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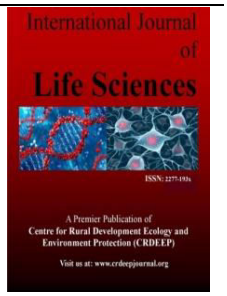

Full Length Research Paper

Inhibitory Potency of Watermelon (*Citrullus lanatus* Linn.) Rind Extract on Bacteria and Fungi and Evaluation of its Fatty acid content

[1]Aderiye, B. I., [1]David, O. M., [1]Fagbohun, E. D., [1]Faleye, F. J. and [1]Okunade, O. E.

[1]Department of Microbiology, Ekiti State University, Ado-Ekiti. Nigeria.
[2]Department of Chemistry, Ekiti State University, Ado-Ekiti. Nigeria.

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Corresponding Author:
Aderiye, B. I

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ABSTRACT

The incidence of multidrug-resistance has been reported globally, and there is need to reduce treatment-failure in communicable diseases. This paper examined the phytochemicals, and the fatty acid components and the antimicrobial potential of watermelon rind extract. Standard microbiological and chemical methods were used to determine the antimicrobial activities and the phytochemical constituents of the extracts respectively, while gas chromatography-mass spectrometry was used to determine the fatty acid contents of the extracts. The amount of the alkaloids was the highest (89.72 mg/g) among the phytochemicals in the diethyl ether rind extract. The concentrations of each of the components reduced with the extraction time. About 77.67% cyanogenic glycoside was recovered within 1 h 30 min delay in extraction. The extract expressed a better antibacterial property against Gram-negative bacteria compared to the Gram-positive microbes. The 1 h rind extract showed better inhibitory activity on the test bacteria. Except on Pseudomonas aeruginosa, Bacillus subtilis *and* Staphylococcus aureus, *the extracts at the tested concentrations performed better than the control, streptomycin. Conversely, Fluconazole performed better than the watermelon rind extract at the tested concentrations on fungi and yeast. Yeast cells were more susceptible than the moulds.* Aspergillus flavus *and* Penicillium chrysogenum *were the most resistant fungi among the array of fungi tested. The antimicrobial effect of* Citrullus lanatus*rind extract on the selected microorganisms may be due to the presence of the phytochemicals. The presence of pentadecanoic acid, 14-methyl-, methyl ester, n-hexadecanoic acid, 8-octadecenoic acid, methylester, phytol in the extract and their probable antimicrobial property have also been discussed. Phytomedicinal compounds from the rind of watermelon may be a potential recipe for the treatment of human ailments if exploited.*

Introduction

The application of medicinal plants in human health care systems is as old as man. They play a significant role in even in modern medicine as most pharmacopeia contains drugs that have been wholly or partially sourced from plant sources. Pawar and Pawar (2014) reported that 74% of drugs used in modern medicine were obtained from different medicinal plants. Nature still has more curative recipes that have not been discovered and investigated for their applications in the treatments of both animal and human infections. Different plant parts like the calyx, flowers, fruits, gum, latex, leaves, peels (of fruits and tuber), roots, seed, and stem bark have been demonstrated to contain different phytochemicals that are very useful in treatment of both communicable and non-communicable diseases of human (Ahmed and Al-Sayeda, 2013).

Watermelon (*Citrullus lanatus* var. lanatus, family Cucurbitaceae) is a vine-like plant (scrambler and trailer) originating about 11,000 years ago in the New World and Asia, and recently in Africa. It has a smooth hard rind with sweet juice and an interior flesh which is usually deep red to pink or sometimes orange (Wasylikowa and van der Veen,2004; Chomicki*et al.,* 2020). The combination of beta (β) carotene, citrulline, cucurbitacins, lycopene, polyphenolic compounds and vitamin C in watermelon is unique. These phytochemicals modulate the immune system of human and hence aid the body fight against disease causing microbes. These phytochemicals present a very significant antioxidant activity (Murthy*et al.,* 2013). The watermelon fruit contains about 6% and 91% sugar and water by weight respectively. The rind of watermelon is rich in phytochemicals more than the pulp and the juice (Volz and Renner,2009; Zhang *et al.,* 2017) however; it is being discarded after consuming the juice and the pulp. The development of new

antimicrobial from common natural products especially those mostly considered as wastes can add to part of solution to curbin g the menace of drug-resistant pathogens currently reported in clinical medicine. In line with this we investigated the ability of the extract of watermelon rind to inhibit the growth of bacteria and fungi isolates associated with human diseases. Also, we determine the phytochemical constituents and fatty acid profile of the extract of the plant.

