in Table 3. From the result, different minerals were detected. These are Calcium, Magnesium, Iron, Sodium, Potassium, Copper, Zinc and Manganese. It was observed that the leaves were particularly high in Potassium (27.61-27.7%), Calcium (27.2-27.35%), and Magnesium (13%), but low, as expected of trace elements, in Manganese, Zinc and Copper (Table 3). Overall, the amounts of the mineral elements in the researched plants can be listed in the following order: potassium, calcium, magnesium, sodium, zinc, copper, iron, phosphorus, and manganese, from highest to lowest.

Table 3: Mineral element composition (ppm) in the two species of *Capsicum* studied

	Mn	Zn	Cu	Na	K	Mg	Ca	Fe	P
ANN	0.24a ±	0.56a ±	0.42a ±	1.71a ±0.02	27.70a ±	13.0 4a ±	27.350a ±	0.336 a±	0.032b
	0.013	0.002	0.02		0.12	0.002	0.111	0.011	±0.011
CHI	0.25a ±	0.54a ±	0.44a ±	1.72a	27.61a ±	13.02a ±	27.200b ±	0.312b	0.322a ±
	0.003	0.001	0.02	±0.002	0.01	0.014	0.114	±0.010	0.001

ANN= *C. annuum* and CHI= *C. chinense*. *Mean values in columns with different superscripts of alphabets are significantly different at P≤0.05 while those with the same alphabets are not significantly different at P≤0.05.

As essential components of bones, muscles, teeth, tissues, nerves, and blood cells, minerals are essential for the general physical and mental well-being of man (Soetan et al., 2010). While O'Dell said that minerals from plants are less accessible than those from animals, a study found that minerals are crucial for human nutrition (Ibanga and Okon, 2009; O'Dell 1979). They are useful for the maintenance of acid-base balance, nerve responses to physiological stimulation and clotting of blood (Hanif et al., 2006). Calcium and phosphorus are jointly essential for growth and maintenance of muscles, bones and teeth (Okaka et al., 2006). Chlorophyll contains magnesium, and calcium metabolism in the bones depends on magnesium, a lack of which can cause ischemic heart disease (Borgert et al., 1975). The immune system's normal operation depends on zinc, which is also linked to protein metabolism. According to other research, iron is a crucial trace element for the production of hemoglobin as well as the proper operation of the central nervous system (Asaolu et al., 1997). Animal health is known to suffer when certain nutrients and minerals are inadequate.

The outcomes of the GC-MS analysis performed on the leaves of the investigated Capsicum cultivars are displayed in Table 4, Plates 1 and 2. Eight distinct organic compounds in all, including members of the esters, alkanoic acids, and alkanes chemical families, were found. Long-chain unsaturated fatty acids, like linoleic acid, also exhibit antibacterial activity and are the main components of antimicrobial food additives and some antibacterial herbs (Chang et al., 2005); unsaturated fatty acids are also speculated to be responsible for the anti-inflammatory activity (Li et al., 2004). Hexadecanoic acid has been known to possess potential antibacterial and antifungal activities. Then, the methyl esters of hexadecanoic acid and 9,12-octadecadienoic acid (Z,Z) have demonstrated antioxidant and anticancer properties (Kumar et al., 2010).

Table 4: The % peak area value of some organic compounds quantified in the leaves of *Capsicum annuum* and *Capsicum chinense*

Compound	Class	Age Peak Area Values (%)	
		[ANN]	[CHI]
UAMME	Ester	0	10.33
710-OCME	Ester	0	3.94
912-OCME	Ester	8.43	0
912-OCRME	Ester	14.12	0
13-OCME	Ester	0	29.88
H-16-MME	Ester	2.07	0
DODEA	Alkanoic acid	38.78	0
PHYTOL	Alkane	4.90	0

The names of the plants are in block parentheses: [ANN]= *C. annuum* and [CHI]= *C. chinense*.

