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Nutritional Properties, Antioxidant and Antimicrobial Activity of Seed and Peel Extracts of Grapefruit (*Citrus paradisi*) on Some Selected Clinical Organisms

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Authors' contributions

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

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ABSTRACT

The need for new antimicrobial agent is linked with the emergence of strains that are restraint to most antibiotics and plants are safer alternative source of antimicrobials. This study aimed at determining the nutritional properties, phytochemical constituents, antioxidant and antimicrobial activity of seed and peel *Citrus paradisi.* The test organisms were obtained from a tertiary hospital were analyzed using conventional microbiological methods. The ethanol and aqueous extracts of *C. paradisi* was obtained using the rotary evaporator. Antimicrobial activity was determined using agar well diffusion method. Proximate composition of seed and peel of *C. paradisi* were moisture, protein, ash, fibre, lipid and carbohydrates. Qualitative phytochemical constituents revealed the presence of alkaloids, saponin, tannin and flavonoids, and Quantitative phytochemical constituents revealed 19.41 mgGallic acid equivalent/g and 8.07 mgGallic acid equivalent/g of total phenols of ethanolic and aqueous peel extracts respectively. The ethanolic extract of seed had phenolic

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content of 3.73 mgGAE/g. The ethanolic peel and aqueous seed extracts showed higher 2,2-diphenyl-1-picrylhydrazyl (DPPH) antioxidant activity of 35.32% and 25.32% respectively. The ethanolic seed extract of *C. paradisi* exhibited antimicrobial activity against all the bacterial test isolates at different concentrations. At 500mg/ml and 250mg/ml, *P. aeruginosa* showed the mean zone of inhibition of 18mm respectively. The largest mean zones of inhibition for *S. aureus* and *E.coli* were seen at 500mg/ml and 250mg/ml with 20mm and 27mm respectively. The ethanolic peel extract of *C. paradisi* exhibited antimicrobial activity at 500mg/ml against *P. aeruginosa* and *S. aureus,* with the largest zones of inhibition of 25mm and 20mm respectively. At 250mg/ml, *E. coli,* had the largest mean zone of inhibition of 25mm. No antimicrobial activity was observed for both ethanolic peel and seed extracts of *C. paradisi* against *Aspergillus* spp. The aqueous extract of the seed of *Citrus paradisi* at the different concentrations showed no antimicrobial activity against both the bacterial and fungal isolates. The aqueous extract of the peel had antimicrobial effect on *P. aeruginosa* at 125mg/ml with mean zone of inhibition of 15mm. At 500mg/ml *S. aureus* and *E. coli* exhibited zones of inhibtion of 15mm and 20mm respectively. No zone of inhibition was observed with *Aspergillus* spp. This investigation indicates the peel of *C. paradisi* has medicinal activity and holds the potential as therapeutic agent for treating microbial infections.

Keywords: Nutritional properties; antioxidant; antimicrobial activity; citrus paradisi and clinical isolates.

1. INTRODUCTION

Grapefruit (*Citrus paradisi*) is a subtropical and tropical tree known for its relatively large sour to semi-sweet and somewhat bitter fruit. Citrus fruits are one of the world's most important crops and are known for the secondary metabolites they contain [1]. These metabolites possess significant biological activity, and antioxidant, antitumor, neuroprotective and other properties [2]. Notably, among the most commonly consumed citrus fruits in Nigeria are tangerine, lime, lemon, and grape. These group of plants are of great medicinal value [3]. Several groups of polyphenolic flavonoids, which have been demonstrated to have antibacterial, antifungal, and antioxidant properties, are responsible for the medicinal effectiveness of grapefruit [4].

Grapefruit is known to be a source of vitamin C, fiber, potassium, pectin, and other nutrients. Some components might have antioxidant effects that might help protect cells from damage or reduce cholesterol [5]. It contains high levels of ascorbic acid and flavonoid antioxidants including naringin and naringenin [6,7]. Flavonoid properties include anti-inflammatory, antiviral, and anticancer activities, an ability to inhibit platelet aggregation, and effects on capillary fragility [8,9].