Materials and Methods

Source and Extraction of Plant Material

Watermelon fruits were purchased at fruits and vegetable stands opposite Ekiti State University main gate and identified as *Citrullus lanatus* variety in the Department of Plant Science and Biotechnology, Ekiti State University, Ado-Ekiti, Nigeria. Watermelon extract was prepared by the method of Aderiye (1987) with minor modification. At 30 min, 1 h and 1 h 30 min after peeling about 2-3 mm thick layer of the watermelon rind (peel) was diced into small cube. Pieces of water melon rind were soaked in diethyl ether for 48 h with constant agitation. At the end of extraction, the extract was filtered through Whatman No. 1 filter paper (Whatman, UK) and concentrated under reduced pressure using rotary evaporator (Stuat, United Kingdom). The extract was kept at refrigeration temperature until when needed.

Qualitative and Quantitative Phytochemical Analyses of Watermelon rind extract

Determination of Alkaloids

About 5 drops of Hager's reagent was added to the extract. The formation of yellow precipitate indicates the presence of alkaloids (Singh *et al.,* 2004). However, the estimation of alkaloid content was determined as described by Harborne (1973).

Determination of Phenols

The plant extract was treated with five drops of ferric chloride solution and the formation of bluish black color proves the presence of phenols (Tiwari *et al.,* 2013). Folin-Ciocalteu method described by Hagerman *et al.* (2000) was used for the quantification of phenol.

Determination of Flavonoids

About 5 g of the extract was treated with few drops of sodium hydroxide and if the intense yellow color solution becomes colo rless on addition of dilute acid, it then proves the presence of flavonoids (Saxena *et al.,* 2013). The method of Kumaran and Karunakaran (2006) was used in the estimation of flavonoid content, expressed as quercetin equivalents (QE).

Determination of Glycoside

Two (2) mL of the filtrate was mixed with 3 mL chloroform and 10% ammonia was later added. A pink color solution in dicated the presence of glycosides. Thereafter, 20% NaOH was added for colour development and absorbance was read at 510 nm on a Spectrum Lab 70 spectrophotometer (Brimer, 1988).

Determination of Oxalate

A purple colour emanating after titration against 0.1 M potassium permanganate ($KMnO_4$) solution while hot (80-90 °C) revealed the presence of oxalate. oxalate content was determined using the method of Sanchez-Alonso and Lachica (1987)

Determination of Phytates

The method of Olayeye*et al.* (2013)was used to determine the level of phytate in the extract. Iron (III) chloride solution was gently added to the extract and left for 5 min, the persistence of a brownish yellow colour was taken to the presence of phytate in the sample. The method of Haug and Lantzsch(1983)was employed for quantification.

Determination of Saponins

About 50 mg of the plant extract was diluted with distilled water up to 20 mL and shaken for 15 min in a graduated cylinder. The formation of 2 cm thick foam indicated the presence of saponins. The saponin content was quantified by using the spectrophotometric method described by Brunner (1984).

Determination of Tannins

A few drops of 1% gelatin solution containing sodium chloride were added to the plant extract. The formation of white p recipitate indicated the presence of tannins (Tiwari *et al.,* 2013). Little modification to the standard protocol 0.5 mL of the sample extract diluted with 80% ethanol revealed the tannin content estimated using the tannic acid curve as standard.

Determination of Terpenoids

A 20 mg of the extract was treated with 2.5 mL of acetic anhydride and 2.5 mL of chloroform. Then concentrated solution of sulphuric acid was added slowly. A red violet colour indicated the presence of terpenoids (Indumathi 2014). The sa me method was also used to quantify the quantity of terpenoids.

Source of Test Organisms

Stock cultures of bacterial and fungal isolates include six Gram negative bacteria (*Enterobacter cloacae*, *Escherichia coli*, *Klebsiella pneumoniae*, *Proteus mirabilis, Pseudomonas aeruginosa* and *Salmonella enteritidis*), six Gram positive bacteria (*Bacillus cereus,*

Bacillus subtilis, *Enterococcus faecalis*, *Lactococcus lactis, Staphylococcus aureus* and *Staphylococcus epidermidis*) and eight fungi (*Aspergillus flavus*, *Aspergillus fumigatus*, *Aspergillus niger*, *Candida albicans*, *Candida tropicalis*, *Colletotrichum gloeosporioides, Fusarium solani*and *Penicillium chrysogenum*) were obtained from the Department of Microbiology, Afe Babalola University, Ado-Ekiti, Nigeria.

