

## *Physalis angulata* L. (Solanaceae): Antimicrobial and Antioxidant Studies of the Aqueous Methanol Leaves Extract

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### ABSTRACT

*Physalis angulata* has several ethnomedical uses. The study was aimed at investigating the potential antimicrobial and antioxidant of the aqueous-methanol extract of *P. angulata* leaves. The extract was cold macerated in 80% methanol and tested for phytochemicals, antioxidants, and antimicrobials. The agar well diffusion method was used to determine antimicrobial activities at 6.25–100 mg/mL. The microorganisms tested included *Escherichia coli*, *Bacillus subtilis*, *Staphylococcus aureus*, *Proteus vulgaris*, *Candida albicans*, and *Aspergillus niger*. The quantification of total phenols and flavonoids was conducted using the Folin-Ciocalteu reagent method and the Aluminium Chloride colorimetric method, respectively. The assessment of radical scavenging activity was performed using the DPPH and FRAP models. The plant extract exhibited antibacterial activity, demonstrating concentration-dependent activity against all tested organisms. At 25 mg/mL, *S. aureus* and *A. niger* recorded zones of inhibitions of 19.00 and 23.00 mm while *B. subtilis*, *E. coli*, *P. vulgaris* and *C. albicans* recorded 18.83, 18.67, 14.00 and 4.35 respectively. However, at the maximum concentration of 100 mg/mL, *A. niger* recorded the highest zone of inhibition of 26.33 mm. The MIC was observed at 12.5 mg/mL against *S. aureus*, *A. niger* as well as 25 mg/ml *B. subtilis*, *E. coli*, *P. vulgaris* and *C. albicans* respectively. The total flavonoids and phenolic activities was reported to be of 56.11±0.03 mg QAE/100 g and 96.13±0.07 mg QAE/100 g respectively. The DPPH and FRAP scavenging activities recorded IC<sub>50</sub> of 0.05 and 0.07 mg/mL against 0.01 and 0.02 mg/mL of the control. The methanol extract of *P. angulata* leaves exhibited promising antioxidant and antimicrobial properties, supporting its traditional usage in ethno-medicine for treating many diseases.

**Keywords:** *Physalis angulata*, Phytochemicals, Antioxidant activity, Antimicrobial activity, Ketoconazole, Ciprofloxacin, Scavenging

### Introduction

The therapeutic properties of plants have consistently had significant importance in the evolution of human civilization (Negrutiu *et al.*,

2020). Numerous efficacious pharmaceuticals trace their origins to the abundant array of therapeutic plants found in the natural realm (David and Gordon, 2020; Yimam *et al.*, 2022).

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The development of these medications was informed by historical information pertaining to the plants from which they are derived, facilitating their production (Ozioma and Nwamaka, 2019).

The utilization of herbal medicine has been documented for an extensive period, potentially spanning millennia, with the purpose of treating injuries, bolstering the immune system, extending the shelf life of food, and mitigating the occurrence of illnesses (Nigussie and Wale, 2022). Throughout the course of human history, medicinal plants have been widely utilised as a significant and esteemed resource (Rakotoarivelo *et al.*, 2015) in the treatment of many medical ailments. Plants possess a diverse array of physiologically active chemicals, indicating the presence of unexplored therapeutic properties (Atanasov *et al.*, 2021).

Extensive research has been conducted to investigate the antimicrobial and healing capabilities of plant extracts and their constituent phytochemical components (Mahmood *et al.*, 2019). Several studies undertaken in recent years have provided evidence for the antibacterial characteristics of certain plants that are of medical importance (Vaou *et al.*, 2021). Bittner *et al.*, (2021) shown that numerous plant species exhibit antibacterial properties that are equivalent to, or perhaps surpass, the efficacy of some currently employed powerful pharmaceuticals.