The fruit is commonly taken by mouth for weight loss. It is also used for asthma, high cholesterol, cancer prevention [10] (Ayat et al., 2019)., and many other conditions. In agriculture, grapefruit seed extract is used to kill bacteria and fungus, fight mold growth, kill parasites in animal feeds, preserve food, and disinfect water. It is also used as an ingredient in cosmetics to tone up the epidermis and treat acne and the flushed epidermis, soaps, and detergents [11,12] (Al–Âni et al., 2011; Okungbowa and Oviasogie, 2011). The oil from the peel extract has been reported to be an insecticide [13]. The peel of grapefruit contains pectin, an ingredient known to lower cholesterol and fiber which adds to its healthy qualities. Due to its medicinal value, the flesh of this fruit is used as a cure for poisoning, and the seed extracts for the treatment of ulcers, cataracts, and urinary and alimentary tract infections [14].

The emergence of resistance to antimicrobial drugs today has generally imposed burden and high costs to health system [15], and over $20 billion are spent on treatment cost every year [16]. This increasing rate at which harmful microbes are becoming more resistant to antimicrobial drugs has prompted the search for new bioactive properties from plants to combat microbial resistance [17]. The high cost of important antimicrobial resistance drugs for treating diseases and accessibility to modern healthcare facilities has led to dependence on herbal medicine due to its availability and lower cost, and little or no little side effects.

Natural plants have phytochemical constituents that are comparable to those of commercial antibiotics, and have been utilized in traditional medicine to cure infections [18]. The need for new antimicrobial agents is linked with the

emergence of strains that are restraint to most antibiotics and plants are safer alternative sources of antimicrobial [18]. The quest for naturally occurring compounds of plant origin that could be of benefit as antibacterial agents and antinutritional agents stimulated the interest in seed and peel of *Citrus paradisi* as stimulants. Therefore, the study is aimed at determining the nutritional properties, phytochemical constituents, antioxidant and antimicrobial, activity of seed and peel *C. paradisi* on some selected clinical isolates.

2. MATERIALS AND METHODS

2.1 Collection and Processing of Plant

The grapefruits were purchased from Nkwo-Ado market Nnewi, Anambra state. The seeds and peels of the grapefruit were air dried for three weeks and blended to powder by milling.

2.2 Isolation and Identification of Organisms

Four test isolates consisting of three bacterial strains; *Staphylococcus aureus*, *Pseudomonas aeruginosa* and *Escherichia coli* and one fungal strain *Aspergillus* species were used. The test isolates were obtained from Federal Medical Center, Otuoke, Bayelsa State, Nigeria. The organisms were subcultured on nutrient agar for bacteria and sabouraud dextrose agar for fungi to obtain pure culture. Further identification of isolate of *E. coli* was on Eosin Methylene blue agar, *S. aureus* on Mannitol salt agar, and *P. aeruginosa* on MacConkey agar. Confirmation after incubation was done using morphological, Gram staining and biochemical characteristics which include catalase, coagulase, oxidase, indole and citrate.

2.3 Preparation of Extracts

The powdered plant materials were subjected to extraction with 80% ethanol. The milled sample was divided into two portions, one portion was mixed with water while the other was mixed with ethanol at a ratio of 1:25 (w/v) at ambient temperature and left to stand for 48 hr. The mixture was then filtered using a filter paper (Whatman No. 1). The hydroethanolic extracts were concentrated using a rotary evaporator (Büchi, Rotavapor R-200) and were then transferred to a sterile beaker kept on a water bath at 50°C to obtain a semi-solid form. A gel semi-solid colored substance was obtained for the extracts and then stored at 4^{o}C until used. Extracts were dissolved in the appropriate solvent for the antimicrobial and antioxidant assays.

2.4 Proximate Analysis

Percentage moisture crude protein, crude fat, crude fiber and ash content of the formulation were determined based on the official method of analysis [19]. Percentage carbohydrate was determined by difference. The food energy level was determined by calculation using the Atwater factor [20].

2.5 Phytochemical Analysis

Both qualitative and quantitative phytochemical studies were used for phytochemical screening. Tests for alkaloids, terpenoids, tannins, flavonoids, carbohydrates, glycosides, saponins, and resins were part of the qualitative analytical process. Standard procedures were used for screening [21,22,23,24].

