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Antimicrobial Activity of Coconut Water, Coconut Oil and Palm Kernel Oil on selected Clinical *Enterobacteriaceae* Isolates

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Abstract

Antimicrobial resistance and the decreasing efficiency of antimicrobial drugs have resulted in the search for antimicrobial agents as an important strategy for the establishment of alternative therapies in handling difficult infections. This study was carried out to compare and investigate the in vitro antimicrobial activities of coconut water, coconut and palm kernel oil on selected clinical *Enterobacteriacae* isolates from Edo state, Nigeria. The antimicrobial activities of the samples were screened using agar well diffusion assay methods. The physicochemical properties of coconut and palm kernel oil was determined using previously described methods to characterize the oil samples. Using previously described methods, the proximate analysis and qualitative presence of phytochemical constituents were analyzed in the coconut water sample. The assay of antibacterial activity of the *Enterobacteriaceae* isolates showed the highest susceptibility to Coconut water. *Enterobacter cloacae* showed the highest zone of inhibition of 20mm when compared with the positive control. Coconut and palm kernel oil also showed inhibitory effects on the isolates. The phytochemical and proximate tests of the coconut water sample revealed the presence of reducing sugar and terpenoids and also a good proximate composition (ash, moisture, crude lipid, crude fiber and protein). The oil characterization results for coconut and palm kernel oils are acid value (4.348 mgKOH/g, 3.363 mgKOH/g), saponification value (413.036 mgKOH/g, 267.177 mgKOH/g), peroxide value (0.55 mEq/kg, 8.8 mEq/kg) and iodine value (14.657 g/100g, 14.276 g/100g). Our study showed good promising evidence for the antimicrobial effects of the samples and their usefulness in food and manufacturing industries

Keywords: Antimicrobial Activity; Coconut; Palm Kernel; Phytochemicals; Proximate Analysis

1. Introduction

The emergence of drug-resistant pathogens most especially to the chemically synthesized antibiotics has been of global concerns due to its hindrance to effective and successful treatment of microbial infections and diseases [1]. Antibiotic resistance have impacted negatively economically on the patient by way of prolonged hospital stay as well the search and purchase of more expensive alternatives and the possibility of death after a prolonged treatment. The rising trend of multidrug resistance as a result of the overuse and misuse of antibacterial agents is of significance thus necessitating the need of alternative sources and reduction in the over dependence on conventional antibiotics [2].

Medicinal plants also called medicinal herbs have always been pivotal to the sustenance of traditional medicine and conventional medicine, as these plants contain components that serve as a source for drug lead compounds [3]. The advent of ethno medicine with the frequent use of medicinal plants by 88% member countries of the World Health Organization provides the indices for reference as a readily available alternative with promising outcomes when

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compared with the conventional antibacterial agents [4]. Medicinal plants can thus be best described as plants that are used to manage or treat specific health conditions [5] as they possess therapeutic natural compounds that exert pharmacological properties on the human and animal body [6]. Natural products offer an untold diversity of chemical structures. These natural compounds often serve as lead molecules whose activities can be enhanced by manipulation through combinations with chemicals and by synthetic chemistry [7]. Plants are rich in a wide variety of secondary metabolites, such as tannins, terpenoids, alkaloids, and flavonoids. These metabolites have been found in vitro to have antimicrobial properties. Interest in medicinal plants has increased in recent years. This interest has led to the discovery of new biologically active molecules by the pharmaceutical industry and the adoption of crude extracts of plants for self-medication by the public [7]. Many plants have been evaluated not only for their inherent antimicrobial activity, but also for their action as a resistance-modifying agent [7]. The enhancement of antibiotic activity or the reversal of antibiotic resistance by natural or synthetic non-conventional antibiotics has led to the classification of these compounds as modifiers of antibiotic activity [7]. Coconut water, coconut oil and palm kernel oil have been found to be pharmacologically useful [8] as well as its use in the treatment of different microorganisms due to their various phytochemical properties [9]. They also show other biological activities such as anti-inflammatory, anti-diabetic, antibacterial, antioxidant, diuretic effects amongst many others thus indicating their pharmacological significance [10, 11]. The prevalence of antibiotic resistance continues to be on the rise thus causing a major setback in the effective control and treatment of bacterial infections and diseases. The discovery of new bacterial organism and the development of mechanism of resistance to the conventional antibiotics have brought about the need for an alternative source of treatment. Ethno medicine and the use of medicinal plants through research done over the years have proven to be a suitable alternative for antibacterial therapy. This study was carried out to compare and investigate the in vitro antimicrobial activities of coconut water, coconut and palm kernel oil on selected clinical *Enterobacteriacae* isolates from Edo state, Nigeria.