The inherent antioxidants found in plants play a crucial role in mitigating the risk of sickness by effectively neutralizing detrimental free radicals. Antioxidants have the ability to decrease the generation of reactive oxygen species (ROS) by either blocking enzymes or chelating trace elements. Free radicals, which are chemical entities possessing an unpaired electron, play a substantial influence in the overall health of individuals and are utilized in the treatment or prevention of several ailments (Llauradó *et al.*, 2020). Antioxidants play a vital role in protecting the body from the detrimental effects of oxidative damage induced by free radicals. Consequently, it

is imperative to subject plant materials to antioxidant assays in order to evaluate their efficacy (Ayoka *et al.*, 2022).

*Physalis angulata* L. is classified as a member of the Solanaceae family, commonly known as the nightshade family. It is characterized as an erect annual herbaceous plant (Ozaslan *et al.*, 2017). The plant has fruit that are spherical in shape resembling balloons, and its flowers are characterized by a bell-shaped structure. In the study carried out by Almeida *et al.* (2017), it was discovered that the fruits of *P. angulata* possess beneficial nutritional qualities and are also believed to be pleasant in taste. The medicinal capabilities of several plant components, such as the roots, flowers, leaves, and stems, have been documented in the case of *P. angulata* (Wali *et al.*, 2022).

According to the findings of a team of investigators (Fan *et al.*, 2018), this salad staple plant goes by several distinct English names, including camapu, cut leaf groundcherry, wild tomato, and winter cherry. The indigenous population of Nigeria known as the Hausa refer to this particular entity as "Saada biri." According to Shangguo *et al.* (2020), *P. angulata* has demonstrated many pharmacological activities, including antiallergic, antiasthmatic, antileishmanial, antimalarial, and immunomodulatory properties. Naz and Bano (2012) assert that numerous countries rely on the utilization of medicinal plants to facilitate the production of pharmaceuticals of utmost excellence. The scientific community has become intrigued by the evidence suggesting that *P. angulata* possesses therapeutic potential for a wide range of ailments.



Fig. 1: Showing *P. angulate* in a natural environment

## Materials and Methods

### *Collection and Preparation of Plant Material*

The fresh leaves of *P. angulata* were collected at Ugono, Abraka, Delta State in January, 2022, and was authenticated in the Department of Plant Biology and Biotechnology, Faculty of Life Sciences, University of Benin, Benin City where a voucher specimen number UB4176H was obtained. Thereafter, the leaves were dried in the Laboratory at ambient temperature for 5 days and subsequently in the oven at 50 °C. The dried leaves were then milled to a coarse powdered form with the aid of a grinding machine.

### *Extraction*

With the cold maceration method, 75 % methanol was used to macerate 196.7 g of dried leaves of the plant sample and was left to stand for 72 h. The macerate was then filtered, and the filtrate was concentrated to a solid paste using a 40 °C rotary evaporator. The extract obtained was weighed and refrigerated.

### *Qualitative Phytochemical Screening of Plant Extract*

To identify the secondary metabolites present in the *P. angulate* leaves extract, it was subjected through a series of routine phytochemical tests using previously described methods (Ukwubile *et al*, 2019).

### *Collection and processing of isolates*

The organisms were obtained from the Laboratory of Pharmaceutical Microbiology Department, Faculty of Pharmacy, Delta State University, Abraka. Following that, a comprehensive investigation was conducted on these organisms. The organisms includes Gram positive (*Staphylococcus aureus*, *Bacillus subtilis*), Gram negative (*Escherichia coli*, *Proteus vulgaris*) and Fungi (*Aspergillus niger* and *Candida albicans*). Bacterial and fungi isolates were initially stored on nutritional agar and potato dextrose agar, respectively, at 40 °C, before being sub-cultured. The bacterial and fungal isolates were originally preserved on nutritional agar and potato dextrose agar, respectively, at a temperature of 40 °C prior to undergoing sub-culturing. The organisms in question were identified through the implementation of a conventional biochemical test process, as outlined in the publication by Franco-Duarte *et al.* (2019).