The total amounts of tannin, flavonoids, anthocyanins, and phenols were ascertained using quantitative analysis. With slight modifications, the Folin-Ciocalteau reagent (FCR) was used to calculate the total phenolics as described by Velioglu et al., [25]. Using Insoluble polyvinyl-polypirrolidone (PVPP), which binds tannins according to description by Makkar et al., [26], the amount of tannin in each sample was determined. The flavonoids content was ascertained using the technique outlined by Kumaran and Karunakaran [27] with slight modifications. The principle of this technique was based on the development of a flavonoid-aluminum complex, which has a maximum absorption at 415 nm. A spectrophotometric pH differential protocol, with minor changes, was used to determine the total anthocyanin contents of the plant extracts as described by Giusti and Wrolstad [28] and Wolfe et al., [29].

2.6 *In vitro* Antioxidant Analysis

2.6.1 Estimation of DPPH scavenging activity

The stable free radical 2, 2-Diphenyl-1-picrylhydrazyl (DPPH) was used to measure antioxidant activity using a modified version of the approach described by Brand-Williams et al., [30]. DPPH's methanolic stock solution was made at a concentration of 1000 µg/ml [31]. Extract solutions were prepared by dissolving

0.05g of dry extract in 50 ml of methanol. An aliquot of 2 ml of 0.004 % DPPH solution in methanol and 1 ml of plant extract in methanol at various concentrations (100 µg/ml, 200 µg/ml, 400 µg/ml) were mixed and incubated at 250 C for 30 min and absorbance of the test mixture was read at 517 nm using a spectrophotometer against a DPPH control containing only 1 ml of methanol in place of the extract. The DPPH solution in methanol was prepared daily before the absorbance measurement. DPPH is a purple colored stable free radical. When reduced it becomes the yellow colored Diphenyl picryl hydrazine. All experiments were performed thrice and the results were averaged. Ascorbic acid was used as a standard. All experiments were performed thrice and the results were averaged. Ascorbic acid was used as a standard.

2.6.2 Estimation of ABTS scavenging activity

ABTS scavenging effects (2,2-azino-bis 3-ethyl benz thiazoline-6-sulfonic acid) [32] ABTS radical cations (ABTS+) were produced by reacting ABTS solution (7mM) with 2.45mM ammonium persulphate. The mixture was allowed to stand in the dark at room temperature for 12-16 hours before use. Aliquots (0.5ml) of the three different extracts were added to 0.3ml of ABTS solution and the final volume was made up to 1ml with ethanol. The absorbance was read at 745nm in a spectrophotometer (Jenway 6715) and the per cent inhibition was calculated using the formula: %Inhibition (%) = (Control – test) x 100/control.

2.6.3 Hydrogen peroxide scavenging activity

The principle of this method is that there is a decrease in the absorbance of Hydrogen Peroxide upon oxidation of Hydrogen Peroxide [33,34].

2.6.4 FRAP capacity

The preparation of FRAP solution was adopted from Benzie and Strain, which was prepared in acetate buffer pH 3.6. Each extract 50 µg/ml was added into FRAP solution 50 µg/ml (1:1) to initiate the reaction. After 30 minutes incubation, the absorbance was observed at wavelength 593 nm using UV-Vis spectrophotometer Hewlett Packard 8435. Acetate buffer was used as a blank, FRAP 50 µg/ml as control, and ascorbic acid as standard. The analysis was conducted in triplicate for standard and each extract. Antioxidant capacity of each extract was determined based on increasing in Fe (II)-tripyridyl triazine (TPTZ) absorbance by calculating the percentage of antioxidant capacity.