UAMME=Undecanoic acid, 10-methyl, methyl ester; 710-OCME=7,10-

octadecanoic acid methyl ester; 912-OCME=9,12- octadecanoic acid methyl ester (E,E); 912-OCRME=9,12,15-Octadecatrienoic acid, methyl ester, (Z,Z,Z); 13-OCME=Cis-13-octadecenoic acid methyl ester; H-16- MME=Heptadecanoic acid, 16-methyl-, methyl ester; DODEA=Dodecanoic acid; ET-2-OCD=Ethanol, 2-(9-octadecenyloxy)- Z; and PHYTOL=Phytol.

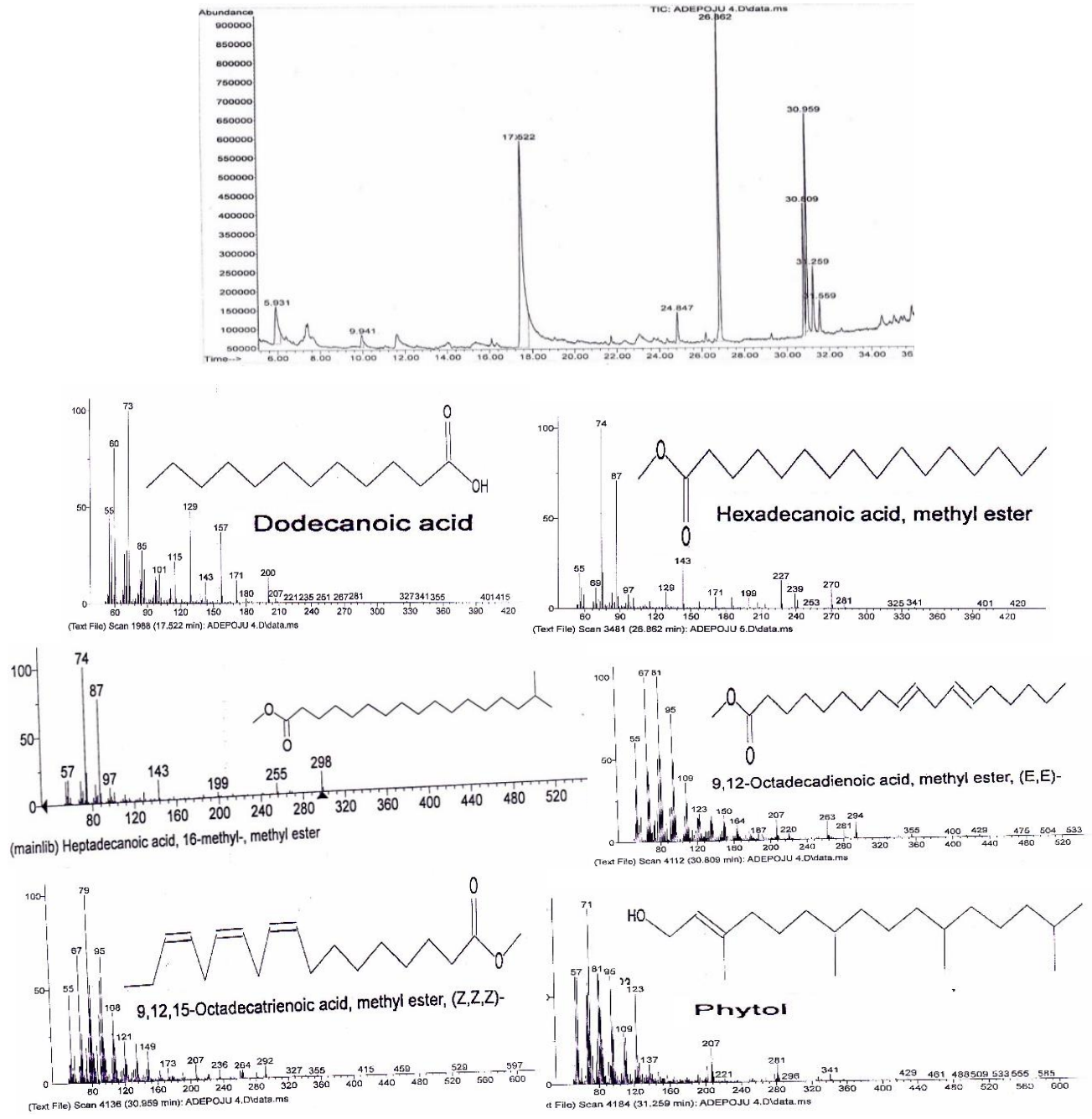

Plate 1: GC-MS Spectrum and some phytoconstituents in *C. annuum*

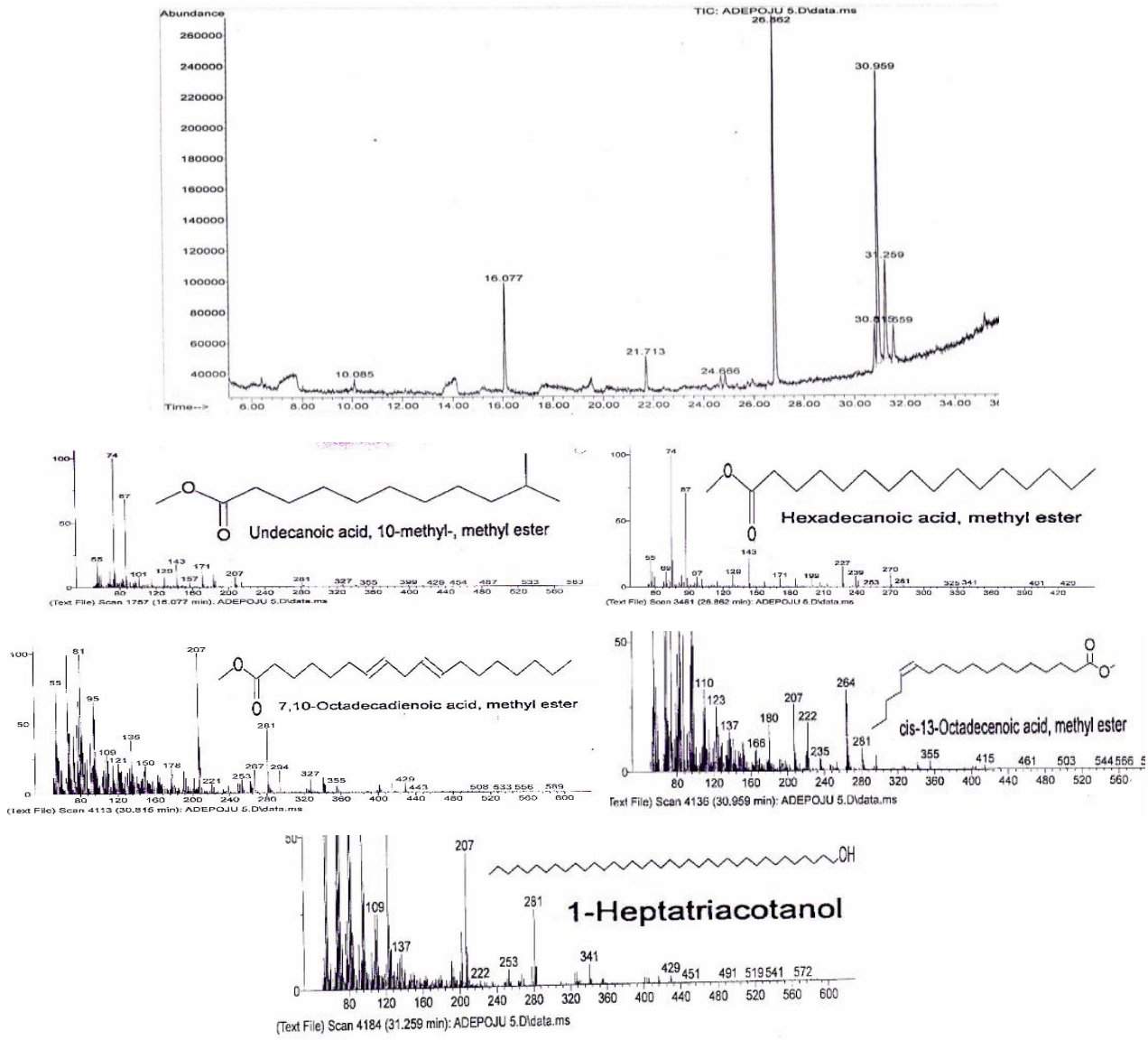

Plate 2: GC-MS Spectrum and some phytoconstituents in *C. chinense*

The antibacterial and antifungal studies revealed that the extracts are potent antimicrobials at all concentrations. Figure 1 and 2 show the antimicrobial potentials of the plant extracts at 5-250mg against pathogens. From the results obtained, it can be inferred that *C. annuum* had the highest inhibition zone of 18mm at 100mg/ml against *Bacillus cereus* and 5mm at 5 and 25mg/ml concentrations for *Aspergillus* sp. *Capsicum chinense* was found effective for all pathogens and these are dose-dependent on the extract.