Determination of Antimicrobial Activity

The concentration of the bacterial and yeast cells was adjusted to 0.5 McFarland standards with approximately 10^6 cells/mL. Fungal spores were harvested by flooding each of the Petri dishes containing 5-day old culture of each of the fungi with fifteen (15) mL of 1.0% Tween 80 and gently dislodged with sterile L-shaped spreader and then homogenized manually and gently decanted. The suspension was filtered through sterile cheesecloth and the spore suspension diluted to about 6 x 10^3 CFU/mL. The antimicrobial activity was studied using modified Kirby-Bauer disc diffusion method (Bauer *et al.,* 1966).

All the bacterial and fungal strains were cultured on nutrient agar and yeast extract agar respectively. Antimicrobial activity of each extract was evaluated by the paper disc diffusion method. The extracts at two different concentrations namely 0.5 and 1.0 mg/mL were used for antimicrobial activity. The antibiotic disc, Gentamycin, Streptomycin and/or Fluconazole (30 µg) was taken as control. Nutrient agar and PDA media were inoculated respectively with the bacteria and fungi by spreading the microbes on the medium. Sterile filter paper discs impregnated with either 0.5 or 1.0 mg/mL of the extract. The extract was reconstituted with 5.0% Tween 80 to achieve different concentrations ranging between 0.5 and 1.0 mg/mL.

The standardized inocula culture of the respective test organisms was seeded evenly on the surface of nutrient agar plates. Wells of 6 mm diameter were aseptically bored on the agar using a sterile cork borer allowing at least 30 mm between adjacent wells. The Petri dishes were incubated at 37ºC for 18 h while the fungal cultures were incubated at 25 ± 5°C for 48-72 h. Antimicrobial activity was determined by measuring the zone of inhibition around each well and estimated as described by Aderiye and David (2013).

Gas Chromatography-Mass Spectrometry (GC-MS) Analysis

The analysis of the extracts was performed on a GC-MS equipment on Varian 4000 GC-MS system (Agilent Technologies, Santa Clara, CA, USA) equipped with an HP-5MS capillary column (30 m × 0.25 mm × 0.25 µm) (Agilent J and W Scientific, Folsom, CA). Runtime was 40 minutes. MS Varian 3800 mass spectrometer, coupled to a Varian 4000 gas chromatograph (Varian) was used according to the manufacturer's protocol. An Agilent column, HP-5MS capillary column (30 m × 0.25 mm × 0.25 µm) was used.

Statistical Analysis

The determinations reported are mean of results of triplicate determination of experiments ran two times.

Results

The presence and the concentration of each phytochemical component in the water melon rind extracts were shown in Table 1. Qualitatively, the presence of all the phytochemicals was observed in the 30 min, 1h and 1h 30 min watermelon rind extracts except the cyanogenic glycosides that was not detected at 1h and 1h 30 min of the extracts. Generally, the concentration of each component of the extract reduced as the time required to commence extraction was extended. The alkaloids constituted the highest amount (89.72 mg/g) among the phytochemicals in the 30 min extract while the oxalate content was the least (0.48 mg/g). Even when extraction was delayed for about 2 h, all the components were still detectable quantitatively, with the alkaloids and oxalates contributing 17.38 mg/g and 0.26 mg/100g respectively in the watermelon rind extract. When extraction was delayed for 1 h 30 min, about 80.63% of the alkaloids in the 30 min extract (89.72 mg/g) were lost (i.e. with 2 h extract, 17.38 mg/g). The phytates (18.29 mg/g) and saponins (15.36 mg/g) constituted almost half of the total amount of the alkaloids in the 30 min extract. However, only 60.36% of these were lost in the 2h peel extract. Approximately 77.67% cyanogenic glycoside was lost within 1 h 30 min delay in extraction. Meanwhile, it was observed that oxalate retained 54.17% of its initial content (0.48 mg/100g, at 30 min) in the 2 h peel extract.