2.7 Antimicrobial Assay

This was carried out using the protocol described by Owoseni and Ajayi [35]. Test organisms were subcultured onto tryptophan broth medium. Broth cultures were then incubated at 37°C till the turbidity of 0.5 McFarland's standard was obtained. Petri dishes containing 20ml Muller Hinton medium were seeded with 24hr culture of bacterial strains and Sabouraud agar for the fungus. This was used to flood the surface of solid Mueller–Hinton agar plates and then drained dry. Wells of 5mm in diameter and about 2 cm apart were punched in the culture media with sterile cork borer. 20µl of the plant extracts (namely aqueous, methanol and chloroform extracts) were then used to fill the boreholes. Each plate was kept in the refrigerator at 4°C for 1h. The bacterial plates were then incubated at 37°C for 24 hours and 72hours for fungi. Zones of inhibition around the wells, measured in millimeters, were used as positive bioactivity [36]. A positive control was employed, using chloramphenicol disc.

2.8 Statistical Analysis

Every experiment was carried out, and the mean standard error of the results was provided. The study conducted statistical analysis utilizing analysis of variance and Bonferroni post-test at 95% confidence level using GraphPad PRISM Version 5.01 to ascertain significant difference between the *C. paradisi* seed and peel [37].

3. RESULTS

The proximate composition of the citrus peel and seed of *C. paradisi* is as shown in (Fig. 1), with the seed having significantly higher crude lipid and fiber content of 32% and 21% respectively while the peel had crude lipid of 2% and crude fiber of 15.1%. The carbohydrate content of peel was 55.7% which was significantly higher than seed 27.9%. The peel and seed of citrus have small amount of protein while ash content was significantly higher in the peel, 11.98 % than in the seed 8.18%.

The phytochemical composition of aqueous and ethanolic extracts of *C. paradisi* is shown in Table 1. Alkaloids were highest in the peel

ethanol extract (14.78 %) while the lowest in the aqueous extract of seed (0.06%). Saponin was highest in the ethanolic extract of the peel with 4.32 % while least in the aqueous extract of seed with 0.17 %. Tannin was of high concentrations in the peel of ethanolic extract having 5.45 % and aqueous extract at 4.45 % while the ethanolic and aqueous seed extracts 1.47% and 1.07% respectively. Flavonoids were in high concentration in ethanolic extract of peel with 20.12 mgCE/g compositions and least in seed ethanolic extract with 1.25 mgCE/g compositions.

Fig. 2 shows the total phenols of the aqueous and ethanolic extracts of *C. paradisi.* The phenol in peel extracts was higher than those of seed extracts. The maximum range of phenols was 19.41 mgGAE/g and 8.07 mgGAE/g which were in the ethanol extract of peel and aqueous extract of peel respectively. The ethanolic extract of the seed showed a phenolic content of 3.73 mgGAE/g.

The *in vitro* antioxidant activity of the aqueous and ethanolic extracts of peel and seed of grapefruit was assessed by DPPH and ABTS assays is as shown in (Table 2). The ethanolic peel extract of *C. paradisi* showed higher DPPH antioxidant activity (35.32 %) compared to the seed extract of 13.04% activity. The aqueous seed extract also exhibited significantly higher activity (25.32%) when compared with the aqueous peel extract (0.96%). ABTS scavenging effect was highest in ethanolic peel extract of *C. paradisi* (79.45%) while it was lowest in aqueous seed extract (0.72%), aqueous extract of peel showed moderate scavenging effect (35.51%) while ethanolic extract of seed showed little effect (5.37%).

The findings of this investigation demonstrated that *C. paradisi* inhibits the growth of *S. aureus*, *E. coli*, and *P. aeruginosa*. There was no statistically significant difference between the peel and the seed ($p>0.05$), despite the fact that both the seed and peel ethanol extracts showed greater antibacterial efficacy against all of the bacterial test isolates. Additionally, all the bacterial isolates were susceptible to the antibacterial effects of peel aqueous extract. On contrary, the peel and the seed of ethanol and aqueous extracts did not show any zones of inhibition against *Aspergillus* spp. However, ethanolic extracts of *C. paradisi* in this study proved to be a better antimicrobial agent in comparison with the aqueous extracts. The obtained zones of inhibition were between 15 and 25 mm. Our results indicate that the ethanolic peel and aqueous seed extracts of *C. paradisi* differ significantly ($p<0.05$).