2. Materials and Methods

2.1. Plants collection

Coconut fruit, coconut oil and palm kernel oil were purchased at the Okada central market, Ovia north east local government area of Edo state. Nigeria. The purchased items were transported to the pharmaceutical-microbiology laboratory, Igbinedion University, Okada.

2.2. Extraction Process

Coconut fruits were first washed with distilled water and surface sterilized using alcohol before opening at one of the eyes on the apical region using a sterile knife. The coconut water was aseptically collected into a sterile glass container

2.3. Micro-organisms used

Gram positive and Gram-negative bacteria *Bacillus pumilus, Enterococcus faecalis, Pseudomonas aeruginosa, Escherichia coli, Salmonella spp. Klebsiella pneumoniae, Klebsiella variicola, Providencia stuartii, Enterobacter cloacae* from different clinical sources (Urine, wound, sputum, catheter tip) were collected from the University of Benin Teaching Hospital, Benin City (UBTH) Edo state and used for the antimicrobial studies. Isolates were sub-cultured on nutrient agar plates to obtain pure colonies. Previously described standard microbiological techniques [12] and Matrix-assisted laser desorption ionization time of flight (MALDI-TOF) mass spectrometry (Bruker Daltonik GmbH, Bremen, Germany) analysis was used for species identification. All the isolates were maintained on nutrient agar slants at 4°C.

2.4. Oil Characterization

2.4.1. Acid Value Determination

Two grams of the sample was dissolved in 50 cm^3 of mixed neutral solvent (25 cm^3 diethyl ether with 25 cm^3 ethanol carefully neutralized with 0.1M NaOH using 1% phenolphthalein solution). The mixture was titrated with 0.1M NaOH aqueous solution with constant shaking to faint pink colour [13].

$$\textbf{Acid value} = \frac{VNaOH \times M \times 56.1}{W}$$

where VNaOH = Volume of sodium hydroxide titrant used (mL)

M = Molarity of NaOH

W = Weight of the fatty oil being examined (g)

2.5. Determination of Ester Value

The ester value is calculated by subtracting the acid value of oil from the saponification value of the corresponding oils.

2.5.1. Determination of the Saponification Value

0.5 M KOH was prepared in 95 % ethanol, 2g of oil sample was weighed and 25 cm^3 of KOH was added, 25 cm^3 of the blank solution was also measured into a conical flask. The two samples were then connected to a reflux apparatus and allowed to boil for an hour until the reflux is completed, 1 cm^3 of phenolphthalein was added to the mixture and the resulting mixture was titrated while hot against 0.5 M HCL acid solution. The volume of the acid used to attain the end point was recorded, the blank determination was carried out using the same procedure described above until the colour changes from blue to transparent white, then the volume of acid used was noted, the Saponification value was determined using the relationship below [13].

$$\textbf{Saponification value} = \frac{56.1 \times T\ (V_0 - V_1)}{M}$$

Where, T= Molarity of the standard KOH solution used (M), V_o = Volume of acid used for the first titration with oil sample (cm^3), V_1= Volume of acid used for the second titration of the blank solution (cm^3), M= Mass of the oil sample used (g).

2.6. Peroxide Value Determination

Known weight (2g) of sample was weighed into clean dried boiling tube, 1 gram of potassium iodine (KI) powder was added to the oil and 20 cm^3 of the solvent mixture (i.e, glacia acetic acid and chloroform in the ratio 2:1). The boiling tube was placed in boiling water bath so that the liquid mixture boils within 30 seconds and allowed to boil vigorously for not more than 30 seconds, the content after boiling was quickly poured into a flask containing 20 cm^3 of 5 % potassium iodine (KI) solution and the tube was washed out twice with 25 cm^3 of water. The mixture was titrated with 0.002 M sodium thiosulphate using fresh 1 % starch solution, a blank titration was carried out at the sample time, and the peroxide value was calculated using the relationship below [13].

