

Chemical Contents in Relation to the Antimicrobial Efficacies of *Solanum* Spp. Sect. Petota

Adeyinka A. Aladesida, Adeyinka O. Adepoju¹, Bunmi Adesola-Famide², Temitope Olushola Ajiboye³, Tolulope A. Fagbolu⁴

Department of Pure and Applied Zoology, Federal University of Agriculture, Abeokuta, ²Department of Microbiology, University of Ilorin, ³Department of Science Laboratory Technology, Microbiology Unit, Kwara State Polytechnic, Ilorin, ⁴Department of Public Health and Policy Management, College of Medicine, University of Ibadan, Ibadan, Nigeria, ¹Department of Biological Sciences, Fourah Bay College, University of Sierra Leone, Freetown, Sierra Leone

Abstract

Background: Both *Solanum lycopersicum* and *S. Pimpinellifolium* possess much nutritional and therapeutic usefulness. **Aim:** This study is aimed at investigating the phytochemical, chemical and antimicrobial contents of foliar extracts of both plants. **Methodology:** The analyses were carried out using standard methods; the organic contents of the extracts were determined by GC-MS before the extracts were tested for antibacterial and antifungal potentials using the disc diffusion method. **Results:** The biochemical analysis revealed the presence of crude fibre, crude fat, crude carbohydrate, moisture content, total ash, dry matter and crude protein. Various mineral elements such as Manganese, Zinc, Copper, Sodium, Potassium, Magnesium, Calcium, Iron and Phosphorus were detected in the extracts, even as GC-MS revealed 6 different organic compounds belonging to two groups of chemicals (ester and alkanol). The methanolic extract of both plants showed significant antibacterial and antifungal activities on some of the test organisms at a dose range of 5 and 25mg/ml. Cardiac glycosides was observed to be the highest constituent of the phytochemicals detected and it has been reported to inhibit sodium and potassium pump which in turn cause an increase in the amount of calcium ions and are thus useful in the treatment of heart failure and cardiac arrhythmia. **Conclusion:** This study concluded that the leaf extracts of both plants investigated are highly nutritive, containing appreciable amounts of nutrients which are required in human and animal diet. **Recommendation:** An advocacy for a higher consumption of these tomatoes as well as their use in the formulation of antimicrobial agents and drugs is highly recommended.

Keywords: Antimicrobials, GCMS, minerals, petota, phytochemicals, *solanum*

INTRODUCTION

Since antiquity, plants have been employed not just as a source of food, clothing, and shelter but also for therapeutic use in traditional medicine. Over 1340 plants with defined antimicrobial activities are said to exist and over 30,000 antimicrobial compounds have been isolated from plants.^[1,2] Plants which are used for therapeutic purposes are referred to as medicinal plants. Different parts of medicinal plants such as leaves, roots, rhizomes, stems, barks, flowers, fruits, grains, or seeds have been used to prevent and treat ailments; ranging from respiratory illnesses, urinary tract infection, gastrointestinal system illness as well as skin infections.^[3]

Medicinal plants are said to be the richest source of antimicrobial agents; a single plant could have many antimicrobial properties and could therefore be used for the treatment of several ailments. In recent years, herbal medicines have attracted enormous

attention as significant alternatives to commercial and synthetic drugs, even among literates in urban regions. This could be as a result of some adverse effects caused by certain antibiotics (e.g., hypersensitive reaction to penicillin and ototoxicity by aminoglycosides); increasing cost of antibiotics, which in turn affects maintenance of health; and increase in antibiotic resistance by various bacteria e.g., Methicillin-resistant *Staphylococcus aureus*, *Klebsiella pneumoniae*.^[4,5]

The two species under study; *Solanum lycopersicum* (tomato) and *Solanum pimpinellifolium* (currant tomato, a small-sized

Address for correspondence: Dr. Adeyinka O. Adepoju,
Department of Biological Sciences, Fourah Bay College, University of Sierra Leone, Freetown, Sierra Leone.
E-mail: adeyinka.adepoju.phd@gmail.com

This is an open access journal, and articles are distributed under the terms of the Creative Commons Attribution-NonCommercial-ShareAlike 4.0 License, which allows others to remix, tweak, and build upon the work non-commercially, as long as appropriate credit is given and the new creations are licensed under the identical terms.

For reprints contact: WKHLRPMedknow_reprints@wolterskluwer.com

How to cite this article: Aladesida AA, Adepoju AO, Adesola-Famide B, Ajiboye TO, Fagbolu TA. Chemical contents in relation to the antimicrobial efficacies of *Solanum* spp. sect. petota, Matrix Sci Pharma 2021;5:77-83.