Table 3 shows the mean zone of inhibition of ethanol seed extract of *C. paradisi* against the test organisms. The ethanolic seed extract of *C. paradisi* exhibited antimicrobial activity against *P. aeruginosa, S. aureus and E. coli.* At concentrations of 500mg/ml and 250mg/ml, *P. aeruginosa* showed the mean zone of inhibition of 18mm respectively. The largest mean zone of inhibition for *S. aureus* was seen at concentration of 500mg/ml with 20mm, with the least zone of inhibition of 17mm at 125mg/ml. The largest mean zone of inhibition for *E. coli* was at 250mg/ml with 27mm while the least at 125mg/ml with 20mm. No zone of inhibition was observed for *Aspergillus* spp; this shows ethanol seed extract of *C. paradisi* had no antimicrobial effect on *Aspergillus* spp.

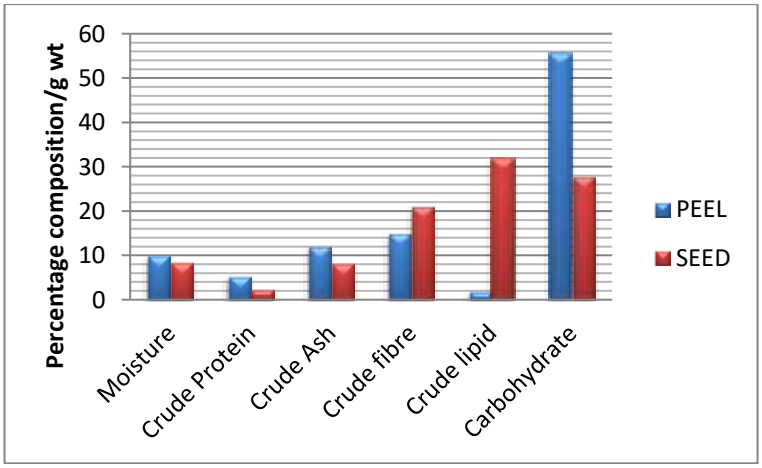

Fig. 1. Proximate composition of seed and peel of *C. paradisi*

Table 1. Phytochemical composition of seed and peel extracts of *C. paradisi*

	Peel		Seed	
	Aqueous extract	**Ethanol extract**	**Aqueous extract**	**Ethanol extract**
Alkaloid %	5.14	14.78	0.06	0.13
Saponin %	0.97	4.32	0.17	1.14
Tannin %	4.45	5.45	1.07	1.47
Flavonoid (mgCE/g)	7.30	20.12	3.10	1.25
Phenol (mgGAE/g)	8.07	19.41	1.01	3.73