$$\textbf{Peroxide value} = \frac{T \times M \times 1000}{Weight\ of\ sample(g)}$$

where T = titre value of $Na_2S_2O_3$ = Sample titre – Blank titre, M = Molarity of $Na_2S_2O_3$

2.6.1. Iodine value

For Iodine value (Wij's method) of each sample 2g of oil was dissolved in 15 mL carbon tetrachloride in 250 mL glass stoppered flask. 25 mL of Wij's solution was added, the flask stoppered and allowed to stand for 2 hours in the dark at 25°C, 20 mL of 10% potassium iodide (kI) solution was added and mixture titrated with 0.2N sodium thiosulphate ($Na_2S_2O_3$) using starch indicator. A blank determination was carried out and the Iodine value calculated using the formula:

$$\textbf{Iodine value} = \frac{12.69N(V2 - V1)}{W}$$

Where N = Normality of thiosulphate
V1 = Volume (in mL) of thiosulphate solution 1 used in test.
V2 = Volume (in mL) of thiosulphate solution 2 used in blank
W = Weight of sample (2g).

2.7. Proximate Analyses of Coconut water

2.7.1. Determination of moisture content

The method described by A.O.A.C [14] was adopted, a clean crucible was dried to a constant weight in air oven at 105°C, cooled in a desiccator and weighed (W1). Five grams of sample was accurately weighed into the previously labeled crucible and reweighed (W2). The crucible containing the sample was dried in an oven at 105°C to constant weight (W3). The percentage moisture content was calculated thus:

$$\% \text{ Moisture content} = \frac{W2 - W3}{W2 - W1} \times 100$$

2.7.2. Determination of ash content

The A.O.A.C [14] method was used. The porcelain crucible was dried in an oven at 105°C for 10 min, cooled in a desiccator and weighed (W1). Five grams of the sample was placed into a previously weighed porcelain crucible and reweighed (W2), it was first ignited and then transferred into a furnace which was set at 550°C. The sample was left in the furnace for eight hours to ensure proper ashing. The crucible containing the ash was then removed; cooled in a desiccator and weighed (W3). The percentage ash content was calculated as follows:

$$\% \text{ Ash Content} = \frac{W3 - W1}{W2 - W1} \times 100$$

2.7.3. Determination of crude lipid content by soxhlet method

A clean, dried 500 cm^3 flat bottom flask was weighed (W1) with 300 cm^3 petroleum ether poured into the flask filled with soxhlet extraction unit. The extractor thimble with sample weighing five grams was fixed into the Soxhlet unit. The round bottom flask and a condenser were connected to the Soxhlet extractor and cold water circulation was connected. The heating mantle was switched on and the heating rate adjusted until the solvent was refluxing at a steady rate. Extraction was carried out for 4 h. The solvent was recovered and the oil dried in an oven set at 70°C for 1 h. The round bottom flask and oil was then weighed (W2). The lipid content was calculated thus:

$$\% \text{ Crude Lipid content} = \frac{W2 - W1}{Weight\ of\ sample} \times 100$$

2.7.4. Determination of crude fibre

The defatted sample (5 g) was weighed into a round bottom flask, 200 cm^3 1.25% sulphuric acid solution was added and the mixture boiled under reflux for 30 min. The hot solution was quickly filtered under suction. The insoluble matter was washed several times with hot water until it was acid free. It was quantitatively transferred into the flask and 200 cm^3 of hot 1.25% Sodium hydroxide solution was added, the mixture boiled under reflux for 30 min and filtered under suction. The residue was washed with boiling water until it was base free, dried to constant weight in an oven at 100°C, cooled in a desiccator and weighed (C1). The weighed sample (C1) was then incinerated in a muffle furnace at 550°C for 2 h, cooled in a desiccator and reweighed (C2).

The loss in weight on incineration = C1- C2

$$\% \text{ Crude fibre} = \frac{C1 - C2}{Weight\ of\ original\ sample} \times 100$$

2.7.5. Determination of percentage protein

5 g of the sample were transferred to a Kjeldahl digestion flask and 10 g of anhydrous sodium sulphate, 0.3g of copper sulphate were added. 20 mL of conc. H_2SO_4 was added in an inclined position and shaken occasionally on a heating mantle for 2 h. The liquid formed was cooled and washed into a 100 mL volumentary flask and made to mark with distilled water. 50 mL of 1% boric acid solution and mixed indicator were added to the receiving flask. The distillation apparatus was collected with the delivery tube deeping below the acid solution. The diluted digest was made alkaline by the addition of 50 mL 45% NaOH solution. About 50 mL of the distillate were collected and back titrated with 0.5 N NaOH. A blank was also titrated under the same condition [14].

$$\% \text{ by mass protein} = \frac{8.75 \times (B - A) \times N}{M}$$

Where;

B = Titre value in blank, A = Titre value in sample, N = Normality of sodium hydroxide (2N), and M = Mass of sample.