In subsequent experiments, the 1 h and 2 h watermelon rind extracts were used. The inhibitory effect of the 2 h extract of the watermelon peel was usually less effective than the 1h extract, in all the test fungi except *C. gloeosporioides* and *F. solani,* where the zone of inhibition was as high as 53.35 and 73.93 sq. mm respectively (Table 2). Meanwhile, only the mycelia mass of *C. gloeosporioides* and *F. solani*were adversely affected by the 2 h peel extract (53.35 and 73.93 sq. mm), exhibiting over 1403.9% and 287.6% effect over the 1 h peel extract. Compared to the control, fluconazole, the extract has a reduced spectrum of activity.

Table 1: Qualitative* and quantitative** estimation of the phytochemical components of Watermelon rind extracts

Phytochemical component (unit)	**Diethyl ether extracts of Watermelon rind**							
	30 min*	**30 min****	**1h***	**1h****	**1h 30 min***	**1h 30 min****	**2h***	**2h****
Alkaloids (mg/g)	+	89.72	+	60.56	+	30.84	+	17.38
Cyanogenic glycoside (mg/g)	+	12.36	-	8.41	-	5.03	-	2.76
Flavonoid (mg QE/g)	+	6.83	+	6.11	+	5.80	+	3.24
Oxalate (mg/100g)	+	0.48	+	0.41	+	0.33	-	0.26
Phenol (mg GAE/g)	+	6.41	+	5.45	+	4.11	+	2.25

Phytate (mg/g)	+	18.29	+	14.16	+	10.24	-	7.01
Saponin (mg/g)	+	15.36	+	13.69	+	9.35	+	6.33
Tannin (mg/g)	+	5.05	+	4.93	+	4.50	+	3.42
Terpenoid (mg/g)	+	6.12	+	5.38	+	4.77	+	3.29

Table 2: Inhibitory effect of 1 h and 2 h watermelon peel extracts against test organisms (zone of inhibition in sq.mm)

Bacteria/Fungi	Test Organisms	Extract (2 mg/ mL)		Control (30 µg/mL)	
		1 h	2 h	Fluconazole	Streptomycin
Gram negative bacteria	*Enterobacter cloacae*	98.69	30.59	-	14.53
	Escherichia coli	39.61	51.31	-	8.66
	Klebsiella pneumoniae	16.05	15.91	-	8.66
	Pseudomonas aeruginosa	29.24	13.08	-	32.18
	Proteus mirabilis	23.08	22.91	-	8.66
	Salmonella enteritidis	13.85	13.60	-	13.86
Gram negative bacteria	*Bacillus cereus*	60.60	74.54	-	49.53
	Bacillus subtilis	14.94	14.80	-	52.83
	Enterococcus faecalis	54.91	54.39	-	15.77
	Lactococcus lactis	23.08	9.08	-	15.97
	Staphylococcus aureus	19.80	19.64	-	59.74
	Staphylococcus epidermidis	56.50	56.23	-	26.61
Fungi					
	Aspergillus flavus	3.80	4.01	198.14	-
	Aspergillus fumigatus	14.94	14.73	165.65	-
	Aspergillus niger	9.30	9.08	158.87	-
	Candida albicans	44.91	15.95	322.51	-
	Candida tropicalis	52.83	21.57	394.24	-
	Candida gloeosporioides	3.80	53.35	122.77	-
	Fusarium solani	25.71	73.93	113.52	-
	Penicillium chrysogenum	8.25	8.05	90.63	-

In all cases, fluconazole had tremendous inhibitory effect on the test fungi, with zones of inhibition ranging between 90.63 and 394.24 sq. mm as recorded in *P. chrysogenum* and *Candida tropicalis* respectively. *Candida* spp. were the most susceptible fungi to fluconazole (*C. albicans,* 322.51 sq. mm; *C. tropicalis*, 394.24 sq. mm). Similarly, these two (2) yeasts were very sensitive to the one (1) hour peel extract (with 44.91 and 52.83 sq. mm respectively). The peel extracts showed very poor inhibitory effect on *A. flavus* (1 h, 3.80 sq. mm; 2 h, 4.01 sq.mm) *A. niger*(1 h, 9.30 sq. mm; 2 h, 9.08 sq. mm) and *P. chrysogenum* (1 h, 8.25 sq.mm; 2 h, 8.05 sq.mm). Even with fluconazole, *P. chrysogenum* was the least affected (90.63 sq. mm) among the fungi. On the other hand, the 2 h extract impacted more on *E. coli* and *B. cereus* (51.31 and 74.54 sq. mm) than the 1h peel extract that exhibited inhibitory zone of 39.61 and 60.60 sq. mm respectively. When streptomycin was charged against the bacterial cells, *E. coli, K. pneumoniae* and *P. mirabilis* were the least adversely affected, each with 8.66 sq. mm inhibitory zone. *Bacillus cereus, B. subtilis* and *S. aureus* showed high level of susceptibility to streptomycin (49.53, 52.83 and 59.74 sq. mm respectively). Like the fungi, most of the bacteria cells were more susceptible to the 1 h peel extract except for the cells of *B. cereus* and *E. coli* which are more sensitive (74.54 and 51.31 sq. mm) to the 2 h peel extract.