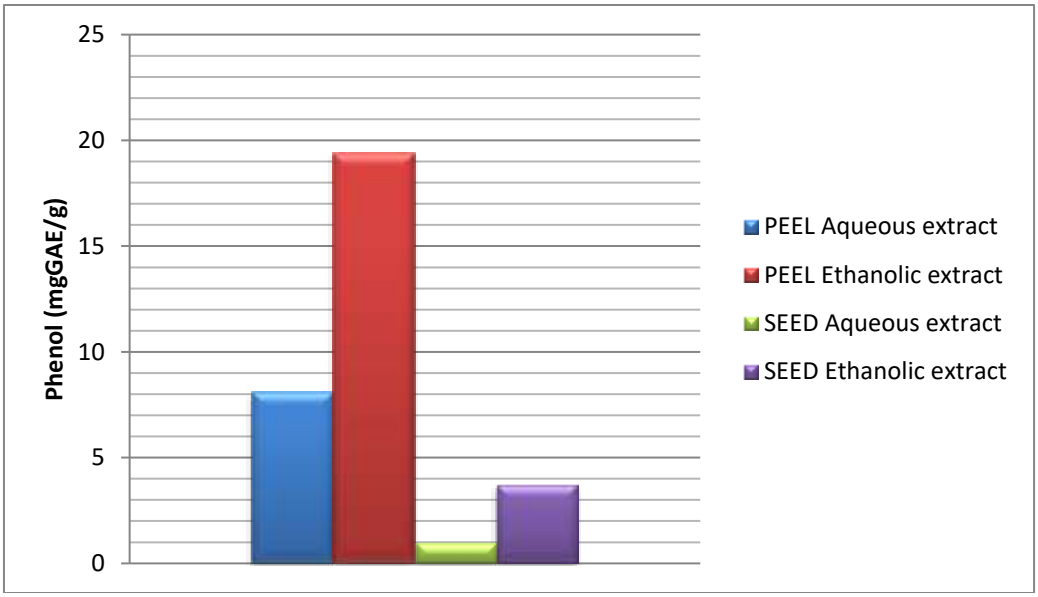

Fig. 2. Phenolic index of the aqueous and ethanolic extracts of *C. paradisi*

Table 2. The antioxidant activity of aqueous and ethanolic extracts of peel and seed of *C. paradisi*

	Aqueous extract Seed	**Peel**	**Ethanol extract Seed**	**Peel**
DPPH %	25.32 ± 3.7	0.96±0.8	13.04 ± 1.5	35.32±1.5
ABTS %	0.72±1.4	35.51 ± 2.8	5.37 ± 0.8	79.45±2.4

Table 3. Mean zone of inhibition (mm) of ethanol seed extract of *C. paradisi* against test organism

Test Organism	**Concentration 500mg/ml**	**250mg/ml**	**125mg/ml**
P. aeruginosa	18 ± 0.64	18 ± 0.64	-
S. aureus	20 ± 1.22	-	17 ± 0.95
E. coli	24 ± 1.22	27 ± 0.95	20 ± 1.34
Aspergillus spp	-	-	-

Data represented as mean ± SEM (n = 3)
Key: mg/ml = milligram per millimeter, mm= millimeter, - = No inhibitory effect

The mean zone of inhibition of ethanol peel extract of *C. paradisi* against the test organism is shown in Table 4. The ethanol peel extract of *C. paradisi* exhibited antimicrobial activity against *P. aeruginosa, S. aureus,* and *E. coli.* The largest zone of inhibition for *P. aeruginosa* was observed at a concentration of 500mg/ml with 25mm, *S. aureus* with the largest zone of inhibition of 20mm at 500mg/ml, and *E. coli,* had the largest mean zone of inhibition at 25mm at 250mg/ml.

There was no zone of inhibition for *Aspergillus* spp, which indicates the ethanol peel extract of *C. paradisi* did not affect the organism.

The mean zone of inhibition of aqueous seed extract of *C. paradisi* against the test organism is indicated in Table 5. The aqueous seed extract of *C. paradisi* at the different concentrations exerts no antimicrobial activity against *P. aeruginosa, S. aureus, E. coli,* and *Aspergillus* spp.

Table 6 shows the mean zone of inhibition of aqueous peel extract of *C. paradisi* against test organism. For *P. aeruginosa,* at concentrations of 125mg/ml, displayed the mean zone of inhibition of 15mm. The largest mean zone of inhibition for *S. aureus,* was seen at concentration of 500mg/ml with 15mm and at 250mg/ml with the least zone of inhibition of 14mm. *E. coli,* displayed mean zone of inhibition of 20mm at 500mg/ml. No zone of inhibition was observed with *Aspergillus* spp, which shows that the aqueous peel extract of *C. paradisi* had no effect on the organism.

4. DISCUSSION

The result of this investigation revealed the phytochemical constituents of seed and peel extract of *C. paradisi* to contain; alkaloids, saponins, tannins, flavonoids, and phenols. These phytochemicals are secondary metabolites of natural products comprising nutritional or non-nutritional bioactive compounds found in fruits, vegetables, cereals, and other plant foods that have numerous health advantages such as reducing the risk of major chronic diseases [38].

The proximate analysis of *C. paradisi* revealed the seed having significantly higher crude lipid and fiber content of 32% and 21% respectively while the peel had crude lipid of 2% and crude fiber of 15.1%. The carbohydrate content of peel was 55.7% which was significantly higher than seed 27.9%. The peel and seed of citrus have a small amount of protein while ash content was significantly higher in the peel, 11.98 % than in the seed 8.18%. This finding agrees with the work done by Mathew et al. [41] who reported that the proximate composition (g/100g) of dry peel of pink grapefruit was crude protein 6.43, crude fat 3.79, crude ash 2.78, crude fiber 8.22 and total carbohydrate 79.08.