### *Serial Dilution of the extract*

The methodology employed in the study conducted by Balouiri *et al.* (2016) was adopted. The test sample underwent a serial dilution process, resulting in a two-fold dilution. The plant extract dilution was noted on the test tube labels: 100, 50, 25, 12.5 and 6.25 mg/mL. A volume of 5 mL of solvent was added to each 100 mg of plant extract, and the resulting mixture was agitated until complete dissolution was achieved. The solution containing the plant extract was transferred to the measuring cups at a concentration of 100 mg/mL. Subsequently, a volume of 2 mL of the extract derived from the initial test tube, specifically

labelled as having a concentration of 100 mg/mL, was introduced into an equivalent volume of methanol contained in the second test tube, denoted as having a concentration of 50 mg/mL. An additional three test tubes underwent an identical procedure. Following the extraction of 2 mL of the plant extract mixture from the fifth test tube, it was subsequently transferred to test tube number.

#### ***Sensitivity Test of the leaves extract of P. angulata***

The Previously described method of Kamath *et al*, 2022 was adopted with little modification. The inhibitory potentials of the extract against selected pathogens was carried out. The microorganisms used were *Escherichia coli*, *Bacillus subtilis*, *Staphylococcus aureus* and *Proteus vulgaris*. *Escherichia coli* and *Proteus vulgaris* are gram-negative bacteria while *Bacillus subtilis* and *Staphylococcus aureus* are gram-positive. The surface of the solidified agar was swapped with the various microorganisms. Using a 6mm cork borer, holes were bore on the agar surface based on the various concentrations of the extract. A few drops of the plant extract were added to each well using a pasteur pipette, and the mixture was let to rest for 15 minutes before being incubated at 37 °C for 24 hours.

#### ***Determination of creatinine, urea and lactate dehydrogenase***

The protocol of Kowalska-Krochmal *et al*, 2021 was followed. Briefly, the various plant extract concentrations were made by serial dilution, and the different plant extract concentrations (100, 50, 25, 12.5, and 6.25 mg/mL) were transferred onto petri dishes containing sterile nutritional agar and allowed to harden. The microbes were introduced into the nutritional agar and plant extract mixture using a sterile wireloop, and each plate was labeled appropriately. It was then allowed to stand for a short period of time before being incubated by inversion for 24 hours at 37 °C.

#### ***Total Phenol Content (TPC)***

The methods of Martínez *et al* (2022) was adopted. The amount of phenolic content in the methanol extract of *P. angulata* leaves was determined using previously described standard protocols. Folin-Ciocalteu reagent method with some modifications. Total of 1.5 mL of 10 % Folin - Ciocalteu reagent and 1 mL of 2 % solution of Na<sub>2</sub>CO<sub>3</sub> were added to the 1 mL of plant extract. The resulting mixture underwent an incubation period of 15 minutes at ambient temperature, followed by measuring the absorbance of the sample at 765 nm using a UV spectrophotometer. The experiment was conducted by replicating the methodology using methanol solutions containing gallic standards, with the purpose of establishing a calibration curve. The technique was repeated using methanol solutions of gallic standards in order to construct a calibration curve. The findings are provided as mg GAE/g dry weight of the plant extracts, and the TPC was estimated by applying a regression equation that was generated from the standard curve.

#### ***Total Flavonoid Content***

The flavonoid content was calculated using a modified version of the aluminum chloride colorimetric technique (Lee *et al*, 2022). A total of 3 mL of methanol, 0.2 mL of 10 % aluminum chloride, 2 mL of 1M potassium acetate, and 5.6 mL of distilled water were added to 1 mL of plant extract. After letting the mixture sit for 30 minutes at room temperature, the absorbance was measured using a UV spectrophotometer set at a wavelength of 420 nm. The quercetin standards were then analyzed in methanol at concentrations ranging from 0.01-0.1 mg/mL to generate the calibration curve. The TFC was calculated using the regression equation derived from the quercetin standard curve. The quercetin equivalents per gram of dry plant extracts (mg QE/g dry weight) were used as the unit of measurement.

### **Antioxidant Activity**

A stock solution with a concentration of 20 mg/mL was obtained by dissolving the extracts in dimethyl sulfoxide (DMSO). The antioxidant activity assessment was performed on the extracts at a concentration range of 10-100 mg/mL using two distinct procedures.