The highest percentage of the essential oil was unsaturated in nature. Figure 1 shows the graphical representation of the percentage composition of the saturated and unsaturated fatty acids in the 1h watermelon rind extract. Tri-unsaturated fatty acids had the lowest percentage composition (0.95%) while di-unsaturated fatty acids had the largest percentage composition (94.3%). Table 3 shows the graphical representation of the percentage composition of the saturated and unsaturated fatty acids. Tri-unsaturated fatty acids had the lowest percentage composition (0.95%) while di-unsaturated fatty acids had the largest percentage composition (94.3%). The percentage of saturated fatty acids, mono-unsaturated fatty acids and tri-unsaturated fatty acids components were 1.08%, 3.64% and 0.95% respectively.

A total of 24 chemical compounds were detected in the hydro-distillate of the sample. The saturated components were detected to be cyclohexene, 4-pentyl-1-(4-propylcyclohexyl), cyclononasiloxane, Octadecamethyl and cyclodecasiloxaneeicosamethyl while other compounds are unsaturated fats of different levels of double bonds. Cyclohexene, 4-pentyl-1- (4- propylcyclohexyl) (0.69%) had the highest percentage composition for saturated fats while Cyclononasiloxane, octadecamethyl (0.19%) had the lowest percentage composition.The percentage composition of pentadecanoic acid, 14-methyl-, methyl ester (1.42%) was highest among mono-unsaturated fatty acids while Lupeol (0.20%) exhibited the least percentage composition. Hexadecanoic acid, Z-11 (0.25%) had the least percentage composition for di-unsaturated fatty acids while 8-Octadecenoic acid, methyl ester was sequenced with the highest percentage composition (85.02%). Of tri-unsaturated fatty acids, vitamin E (0.22%) had the least percentage composition while nonivamide (0.26%) had the highest occurrence as shown in Table 3.

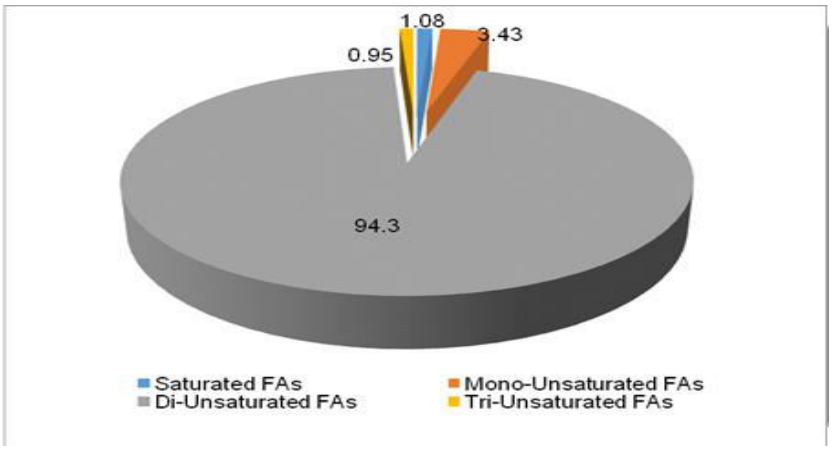

Fig. 1: Percentage composition of fatty acids in watermelon rind extract determined by GC-MS