2.7.6. Determination of carbohydrate by (difference)

The total carbohydrate was determined by difference. The sum of the percentage moisture, ash, crude lipid, crude protein and crude fibre was subtracted from 100.

% Total carbohydrate = 100 - (% moisture + % Ash + % fat + % Protein + % Fibre).

2.7.7. Qualitative Phytochemical Screening of Coconut water

Screening for the presence of secondary metabolites were performed as described by standard methods [15, 16] with slight modifications

2.7.8. Test for Saponin

The filtrate (0.5ml) was placed in a test tube and 5mL of distilled water was added and shaken vigorously. Persistent fronting indicates a positive test for saponin.

2.7.9. Test for Flavonoid

The filtrate (2ml) was added to 2mL dilute ammonia followed by the addition of 1mL of Conc. H_2SO_4 acid. A yellow coloration revealed the presence of flavonoid, which disappeared upon standing of the tube.

2.8. Test for Glycosides and Reducing Sugar

2.8.1. Test for Cardiac Glycoside

To the filtrate (2ml) was added 2mL of glacial acetic acid, 1mL of 0.1% $FeCl_3$ and 1mL of Conc. H_2SO_4 acid. A green-blue coloration indicated the presence of cardiac glycoside.

2.8.2. Test for Reducing Sugar

Fehling solution A and B (2ml each respectively) was added to 2ml of the sample and heated for 30 minutes. A red coloration indicated the presence of reducing sugar.

2.8.3. Test for Alkaloids

A volume of 3mL of 1% HCL was added to 3ml of the sample filtrate and the mixture was steamed for 30 minutes before cooling and centrifuging at 2000-3000rpm for 10 minutes:

2.8.4. Wagner's Test for Alkaloids

One ml (1ml) of wagner's reagent was added to 1ml of supernatant of sample obtained after centrifugation. A reddish-brown precipitate indicated a positive result for alkaloids.

2.8.5. Dragendorff's Test for Alkaloids

One ml (1ml) of dragendorff's test was added to 1ml of supernatant of sample obtained after centrifugation. An orange color precipitate indicated a positive result for alkaloids.

2.8.6. Mayer's Test

One ml (1ml) of Mayer's reagent was added to 1ml of supernatant of sample obtained after centrifugation. A cream color precipitate indicated a positive result for alkaloids.

2.8.7. Test for Phlobotannins

Two ml (2ml) of 1% HCL acid added to 2ml of the sample filtrate and heated in a water bath for 30 minutes. A red colored deposit at the base of the test tube indicated the presence of phlobatannins.

2.8.8. Test for Starch/Polysaccharide

Iodine solution (6 drops) was added to 2ml of the sample filtrate. A Blue-black coloration indicated the presence of starch.

2.8.9. Test for Steroid

To 0.5mL of sample was added 0.5mL of acetic acid anhydride before cooling in ice, thereafter 0.5mL chloroform and 1mL Conc. H_2SO_4 acid was added carefully using a pipette. A reddish brown ring at the interphase of the two liquid revealed the presence of steroid.

2.8.10. Test for Tannins

Two ml (2mL) of 0.1% $FeCl_3$ solution was added to 2ml of the sample filtrate. A blue- black coloration indicated the presence of hydrolysable tannin and brownish- green color indicated the presence of condensed tannin.

2.8.11. Test for Terpenoids

Six drops (6 drops) of Brady's reagent was added to 2ml of the sample filtrate. A yellowish- orange coloration indicated the presence of terpenoids.

2.9. Preparation of Extracts

2.9.1. For susceptibility testing

5ml of various oil extracts was measured and placed in respective universal bottles. 5ml of dimethylsulphoxide (DMSO) was added to the universal bottles to dissolve the extracts giving a concentration of 100% stock concentration. A two-fold serial dilution of the stock concentration was carried out to obtain the following concentrations: 50% and 25%.