The phytochemical composition of aqueous and ethanol extracts of *C. paradisi* revealed alkaloids were highest in the peel ethanol extract (14.78 %) while lowest in the aqueous extract of seed (0.06%). The high alkaloid content shows the peel can be useful medicinally and is associated with notable biological activities such as antioxidant, antimicrobial, antidiabetic, and anticarcinogenic activities [39,40]. Saponin was highest in the ethanol extract of the peel with 4.32 % while least in the aqueous extract of seed with 0.17 %. Tannin was of high concentrations in the peel of ethanol extract having 5.45 % and aqueous extract 4.45 % while the ethanol and aqueous seed extracts had 1.47% and 1.07% respectively. Flavonoids were in high concentration in ethanol extract of peel with 20.12 mgCE/g compositions and least in seed ethanol extract with 1.25 mgCE/g compositions. Our results are in agreement with the studies conducted by Mathew et al. [41] and [42] which reported the presence of alkaloids, saponin, tannin, and flavonoids in citrus fruits. The total phenols of the aqueous and ethanol extracts of *C. paradisi* show the phenols in peel extracts were higher than those of seed extracts. The maximum range of phenols was 19.41 mgGAE/g and 8.07 mgGAE/g dw which were in the ethanol extract of peel and aqueous extract of peel respectively. This finding corroborates with the report by Li et al. [43]. The ethanol extract of the seed showed a phenolic content of 3.73 mgGAE/g.

Table 4. Mean zone of inhibition of ethanol peel extract of *C. paradisi* against test organism

Test Organism	Concentration 500 mg/ml	250 mg/ml	125 mg/ml
P. aeruginosa	25 ± 1.55	21± 1.30	16 ± 0.50
S. aureus	20 ± 1.48	19 ± 0.94	17 ± 0.55
E. coli	22 ± 0.55	25 ± 1.55	-
Aspergillus spp	-	-	-

Data represented as mean ± SEM (n = 3)
Key: mg/ml = milligram per millimeter, mm= millimeter, - = No inhibitory effect

Table 5. Mean zone of inhibition of aqueous seed extract of *C. paradisi* against test organism

Test Organism	Concentration 500 mg/ml	250 mg/ml	125 mg/ml
P. aeruginosa	-	-	-
S. aureus	-	-	-
E. coli	-	-	-
Aspergillus spp	-	-	-

Data represented as mean ± SEM (n = 3)
Key: mg/ml = milligram per millimeter, mm= millimeter, - = No inhibitory effect

Table 6. Mean zone of inhibition of aqueous peel extract of *C. paradisi* against test organism

Test Organism	Concentration 500 mg/ml	250 mg/ml	125 mg/ml
P. aeruginosa	-	-	15 ± 1.37
S. aureus	15 ± 1.37	14 ± 1.18	-
E. coli	20 ± 0.95	-	-
Aspergillus spp	-	-	-

Data represented as mean ± SEM (n = 3)
Key: mg/ml = milligram per millimeter, mm= millimeter - = No inhibitory effect

The *in vitro* antioxidant activity of the aqueous and ethanol extracts of peel and seed of grapefruit assessed by DPPH and ABTS assays revealed the aqueous seed extract of *C. paradisi* was able to inhibit 25.32 ± 3.7% of DPPH and 35.51 ± 2.8% of ABTS while the ethanol seed extract of *C. paradisi* inhibited 35.32 ± 1.5% of DPPH and 79.45 ± 2.4% of ABTS. The aqueous peel extract of *C. paradisi* showed inhibition of 0.96 ± 0.8% of DPPH and 0.72 ± 1.4% of ABTS while the ethanolic peel extract of *C. paradisi* was able to inhibit 13.04 ± 1.5% of DPPH and 5.37 ± 0.8% of ABTS. Our findings can be compared with the studies by Ayat et al. [10] which reported that the ethanol peel extract showed antioxidant activity of 55.80 %, and [44] who also noted that DPPH activity in pink grapefruit dried at 600C was 50.07±2.26 %. However, the results from these findings are relatively higher than our results. The highest ABTS scavenging effect was seen in the ethanolic peel extract of *C. paradisi* (79.45%). Our findings corroborate with the findings of Castro-Vazquez et al. [45] who showed the methanol extract of pink grapefruit dried at 600Chas an ABTS scavenging effect of 210.78±2.19 mg Trolox per g and that the range of scavenging effect from 99.46±12.09 to 537.48±36.10 mg Trolox per g. [46] stated that the antioxidant capacity of all peels was higher than that of pulps, both in terms of the DPPH radical scavenging capacity and the FRAP assay; and the antioxidant potential of citrus fruits appears to be linked to both vitamin C and phenolic components rather than being a characteristic of a single phytochemical molecule.