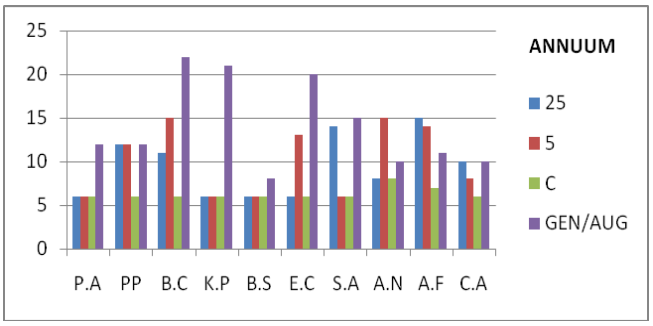

Figure 1: The antibacterial and antifungal potentials of leaf extracts of *C. annuum* on test organisms

Pepper has been previously reported to exhibit great antimicrobial potential against many microorganisms such as Staphylococcus aureus, Pseudomonas aeruginosa, Proteus mirabilis and Escherichia coli. A methanolic extract of red pepper was examined and found to be effective against multi-drug resistant Vibrio cholerae strains, according to a recent publication by Adamu et al. (2005) (Yamasaki et al., 2011). According to earlier research, highly polar ethanol, methanol, and aqueous extracts of C. frutescens pepper have been shown to have antibacterial action against a variety of microorganisms (KoffiNevry et al., 2012; Adepoju et al., 2020). Even the methanolic extract of C. frutescens leaves showed dose-dependent antibacterial activity against S. aureus, K. pneumoniae and P. aeruginosa (Adepoju et al., 2020; Adepoju et al., 2021).