#### **(a). DPPH (2, 2 - Diphenyl -1- Picryl Hydrazyl)**

The DPPH solution was prepared in methanol and 0.5 mL of the DPPH was subsequently added to various concentrations of 2mL of the different extracts (10-100 mg/mL) and the mixture was vortexed for 10 seconds and allowed to stand at room temperature for 20 minutes. The absorbance was recorded at 517nm using UV spectrophotometer. The absorbance result was compared with 70% methanol which acts as control solution and ascorbic acid was used as the standard. These measurements were performed in triplicate and the mean percentage inhibition as well as the standard error of mean (SEM) were calculated

The FRAP reagent, a newly created working solution, was obtained by combining 25 mL of acetate buffer with a concentration of 0.3M, 2.5 mL of TPTZ solution, and 2.5 mL of FeCl<sub>3</sub>. The solution containing 6H<sub>2</sub>O was subjected to pre-heating at a temperature of 37 °C prior to its utilization, as described by Youn *et al* (2018). A sample of appropriate dilution (0.1 mL) was introduced into a mixture consisting of 4.0 mL of FRAP reagent. The solution was subjected to incubation at a temperature of 37 °C for a duration of 10 minutes in a light-restricted environment. Following this, the measurement of the solution's absorbance was measured at a specific wavelength of 593 nm, with a blank reference obtained through the use of distilled water.

#### **(b) Ferric Reducing Antioxidant Power (FRAP)**

The technique is based upon the process of diminishing the Fe (III) -TPTZ complex to its ferrous state under conditions of low pH. A freshly

prepared FRAP reagent working solution was obtained by combining 25 mL of acetate buffer with a concentration of 0.3M, 2.5 mL of TPTZ solution, and 2.5 mL of FeCl<sub>3</sub>. 6H<sub>2</sub>O solution and then warmed (pre-heated) at 37 °C before use (Youn *et al*, 2018). The sample of appropriate dilution (0.1 mL) was introduced into a mixture consisting of 4.0 mL of FRAP reagent. The solution was subjected to incubation at a temperature of 37 °C for a duration of 10 minutes in a light-restricted environment and the absorbance was taken at 593 nm with reference to the blank. The results obtained from triplicate analyses were expressed as aqueous solution of ferrous sulfate (FeSO<sub>4</sub>.7H<sub>2</sub>O) and derived from a calibration curve of the standards (10 – 100 mg/mL). The mean percentage inhibition were obtained by the same procedure.

### **Statistical Analysis**

This was done using SPSS version 12.0. Analysis of variance (ANOVA) with a single factor, followed by the Waller-Duncan post hoc test, was used in group comparisons. For statistical significance, a value of P<0.05 was used.

### **Result**

#### **Phytochemical Composition**

The result of phytochemical screening carried out on the leaf extract of *P. angulata* showed the presence of five (5) secondary metabolites which includes saponins, flavonoids, alkaloids, terpenoids and cardiac glycosides while tannins and anthraquinones were absent (Table 1).

#### **Antimicrobial Activity**

In vitro sensitivity assay of the leaves extract of *P.angulata* against the organisms revealed a concentration-dependent activity. Among the organisms, *A. niger* , *S. aureus* and *E. coli* were more susceptible to the test material. For example, at 12.5mg/mL, they exhibited zones of inhibitions of 22.33, 16.50 and 15.83 mm respectively.

Similarly, at the maximum concentration, the activities was further increased as they recorded zones of inhibitions of 26.33, 22.50 and 21.00 mm (Table 2, Fig.2). The findings indicate that the extracts had significant action against the organisms studied when compared to the standard antimicrobials drugs (Ciprofloxacin and Ketoconazole).

### **Minimum Inhibitory Concentration (MIC) of Extract of *P. angulata***

Antimicrobial activity expressed as minimum inhibitory concentration (MIC) was determined and results were recorded. While the MIC of *S. aureus*, *E. coli* and *A. niger* was recorded as 12.5 mg/mL that of *B. substilis*, *P.vulgaris* and *C. albicans* was 25 mg/mL respectively (Table 3).