2.9.2. Preparation of negative control

Negative control was prepared by adding 2ml of dimethylsulphoxide (DMSO) to 2ml of sterile distilled water in a universal bottle for the oil samples while sterile distilled water was used as the negative control of Coconut water sample

2.9.3. Preparation of positive control

1ml of gentamicin (80mg/2ml) was put into 99ml of sterile distilled water to make 400µg/ml concentration. Then 1ml for 400µg/ml was collected and put into 39ml of sterile distilled water to make a final concentration of 10µg/ml.

2.9.4. Antimicrobial Assay.

The antimicrobial activities of the oil samples and resulting crude extracts were screened using agar well diffusion assay methods with slight modifications [17]. A volume of 0.1ml of 10^{-2} dilution of each isolate was used to inoculate the pre-prepared Muller Hinton Agar plates and surface plated using a sterile swab sticks. The sterile cork borer {8 mm diameter} was used to bore equidistant holes on the plates. Using a Pasteur pipette, 0.1ml of different concentration of the extracts (100%. 50% and 25%) was used for the assay. A volume of 0.1ml of the positive control and negative control were also used. The experiment was carried out in duplicates and examined for zones of inhibition after incubation for 24 hours

3. Results

3.1. Plant Authentication.

The fruit was authenticated as the *Cocos nucifera* linn fruit. This was done at the Dora Akiyuli College of Pharmacy herbarium at the Igbinedion University Okada, Edo state

3.2. Phytochemical screening

Table 1.0 summarizes the qualitative phytochemical analyses of Coconut water sample. The result of the screening showed that the extract under investigation contained reducing sugar and terpenoids**.**

Table 1 Phytochemical analysis of Coconut water

Phytochemical constituents	Coconut water
Alkaloids	-
Phlobatannin	-
Reducing sugar	++
Cardiac glycoside	-
Flavonoid	-

Starch	-
Tannin	-
Terpenoids	++
Saponin	-
Steroid	-

Keys: ++ = moderately present; - = absent

3.3. Proximate analysis result

The following values included in table 2.0 are a summary of the proximate analysis value of the Coconut water. The analysis showed the presence of ash, moisture, crude lipid, crude fiber and protein.

Table 2 Proximate analysis of Coconut water

Component	**% composition of the Sample**
Crude protein	8.4
Ash	5.619
Crude Fiber	0.052
Crude lipids	12
Moisture	29.961
Carbohydrate	43.968

3.4. Oil Characterization result

Table 3.0 gives a summary of the oil characterization of palm kernel oil and coconut oil respectively.

Table 3 Oil Characterization of Coconut and Palm Kernel oil

Test	**Value for Coconut oil**	**Value for Palm kernel oil**
Acid value	4.348mg KOH/g	3.363mg KOH/g
Ester value	408.688	263.814
Saponification value	413.036mgKOH/g	267.177mgKOH/g
Iodine value	14.657gI_2/100g	14.276gI_2/100g
Peroxide value	0.55mEq/kg	8.8mEq/kg

3.5. Antimicrobial Susceptibility Test

Results on the antimicrobial activity of Coconut water, coconut oil and palm kernel oil on the clinical isolates are presented in the Figure 1.0 to Figure 3.0. The extracts showed varying activity on the isolates, Gentamicin which was used as the positive control also had activity on the isolates while dimethylsulphoxide (DMSO) had no activity on the isolates.