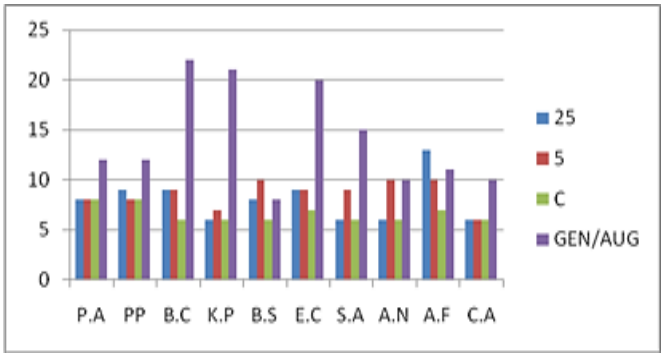

Figure 2: The antibacterial and antifungal potentials of leaf extracts of *C. chinense* on test organisms

P.A= *P. aeruginosa;* P.P= *P. putida*; B.C= *B. cereus*; K.P= *K. pneumonia*; B.S=*B. subtilis*; E.C= *E. coli*; S.A= *S. aureus*; A.N= *A.niger*; A.F= *A. flavus* C.A= *C. albicans*; C = Control; GEN= Gentamycin; AUG= Augmentin

Several studies reported that hot pepper seeds and leave extracts are rich in proteins, fats and minerals (Park et al., 2006). Results from this findings revealed that chili pepper (*Capsicum annuum* L.) is to be rich in proteins,

lipids, carbohydrates, fibres, mineral salts (Ca, K, Mg) and this correlate with the plant seed is a good source of vitamins A, D3, E, C, K, B2 and B12 (El-Ghoraba et al., 2013). *C. annuum* can also contribute significantly to the zinc and iron needed daily in the human diet (Christine et al., 2014).