The ethanol seed extract of *C. paradisi* exhibited antimicrobial activity against *P. aeruginosa, S. aureus,* and *E. coli. P. aeruginosa,* at concentrations of 500mg/ml and 250mg/ml with zones of inhibition of 18mm respectively. This result is similar to the work done by Cvetnic et al. [47] where ethanol extract exhibited the highest antimicrobial effect against the microorganisms tested. The largest mean zone of inhibition for *S. aureus* was seen at a concentration of 500mg/ml with 20mm and 125mg/ml with the least zone of inhibition of 17mm. *E. coli* displayed the largest mean zone of inhibition at 250mg/ml with 27mm and the least at 125mg/ml with 20mm. No zone of inhibition was observed for *Aspergillus* spp; indicating ethanol seed extract of *C. paradisi* had no antimicrobial effect on *Aspergillus* spp. The ethanol peel extract of *C. paradisi* exhibited antimicrobial activity against *P. aeruginosa* at a concentration of 500mg/ml with 25mm, *S. aureus* with a zone of inhibition of 20mm at 500mg/ml, and *E. coli,* with mean zone of inhibition 25mm at 250mg/ml while no zone of inhibition was observed with *Aspergillus* spp. This can be compared with a previous study by Wahab et al. [48] who stated ethanol oil mixture of *C. paradisi* peel inhibited the test bacteria and *C. albicans.* The aqueous seed extract of *C. paradisi* at the different concentrations exerts no antimicrobial activity against *P. aeruginosa, S. aureus, E. coli,* and *Aspergillus* spp. Our finding is in contrast with the result of the study done by Waidulla et al., [49] which reported the ethanolic extract showed no zone of inhibition against all the test organisms. The aqueous peel extract of *C. paradisi* exerted an antimicrobial effect on *P. aeruginosa* at concentrations of 125mg/ml,

with a mean zone of inhibition of 15mm, *and S. aureus* with a mean inhibition zone of 15mm at 500mg/ml. While *E. coli* displayed a mean zone of inhibition of 20mm at 500mg/ml. However, no zone of inhibition was observed with *Aspergillus* spp. The variations in the activity of the extracts could be due to the mode of action of their various bioactive constituents, or the concentration of the extracts [50,51].

5. CONCLUSION

From the overall findings of this study, *C. paradisi* possesses broad-spectrum antibacterial activity against both Gram-positive and Gram-negative and antifungal activity. The ethanol extract has shown greater antimicrobial activity and potency compared to aqueous extract. Both ethanol and aqueous extracts of *C. paradisi* showed antioxidant activity. These in-vitro analyses demonstrated that *C. paradisi* extract could serve as a significant natural rich antioxidant and easily obtainable product that may increase the immunity against oxidative damage and other health issues or it may act as a possible source of therapeutic agent. In addition to our findings, grapefruit seed extract demonstrated good antioxidant activity indicating that the extract has a high antimicrobial effect. Research laboratories should collaborate with traditional herbal practitioners, while the traditional healers provide preliminary information on the uses of medicinal plants based on their historical knowledge, the scientific base for the efficacy of the extract and proper advice can also be given on how the drug should be prepared and administered. Further research should be carried out to determine the effect of different solvents in extracting the bioactive constituent of *C. paradisi*.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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