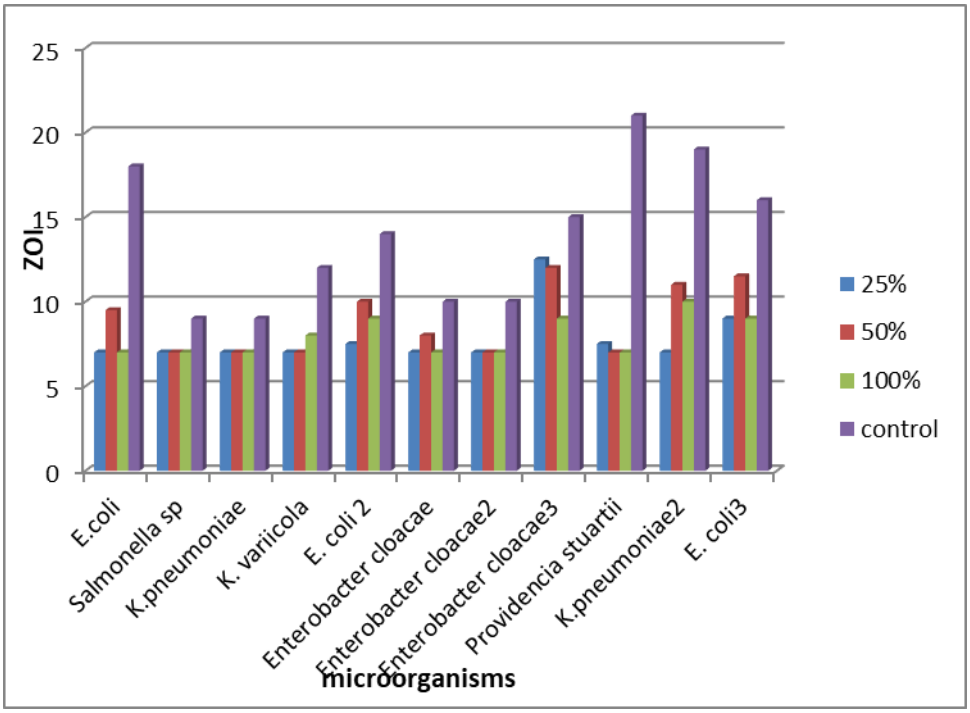

Figure 1 Antimicrobial activity of palm kernel oil on isolates

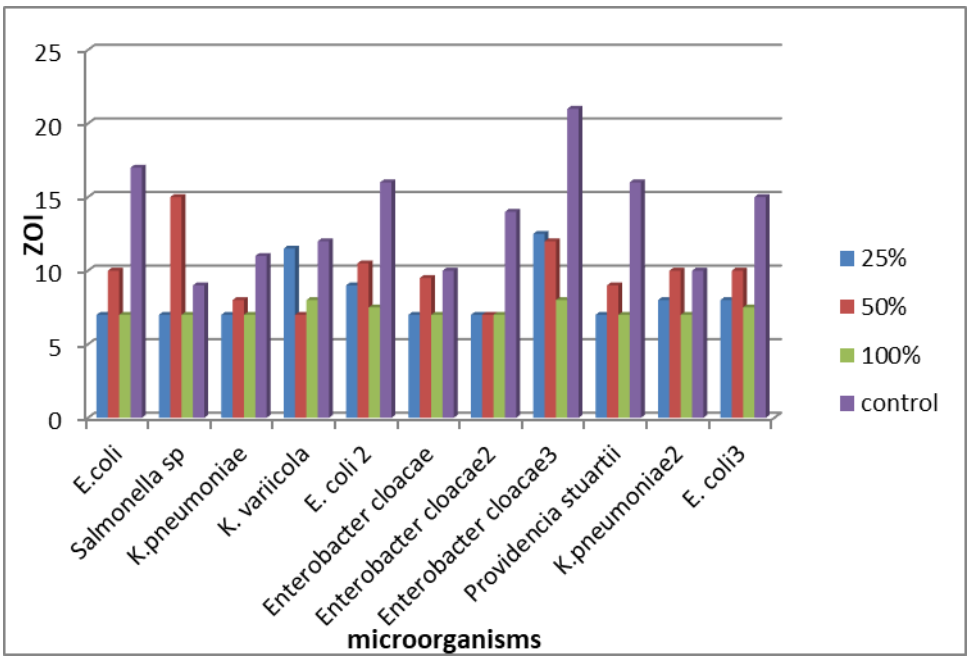

Figure 2 Antimicrobial activity of coconut oil on isolates

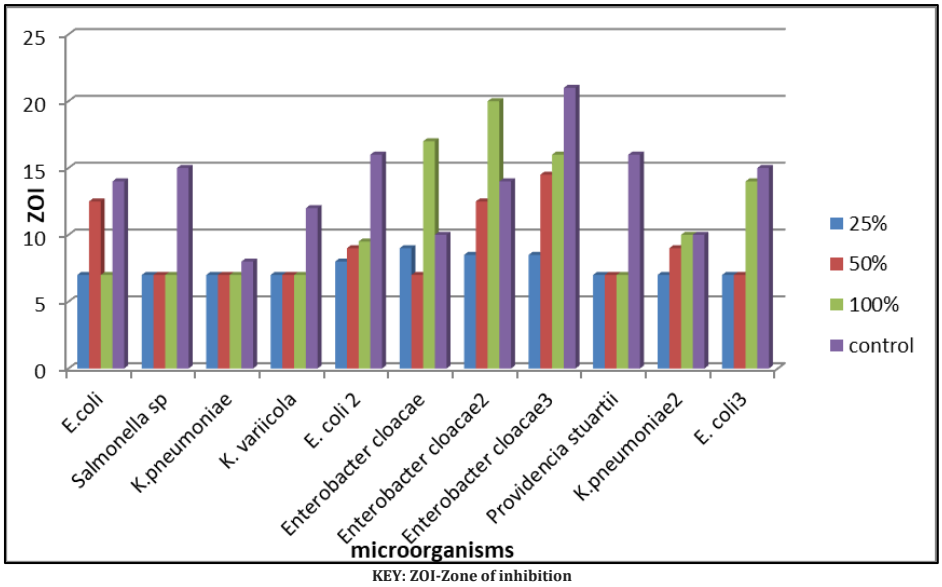

Figure 3 Antimicrobial activity of coconut water to isolates

4. Discussion

Global drug resistant infections have been on the rise due to antibacterial resistance without effective interventions, which alarmingly have led to pandemic scale like projections [18]. This has led to extensive chemical and biological investigation of ethno medicinal plants with high indices of being curative and clinically potent [19]. This research work was undertaken to carry out an in-depth investigation on the reported usefulness coconut water, coconut oil and palm kernel oil.

The phytochemical screening of coconut water showed the presence of glycoside reducing sugars and terpenoids as constituents with potential antimicrobial activity, while the proximate analysis of the coconut water sample indicated a favorable nutritional composition. Sumonsiri [20] reported the chemical composition of coconut water to consist of water (96.11%), sugars (2.7%), proteins (0.25%), lipids (0.51%) and ash (0.43%). In another recent report, coconut water was characterized by a high moisture content of 95.95 ± 0.943%, minimal ash (0.47 ± 0.753%), fiber (0.08 ± 0.292%), and protein (0.51± 0.854%) levels, alongside a moderate carbohydrate percentage of 2.91 ± 0.744%. Additionally, negligible amounts of non-fiber extract (NFE) and crude fat were observed, denoting its low-fat content and richness in essential hydration elements [21]. The slight differences in some of the values obtained in this study could be possibly due to the source of the sample. For example a previous study found the moisture content of 94.96%, carbohydrate at 4.38% and fiber at 0.0355% for street marketed coconut water compared to another that showed moisture content 81.09%, protein 3.96%, fat 12.27% and carbohydrate 5.58% for another sample [22].