Table 3: Fatty acid components of 1h watermelon rind extract

Classes	Compounds Detected	Molecular Formula	Molar Mass	Retention Time	% Area
Saturated Fats	Cyclohexene,4-pentyl-1-(4-propylcyclohexyl)	$C_{20}H_{36}$	276	28.13	0.69
	Cyclononasiloxane, octadecamethyl	$C_{18}H_{54}O_9Si_9$	666	33.7	0.19
	Cyclodecasiloxane, Eicosamethyl	$C_{20}H_{60}O_{10}Si_{10}$	740	36.35	0.20
Unsaturated Fats	Pentadecanoic Acid, 14- methyl-, methyl ester	$C_{17}H_{34}O_2$	270	0.63	1.43
	Hexadecanoic Acid, methyl ester	$C_{17}H_{34}O_2$	270	2.42	0.69
Mono-Unsaturated Fats	Octadecanoic Acid	$C_{18}H_{36}O_2$	284	9.58	0.21
	Octadecanoic Acid, methyl ester	$C_{19}H_{38}O_2$	298	24.16	0.22
	β-Sitosterol	$C_{29}H_{50}O$	414	31.08	0.21
	γ-Sitosterol	$C_{29}H_{50}O$	414	31.66	0.22
	Lupeol	$C_{30}H_{50}O$	426	38.46	0.20
		$CH_3(CH_2)_3CH=CH(CH_2)6$	226		
	Cis-7-Dodecen-1-y1 acetate	$OCOCH_3$		17.54	0.22
	Octadecanoic Acid	$C_{18}H_{36}O_2$	284	39.26	0.24
Di-Unsaturated Fats	Oxacyclohexadecan- 2- one, 16-methyl ester	$C_{16}H_{30}O_2$	254	4.15	0.32
	Hexadecanoic acid, Z-11	$C_{16}H_{30}O_2$	254	6.72	0.25
	Z-7- Hexadecenoic acid	$C_{17}H_{32}O_2$	268	8.53	0.22
	n- Hexadecanoic acid	$C_{16}H_{30}O_2$	254	9.82	5.80
	8-Octadecenoic acid, methyl ester	$C_{19}H_{36}O_2$	296	13.25	85.02
	9, 12- Octadecadienoic acid (Z, Z)-, methyl ester	$C_{19}H_{36}O_2$	296	16.09	0.26
	8-Octadecenoic Acid, methyl ester, (E)	$C_{19}H_{36}O_2$	296	19.92	0.86
	Phytol	$C_{19}H_{36}O_2$	296	39.87	1.57
Tri-Unsaturated Fats	9, 12- Octadecadienoic acid (Z, Z) - , methyl ester	$C_{19}H_{34}O_2$	294	18.61	0.24
	E, Z-1, 3, 12-Nonadecatriene	$C_{19}H_{34}O_2$	294	24.58	0.23
	Vitamin E	$C_{29}H_{50}O_2$	430	26.14	0.22
	Nonivamide	$C_{17}H_{27}NO_3$	293	29.42	0.26

Discussion

Like other plants, the presence of phytochemicals in the watermelon rind could be the major reason the plant is resistant to microbial attack. The rind contains active phytochemicals which have been reported to be effective against different human diseases - communicable and non-communicable alike (Havsteen, 2002). Alkaloids constituted the highest amount of the phytochemicals in the rind, contributing as high as 50.84% of the total concentrations of the components in the 1h rind extract (60.56 mg/g), which may be due to the age of the watermelon, the chemical nature of the soil, the environment and the variety of the watermelon (Tabiri *et al.*, 2016).

Alkaloids (especially at low concentrations) are therapeutically significant natural plant products owing to their analgesic, antispasmodic and antibacterial properties (Adeolu and Enesi,2013). The alkaloid content of the watermelon rind in this study was higher than the concentration reported for *Treculiaafricana* seeds (Ijeh*et al.,* 2010). The tannin content in the 1 h watermelon rind extract (4.93 mg/g) was comparably higher than the value (0.21 ± 0.02 mg/100 g) reported by Antia*et al.* (Antia*et al.,* 2006) for sweet potatoes leaves and *Treculiaafricana* seeds (Antia*et al.,* 2006). The presence of tannins implies that the samples may have astringent properties, which quicken the healing of wound and inflamed mucous membrane (Farquar, 1996), with antimicrobial properties (Adeolu and Enesi2013) and may be considered for treating a wide range of ailments, including inflammation, liver injury, kidney problems, arteriosclerosis, hypertension and stomach problem (Zhu, 1997).