Received: 03-Dec-2021 **Accepted:** 03-Jan-2022 **Available Online:** 20-Apr-2022

Access this article online

Quick Response Code:



Website:
www.matrixscipharma.org

DOI:
10.4103/mtsp.mtsp_12_21

tomato-like fruit), belong to a taxonomic hierarchical group named Petota section; order Solanales and family Solanaceae.^[6,7] *S. pimpinellifolium* are the smallest edible tomato, they grow on intermediate vines. Like *S. lycopersicum*, the plants may get up to 8 feet tall and require staking to keep fruit exposed to light and off the ground. The leaves of the plant are very tiny and delicate with a more acrid odor than other tomato variants). A tomato plant has compound leaves usually 10–25 cm long, made up of leaflets which are about 5–9 on petioles. The leaflets are 8 cm long with serrated margin and have a weak stem which often sprawls over the ground.^[7,8]

S. lycopersicum has a widespread distribution. It is highly and widely consumed either in its raw form or in its processed form as paste, puree, juice, or ketchup.^[9,10] It is a rich source of vitamins, minerals, dietary fibers, essential amino acids, and carotenoids; lycopene and flavonoids.^[11,12] The leaves of tomato have a higher content of antimicrobial metabolites such as chlorogenic acid, α -tomatine, α -terpinene, sabinene, caffeic acid, β -phellandrene, vanillic acid, dehydrotomatine than its fruits.^[13] Aside from the many benefits, the fruit of these plants offers, the leaves are also an exceptional source of lycopene, a naturally occurring pigment, and an antioxidant. It is known to help prevent, fight and repair cell damage in the human body, support healthy eyesight, cardiovascular health, and a lot more.

Even though the classification of some members of the family Solanaceae (to which these plants belong) has been reviewed,^[14] it is essential to also look at some relationship between their chemical content and their beneficial properties. In this study, the antibiotic capability of the extracts of *S. lycopersicum* and *S. pimpinellifolium* against selected clinically important microorganisms as well as their phytochemical and chemical contents was investigated.

MATERIALS AND METHODS

Collection of plant materials

S. lycopersicum and *S. pimpinellifolium* leaf samples were collected into sterile polythene bags from the Botanical Gardens, Ladoko Akintola University of Technology (LAUTECH) research plot where they have been previously grown. The leaves were identified at Lautech Herbarium, Biology Laboratory Complex, LAUTECH, Nigeria. The harvested leaves were cleaned using potable water and air-dried for 4 weeks in the general biology laboratory complex, LAUTECH, Nigeria. The dried leaves of the plants were thoroughly crushed into fine powder using an electric blender and preserved in an airtight container in readiness for the next set of analysis.

Extraction of active ingredients from the plant materials

Extractions were carried out by soaking 20 g of each of the powders in 200 ml of absolute methanol in well-labeled clean conical flasks and corked. After 7 days of extraction, the soaked leaf powders were removed and the decanted solutions were concentrated on a rotary evaporator after they have been filtered using Whatman no 1 filter paper. The dried extracts were kept

in a refrigerator in readiness for various analyses. Enough quantity of powder was kept for various analyses for which they were needed. The extracts were stored in sterile covered sample bottles to keep them from evaporating and then getting more concentrated before use.

Growth and maintenance of test organisms for antimicrobial studies

Bacterial culture of different strains, which included *Pseudomonas aeruginosa*, *Pseudomonas putida*, *Bacillus cereus*, *Bacillus subtilis*, *Escherichia coli*, *S. aureus*, *K. pneumoniae* (maintained at 37°C), fungal culture of *Aspergillus flavus*, *Candida albicans*, *Aspergillus niger* (maintained at 25°C) and yeast culture of *Saccharomyces cerevisiae* (maintained at 25°C) were obtained from the microbial gene bank of Pure and Applied Biology Department, LAUTECH, Ogbomoso, Nigeria.^[15]

Preparation of inoculum

To prepare bacteria inoculum, 5 ml of Nutrient broth was pipetted into each test tube, corked, and autoclaved for 15 min at 121°C; test tubes were then arranged on a slide rack and labeled. Each test tube was inoculated with 2 loop-full of the test bacteria and mixed very well. The mixtures were transferred into the incubator for 2 h at 37°C after which visible growth of the organisms was observed. Fungi inoculum was prepared by mixing 0.2 g of Yeast extract with 1 g of sucrose and 100 ml of water inside a beaker. Five ml of this was pipetted in each test tube, covered with a cork and autoclaved for 15 min at 121°C to sterilize. The media was allowed to cool and two loopful of test fungi were inoculated in each of the bottles and incubated. After 2 h, there was a notable growth of fungi.^[15]