### **Total Flavonoids and Phenolic Activity of the Leaf Extract of *P.angulata***

Result of the total phenolic (TPC) and flavonoid content (TFC) of the leaves extract of *P. angulata* was recorded as 96.13±0.07 mg QAE/100 g and 56.11±0.03 g QE/100g respectively. The linear equations obtained from the gallic calibration curve ( $y = 9.42x + 0.0160, R^2 = 0.18$ ) for TPC and from the quercetin calibration curve ( $y = 28.741x + 0.0382, R^2 = 0.99$ ) for TFC were used to calculate their value.

### **Antioxidants Activities of the leaves extract of *P. angulata* .**

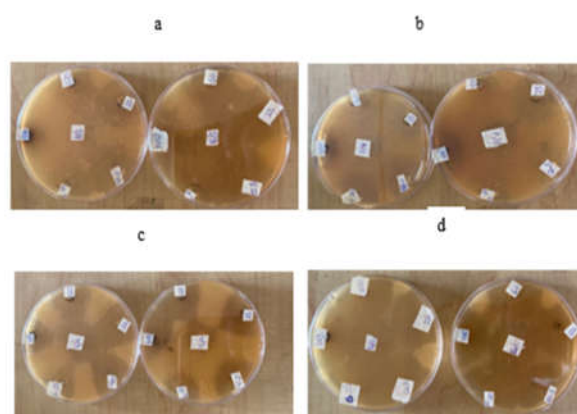
The standard antioxidant, ascorbic acid, was employed as a reference point. Regression analysis of a plot of percent inhibition against the extract concentration (mg/mL) was used to estimate the IC<sub>50</sub> (the concentration of extract or standard that may inhibit 50 % of the DPPH and FRAP capacity). Scavenging activity as an antioxidant was found to increase with increasing concentration. A lower IC<sub>50</sub> value indicates greater DPPH and FRAP radical scavenging activity

which implies that the leaves extract recorded lower scavenging activity compared to the standard drug. The leaves extract of *P.angulata* recorded IC<sub>50</sub> of 0.07 and 0.05 mg/mL for DPPH and FRAP assays respectively. The IC<sub>50</sub> values for the extract was statistically different from ascorbic acid which serves as the control.

**Table 1:** Phytochemical Screening of the Leaf Extract of *P. angulata*

<b>Phytochemicals</b>	<b>Inference</b>
<b>Saponins</b>	+
<b>Tannins</b>	-
<b>Alkaloids</b>	+
<b>Cardiac glycoside</b>	+
<b>Anthraquinone</b>	-
<b>Flavonoid</b>	+
<b>Terpenoids</b>	+

**Key:** + = indicates presence of metabolite ; - = indicates absence of metabolite



**Fig. 2:** Antibacterial activity of *P. angulata* extract against (a) *S. aureus*, (b) *B. subtilis* (c) *P. vulgaris*, (d) *E. coli*

**Table 2:** Antimicrobial activities of the Crude Extract of *P. angulate*

Organisms	Concentration (µg/mL)/ Zones of Inhibition (mm)					Control
	100	50	25	12.5	6.25	
						Ciprofloxacin
<i>S. aureus</i>	22.50±0.50 <sup>a</sup>	20.67±0.17 <sup>a</sup>	19.83±0.17 <sup>b</sup>	16.50±0.50 <sup>a</sup>	15.83±0.73 <sup>b</sup>	7.50±1.68 <sup>a</sup>
<i>B. substilis</i>	19.17±1.74 <sup>b</sup>	18.17±1.74 <sup>b</sup>	14.83±1.17 <sup>c</sup>	12.17±0.73 <sup>b</sup>	10.33±0.67 <sup>c</sup>	6.00±1.01 <sup>a</sup>
<i>E. coli</i>	21.00±0.29 <sup>a</sup>	19.83±0.44 <sup>b</sup>	16.67±1.48 <sup>d</sup>	15.83±0.67 <sup>c</sup>	12.00±1.00 <sup>d</sup>	14.00±2.16 <sup>b</sup>
<i>P. vulgaris</i>	18.33±0.67 <sup>b</sup>	16.17±1.09 <sup>c</sup>	14.00±0.58 <sup>c</sup>	13.17±0.17 <sup>b</sup>	9.17±0.73 <sup>c</sup>	19.00±1.32 <sup>c</sup>
						Ketoconazole
<i>A. niger</i>	26.33±0.60 <sup>c</sup>	24.17±0.73 <sup>d</sup>	23.00±0.50 <sup>e</sup>	22.33±0.17 <sup>f</sup>	20.33±0.17 <sup>f</sup>	0.00±0.00
<i>C. albicans</i>	9.33±0.33 <sup>f</sup>	7.83±0.44 <sup>e</sup>	4.35±0.88	na	na	34.00±0.18 <sup>f</sup>