The fruits are an excellent source of health related phytochemical compounds, such as alkaloid, steroid saponins, flavonoids, and capsaicinoids that are important in the prevention of chronic diseases and also inhibits bacterial growth and platelet agglomeration (El-Ghoraba et al., 2013; Wahyuni et al., 2013). Different mechanisms of action of phytochemicals from *Capsicum sp* have been suggested. They may inhibit microorganisms, interfere with some metabolic processes or may modulate gene expression and signal transduction pathways (Surh, 2003). In general, the mechanism of action is considered to be the disturbance of the cytoplasmic membrane, disrupting the proton motive force, electron flow, active transport, and coagulation of cell contents (Kotzekidou et al., 2008).

According to the study's phytochemical findings, *C. annuum* had more flavonoids, saponins, tannins, and terpenoids than other plants (Christine et al., 2014). A sign of the therapeutic potential of pepper cultivars, particularly *C. annuum*, is the presence of tannins, flavonoids, alkaloids, anthraquinones, phenolic compounds, saponins, glycosides, terpenoids, and carotenoids. Flavonoids are powerful anti-cancer agents that prevent oxidative cell damage and act as free radical scavengers and super antioxidants (Salah et al., 1995). Alkaloids are powerful medicinal agents. Because of their bactericidal qualities, pure separated alkaloids are used as fundamental therapeutic agents (Stray, 1998).

According to Onwuliri and Wonang (2005), tannins are known to cause the proteins in cell walls to coagulate, whereas saponins make it easier for hazardous substances to enter cells or for essential components to seep out. By forming complexes with bacterial cell walls, extracellular proteins, and soluble fats, more lipophilic flavonoids damage microbial membranes or cell wall integrity at low concentrations, which inhibits the action of enzymes (Olajuyigbe and Afolayan, 2012). Consumption of various anti-nutrients such as tannin and saponins has also been encouraged despite their detrimental effect because they have been evaluated to be characterized by beneficial hypocholesterolaemic and h. Although it has been reported that tannins possess anti-nutritional effect on the proximate composition by precipitating dietary proteins and digestive proteins and enzymes to form complexes which are not readily digestible and which could be harmful to (Omoyeni and Adeyeye, 2009; Ojewumi and Kadiri, 2014). The human body The majority of these phytochemical components are strong bioactive substances that are found in plant tissues and serve as building blocks for the creation of effective medications; as a result, they have antibacterial and antifungal properties.

Flavonoids from *Capsicum* spp induce action by their ability to form complex with extracellular and soluble proteins and to complex with bacterial cell walls. Terpenes or terpenoids from C. annuum and chinense have antibacterial, antifungal, antiviral, and antiprotozoal properties. It was noted in vertain experiments that 60% of the derivatives of essential oils that had been tested up to that point were inhibitory to fungi and 30% were inhibitory to bacteria. The changes in the bioactive components or concentrations, extraction techniques, and mechanisms of action of the active elements of the *C. annuum* and *C. chinense* leaf extracts may account for the discrepancies in their antibacterial and antifungal activity (Nwachukwu and Uzoeto, 2010). This variation could also be attributed to the morphological differences between the tested microorganisms.

4. Conclusion

From the results of these findings, it can be concluded that the foliar extracts of the investigated *Capsicum* species contain appreciable amounts of important plant chemicals in high quantities. Such include cardiac glycosides and phlobatannins, and a vast range of mineral elements that are useful as dietary supplements for humans. This comparative study on these varieties proved that they are very rich in essential and bioactive compounds that have antimicrobial potential against Gram-positive and Gram-negative bacteria and fungi which were tested. Based on these, the authors are optimistic that the *Capsicum* varieties investigated, can serve as raw materials for drug production and also as part of herbal formulations for beneficial food supplements in the nearest future. It is also believed that active principles in the extracts from the hereby investigated plants can be isolated and synthesized for various uses which can be of benefit to man.

Conflict of Interest

The authors declare that there are no conflicts of interest to this article.

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