The phytochemical constituents of Coconut water, reducing sugar and terpenoids are known to be of great health significance due to their different pharmacological activities. For example terpenoids are known to possess antitumor, anti-malarial, antiviral, anti-oxidative and antibacterial effects [23]. Reducing sugars are known to influence pharmacological activities in relations to other compounds and on its own possess biological activities such as anticancer, anti-inflammatory, antiviral and anti-microbial activities [24].

The oil characterization results for coconut and palm kernel oils are acid value (4.348 mgKOH/g, 3.363 mgKOH/g), saponification value (413.036 mgKOH/g, 267.177 mgKOH/g), peroxide value (0.55 meq/kg, 8.8 meq/kg) and iodine value (14.657 g/100g, 14.276 g/100g). The coconut and palm kernel oil showed slightly higher iodine value compared to previous reports [25, 26].

The iodine value from this study means both the coconut and palm kernel oils has high percentage of unsaturated fatty acid bonds. The determination of the iodine value of oil classifies oil into drying, semi-drying and non-drying oil. The ability of the oil to undergo across link reaction which is oxygen-induced leads to a formation of a solid film known as drying [27]. The higher the iodine value, the more unsaturated fatty acid bonds are present in a fat, hence its high susceptibility to oxidative degradation [28]. Hence, addition of antioxidants may be necessary to prolong the storage ability of the oils. According to Maliki et al. [29], oil with iodine value above 100g/100g is a drying oil and below

100g/100g is non-drying oil. Non-drying oils are essential in skin care products because of their moisturizing effect. They do this by helping the skin maintain its water permeability barrier. Studies also show that applying non-drying oils on the skin may increase the production of collagen and decrease inflammation. The moisturizing properties of non-drying oils also help manage dry and itchy skin [30].