Values expressed as Mean ± SEM, n (3), Positive Control (Drug) – Ciprofloxacin (50 µg/mL) and Ketoconazole (20 µg/mL). In the same column, the mean diameters of inhibition zones of test samples with distinct superscript letters (a, b, c, d, e, f) are significantly different (p<0.05) from other mean values, whereas those with the same superscripts are not. na: not active

**Table 3:** Minimum Inhibition Concentration of Leaf Extract of *P. angulata*

Organisms	Concentration (mg/mL)					
	100	50	25	12.5	6.25	3.125
<i>S. aureus</i>	-	-	-	-	+	+
<i>B. substilis</i>	-	-	-	+	+	+
<i>E. coli</i>	-	-	-	-	+	+
<i>P. vulgaris</i>	-	-	-	+	+	+
<i>C. albicans</i>	-	-	-	+	+	+
<i>A. niger</i>	-	-	-	-	+	+

Key: + indicates growth - indicates no growth

**Table 4:** Total Flavonoid Activity of the Leaves extract of *P. angulata*

Total Phenolic (GAE g/100 g)	Total Flavonoids (mg QE/100 g)
96.13±0.07	56.11±0.03

Value presented in Mean ±SEM (n=3), Gallic acid (total phenolic), Quercetin (total flavonoids),

a

b



Fig. 3: Antifungal activity of *P. angulata* leaves extract against (a) *C. albicans*, (b) *A. niger*

**Table 5:** Percentage of inhibition of DPPH of the extract of *P. angulata*

Concentration (mg/mL)	% Inhibition	
	DPPH	Ascorbic acid (Control)
10	51.10±0.98	62.09 ±1.08
20	58.19±1.01	76.14±1.13
40	69.64±1.12	89.72±1.67
80	86.17±1.14	96.50±1.19
100	91.74±1.02	99.98±1.07
IC <sub>50</sub>	0.07	0.01

Value presented in Mean ±SEM (n=3); Ascorbic acid (DPPH)

**Table 6:** Percentage of inhibition of FRAP of the extract of *P. angulata*

Concentration ( mg/mL )	% Inhibition	
	FRAP	Ascorbic acid (Control)
10	59.59±0.44	51.26±0.10
20	66.77±0.04	68.77±0.17
40	73.15±0.21	75.18±0.19
80	84.89±0.06	96.16±0.53
100	92.77±0.06	99.52±0.16
IC <sub>50</sub>	0.05	0.02

Value presented in Mean ±SEM (n=3); Ascorbic acid (FRAP)

### Discussion

An increasing number of illnesses are becoming untreatable as a consequence of the widespread growth in the prevalence of drug-resistant

organisms (Akinyemi, 2020). The current study looked at the potential antimicrobial and antioxidant activities of extract of *P. angulata* leaves on selected organisms.

The phytochemical screening findings showed the extract comprised an array of phytochemical groups. Phytochemical screening of methanol extract of *P.angulata* leaves by our team revealed the presence of saponins, flavonoids, terpenoids, alkaloids, and cardiac glycosides. Several of these bioactive compounds were also discovered by Porika *et al* (2014), who examined the same plant samples extracted with a variety of solvents and found similar results. Secondary metabolites in medicinal plants are responsible for their pharmacological effects (Kaushik *et al.*, 2021). Antibacterial, anti-inflammatory, and antioxidant properties are only a few of the many biological effects attributed to compounds including alkaloids, phenols and tannins as well as flavonoids. Flavonoids, for example, have been shown to be effective against a wide range of germs owing to their ability to easily destroy microbial membranes (Ullah *et al*, 2020).