The one-hour watermelon rind extract also exhibited high saponin content (13.69 mg/g), relatively higher than the value (563.33 mg/100g) obtained for plantain bract (Adeolu and Enesi2013). Saponins have been reported to have antibacterial effect against Gram positive bacteria (Soetan *et al.,* 2006). Meanwhile, the glycosides which could potentially be used as natural sweeteners constituted about 8.41 mg/g of the rind extract. The flavonoids content (6.11 mg/g) in the watermelon rind extract was greater than the value obtained in plantain (145 mg/100g) by Adeolu and Enesi (2013). The availability of flavonoids also inferred that the watermelon rind extract can exhibit some biological functions such as protection against allergies, microbes, ulcers, hepatoxins, viruses and possess strong anticancer activity, and protect against the different levels of carcinogenesis (Soetan *et al.,* 2006).

The presence of phenol (5.45 mg/g) in the watermelon rind indicates its possible antimicrobial potency (Okwu 2003; Ofokansi*et al.,* 2005). The role of these phytochemicals as antimicrobial has been reported by many investigators (Okorondu *et al.,* 2010; Hassan *et al.,* 2011). Similarly, their presence in watermelon was also reported by Egbuonu (2015a,b). The presence of these phytochemicals in the extract was a clear indication of the antimicrobial potentials of the watermelon rind as evident in their inhibitory activity against some selected Gram positive, Gram negative bacteria and fungi at varying degrees of concentrations.

Antimicrobial activity of the watermelon rind extracts showed that all the test organisms were susceptible, with the cells of *Staphylococcus aureus, S. epidermidis* and *C. albicans* being the most sensitive organisms. *Proteus mirabilis* was more resistant. The extent of potency of the watermelon rind 1 h extract against *E. coli* was higher compared to the value obtained by Adelani-Akande *et al*. (2015) for *E. coli*.

The antimicrobial effect of the extract against *Staphylococcus* spp. aligns with the result of Adewuyi*et al.* (2013) who evaluated the antibacterial activities of nonionic and anionic surfactants from *C. lanatus* seed oil. In this study, *Klebsiella pneumoniae* was more susceptible to the watermelon rind extract than the strain reported by Adelani-Akande *et al*. (38) with lower zones of inhibition. *Candida albicans* was the most susceptible fungi reported in this study, which correlates with the results of Egbuonu (2015b) who reported the antibacterial and antifungal potentials of the extracts of watermelon (*C. lanatus*) rind and seed. This suggests that the potency of these watermelon extracts on *C. albicans* and possibly the diseases caused by the organism deserves a cursory consideration.

The GC/MS analysis showed that pentadecanoic acid, 14-methyl-, methyl ester, n- hexadecanoic acid, 8-octadecenoic acid, methyl ester, phytol to be most abundant component of the oil. The antimicrobial activities of fatty acids have been reported earlier by Sun *et al.* (2003). Chitra and Radhakrishnan (41) reported that the polyunsaturated fatty acid extracts are potent against Gram positive and Gram-negative bacterial strains which is line with this study. Furthermore, 9,12-octadecadienoic acid (Z, Z)-, 9,12-octadecadienoic acid methyl ester (Wei *et al.,* 2011), and n-hexadecenoic acid (Kalaivani *et al.,* 2012) have been reported to have antimicrobial activity.

Other minor compounds like hexadecenoic acid methyl ester (Wei *et al.,* 2011) have antibacterial properties; both 9-hexadecenoic acid methyl ester (Z)- and octadecanoic acid methyl ester (Meechaona *et al.,* 2007) have antioxidant activities, whereas octadecanoic acid (Prabhadevi *et al.,* 2012) has antimicrobial activity. Phytol has antimicrobial and antioxidant activities (Rani *et al.,* 2011).

Within the series of monounsaturated fatty acids, the most potent usually have 14 or 16 carbon atoms (Feldlaufer *et al.,* 1993). Besides inhibiting or killing bacteria directly, fatty acids also make conditions unfavourable for the growth of certain bacteria on the skin surface by maintaining an acidic pH (Fluhr*et al.,* 1993; Takigawa*et al.,* 2005). Both saturated and unsaturated fatty acids can prevent initial bacterial adhesion and subsequent biofilm formation (Stenz *et al.,* 2005; Davies and Marques, 2009).

Conclusion

The antimicrobial effect of *C. lanatus*rind extract on selected microorganisms suggests that the natural compounds of the watermelon rind have the potential as antimicrobial agents. However, our team is currently investigating the potency of each pure fatty acid component of the diethyl ether rind extract on the test organisms.

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