The saponification value of a sample is the amount of KOH in mg required to completely saponify (breakdown) 1g of fat or oil producing soap. This value gives an index of the average fatty acid chain length present in the test oil [31]. The saponification value of palm kernel oil 267.177mgKOH/g was determined lower than that of coconut oil (408.688 mgKOH/g) but indicated a high saponification value for both oils. Oils with high saponification contains high proportions of low/medium chain fatty acids a unique characteristic that makes them well suited for various industrial uses beyond just culinary use such as in producing soaps with excellent lathering properties, creams and other skin care products [32, 33].

Acid value of oil shows the amount in mg of KOH needed to neutralize free fatty acid existing in a gram of oil sample. The acid value for palm kernel oil, 3.363 mgKOH/g compares with that of reports of Jacobs et al., [34]. Conversely, this value is lower compared with 6.37 mgKOH/g reported by Marius et al., [35]. Literature reports reveal that the higher the acid value of an oil, the greater the fatty acids it contains. This finding suggests that palm kernel oil has high potential for production of quality soap. The acid value of oil indicates the level of spoilage that has occurred in an oil sample, and is usually indicated by the presence of free fatty acids formed as caused by enzymatic hydrolysis. The acid value observed for the coconut oil (4.348 mgKOH/g) is significantly high compared to values previously reported [25, 30]. The observed high acid values indicate the presence of high free fatty acid formation which indicates the low stability of the oil to hydrolysis by enzymes, and its susceptibility to attack during processing and/or storage conditions which negatively affects the quality of oil and has health implications [36, 37].

In this study, coconut oil had a peroxide value of 0.55 mEq/kg signifying a high quality less oxidized product that is more likely to give expected nutritional and health benefits. It is however important to store oil correctly as peroxide value indicates initial stage of oxidation. Prolonged exposure to heat, light or air will increase peroxide value causing rancidity and potential health issues. This makes storage conditions important for maintaining the quality and benefits of oils [38]. The peroxide value of palm kernel oil 8.8mEq/kg is a moderate to high indicator of oxidation suggesting the oil is beginning to degrade and may have a reduced shelf life and nutritional quality. This peroxide value suggests a need for stabilization through antioxidants/ proper strorage to prevent further degradation and ensure its safety and effectiveness [26]. Both peroxide values obtained for the oils in this study are lower to the permitted maximum limit (≤10 meq/kg) stated by the World Health Organisation (WHO) in 1994 [39, 40].

Among the *Enterobacteriaceae* isolates, coconut water exhibited the highest antibacterial activity, with *Enterobacter cloacae* showing the highest zone of inhibition (20 mm) compared to the positive control. Coconut oil and palm kernel oil also demonstrated inhibitory effects on the isolates, with *Enterobacter cloacae* showing the highest zone of inhibition (12.5mm). Generally the bacteriostatic activities was at its highest at 50% and 100% concentrations which was indicating that an increase in concentration of the extracts would result in a reciprocal increase in anti-bacterial activity. The results obtained are in line with those obtained by Akpomie et al [9] which reported high susceptibility of gram positive and gram negative organisms to coconut oil and palm kernel oil due to their lauric acid content and their phytochemical constituents. In a recent report Anyiam and Opara, [41] reported coconut water as a valuable antibacterial agent against *Klebsiella spp, Pseudomonas aeruginosa, Staphylococcus aureus* and *Escherichia coli.* This correlates with results in our study where coconut water exhibited the highest antibacterial activity compared to coconut oil and palm kernel oil.

5. Conclusion

In Conclusion, this study validates the reported usefulness of the plant extracts in combating some bacterial organisms. It highlights the promising antimicrobial potential of coconut water, coconut oil, and palm kernel oil in the fight against antimicrobial resistance, with potential applications in healthcare, food preservation, and manufacturing industries. Further studies and research is recommended in the identification, isolation and production of the bioactive constituents of the plants which would be less toxic and more efficacious in treatment of different infections as caused by the different isolates used in this study.

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Compliance with ethical standards

The isolates used in the study were pre-identified; hence, research ethics approval was not required. No contact was produced with patients and the original samples from the hospital. Informed consent was not required by the institution. The isolate data were obtained from clinical records and anonymously handled.

Disclosure of conflict of interest

No conflict of interest to be disclosed.

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