Phenolic compounds, because of the presence of a hydroxyl group, have a tendency to be more soluble in polar organic solvents. This helps to explain the rationale behind the choice of an aqueous solution of methanol as our extraction solvent. Polyphenols, which comprise flavonoids and phenolic compounds, are naturally occurring antioxidants thought to have a significant role in the prevention of several diseases. Therefore, total phenol (TPC) and total flavonoid content (TFC) measurements are useful for approximating a plant extract's antioxidant potential. Our study recorded the TPC and TFC of *P. angulata* as 96.13±0.07 GAE g/100g and 56.11±0.03g QE/100g respectively. According to this study, *P. angulata* leaves showed presence of a sizeable quantity of both phenolic and flavonoid content as well as other important phytochemicals. It is possible that the presence of these metabolites might be



responsible for the pharmacological activities that have been ascribed to *P. angulata*. This would also help to explain why the plant is used in such a wide variety of traditional medicinal preparations.

The DPPH and FRAP tests were used to report the antioxidant activity. DPPH is a hydrogen transfer assay for antioxidant activity, whereas FRAP is an ion reduction assay that converts ferri (Fe<sup>3+</sup>) to ferro (Fe<sup>2+</sup>) (Munteanu and Apetrei, 2021). The percentage inhibition method provides an expression for the extract concentration needed to inhibit free radicals by 50 %. The findings show that the DPPH-scavenging and ferric-reducing capacities of *P. angulata* leaves extract are both strong. The findings also shows that the antioxidant scavenging activity increases with increasing concentration. The regression analysis of a plot of percent inhibition against extract concentration (g/mL) yielded IC<sub>50</sub> which is the concentration of extract or standard that can inhibit 50% of the DPPH and FRAP capacities. The leaves extract of *P.angulata* recorded IC<sub>50</sub> of 19.75 and 21.68 mg/mL for DPPH and FRAP assays which were statistically different from those of ascorbic acid. Similar results were obtained by Olamide *et al.* (2017) where they compared the antioxidant activities of the stem and leaves extracts of *Grewia carpinifolia*. It also supported the results of an antioxidant research study carried out on *Brugeiera gymnorhiza* and *Aegialitis rotundifolia* by Reddy *et al.* (2016). It is possible that the comparatively high levels of TPC and TFC found in the extract of *P. angulata* could be responsible for the significant radical scavenging activities of the plant.

The antimicrobial activity of *P. angulata* extract against the test organisms shows that the plant had great antimicrobial potency against all test organism. Donkor *et al.* (2016) found that both the aqueous and ethanol extract of *P. angulata's* aerial part were highly effective against *S. aureus* and *P. aeruginosa*, with the diameter of the inhibition zone being 21.00 and 23.00 mm, respectively, at

the highest concentration (250 mg/mL) which is in line with our findings.

However, *S. aureus* and *A. niger* were more susceptible to the extract as they recorded zones of inhibitions of 22.50 and 26.33 mm at 100 mg/mL. While Dias *et al.* (2020) only identified antibacterial activities against gram-positive bacteria, our findings indicate that it is also effective against gram-negative bacteria and fungal isolates, proving its broad-spectrum antimicrobial potential. *S. aureus* and *A. niger* were the most sensitive to the plant extract, with MIC values of 12.5 mg/mL and 12.5 mg/mL, respectively, while *B. subtilis*, *E. coli*, *P. vulgaris*, and *C. albicans* were the most resistant, with MIC values of 25 mg/mL and 25 mg/mL, respectively

The effects of the methanol leaves extract of *P. angulata* on *S. aureus*, *B. subtilis*, *E. coli*, *P. vulgaris*, *C. albans* and *A. niger* confirmed its usefulness in treatment of microbial infections such as boils, sores, cuts, constipation and intestinal and digestive problems (Adewolu *et al.*, 2021).

The study showed that the methanol leaves extract of *Physalis angulata* has antioxidant and antimicrobial potentials with reference to the control drugs. Further comparative antimicrobial studies of different antioxidants present in the plant extract will help to elucidate the roles played by the functional groups of plants.

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