Antimicrobial assay of plant extract

The antimicrobial and antifungal activities were evaluated using the disc diffusion method. Petri plates were prepared with 20 ml sterile nutrient agar for bacteria and Potato dextrose agar for fungi and the bottom of the plates were divided into segments 5, 25, 50, 100, and 250 respectively with the control at the center, with the names of the organisms boldly written on each plate. The test cultures were swabbed on top of the solidified media and the perforated filter paper was put into the extracts of varied concentration (0.25 mg/ml, 0.1 mg/ml, 0.005 mg/ml, and 0.0025 mg/ml) was put into the marked area that matches and the disc with only ethanol. The bacterial plate was incubated in the incubator at 37°C for 24 h and fungi at 28°C for 48 h.^[16]

Antimicrobial assay of broad-spectrum antibiotics

The test organisms were swabbed on the surface of the solidified sensitivity agar using sterile swab sticks to obtain a lawn swab. Two types of antibiotic discs were used depending on the Gram staining property of the test organism under observation, that is, Gram-positive or Gram-negative. The plates were slightly opened and an appropriate antibiotic disc was placed inside. The plates are not turned upside down but

they are incubated at 37°C for 24 h. After incubation, the zones of inhibition around each antibiotic disc were measured.

Proximate analysis

Ten grams of each of the powders were exhaustively processed for various parameters according to the methods described by the Association of Physical Analytical Chemists.^[17] By the use of weight difference, ash and moisture contents were obtained. The fiber content was estimated from the loss in weight of crucible and its content on drying. Carbohydrate was determined by subtracting the sum of the percentages of moisture, crude protein, ash, and fats from 100. The determination of nitrogen value (precursor of protein of a substance) was by micro Kjeldahl method which involves digestion, distillation, and finally titration of the sample. The nitrogen value was then converted to protein by multiplying it by a factor of 6.25. Crude lipids content was determined by the use of Soxhlet type of direct solvent extraction method using petroleum ether boiling at 50°C. The nitrogen free extracts were calculated indirectly by difference as the sum of crude protein, fiber, fats and ash subtracted from 100. All the results of proximate analysis were expressed in percentages.

Phytochemical analysis

Phytochemical analysis for tannins, phenol, flavonoids, terpenoids, saponins, phlobatannin, cardiac glycosides and alkaloids were carried out according to known and standard methods. Tannins and phlobatannins were estimated using the Folin-Denis spectrophotometric method. Saponin content was determined using the method of Liener and modified by Hudson and El-Difrawi. Flavonoids were determined by ethyl acetate extraction and gravimetric measurement, Alkaloids by the alkaline precipitation, and gravimetric method by Harborne and Cardiac glycosides by Keller-Killian's test. For Phenols, 2 ml of distilled water was added to 1 mg of plant sample followed by a few drops of 10% aqueous ferric chloride solution. The formation of blue or green color indicated the presence of phenols.^[18-20]

Mineral content analysis

Minerals were determined after the dried powdered samples were first digested with nitric acid and perchloric acid and the filtered aliquot was used for the determination of Na, K, Ca, Mg, P, Fe, Cu, Mn, and Zn content. K and Na were determined by the flame photometric method. Fe, Cu, Zn, Mn, Ca, Mg and Zn were determined by the atomic absorption spectrophotometric method described by James (1995) and the Association of Official Analytical Chemists (2010).^[21,22]

Gas chromatography-mass spectrophotometry analysis

The gas chromatography-mass spectrophotometry (GC-MS) analysis was conducted by an Agilent 6890 GC system with Agilent 6971 inert mass selective detector (Agilent Tech. Palo Alto, California, USA). Separations were carried out on capillary column, HP5 5% phenyl methyl siloxane nonpolar column (30 000 mm × 0.32 mm diameter, with

a layer thickness of 0.25 mm stationary phase. The oven temperature was set at a temperature of 80°C and maintained for 5 min. Then, the oven temperature was raised 15°C/min to a temperature of 300°C and maintained for 2 min. The carrier gas used was helium ultrapure (99.999%). The temperature of injector, interface, and ion source were 310, 280, and 230°C, respectively. The injection volume was 1 mL, using a model with a 1:10 split inlet, with gas flow rate in the column at 1.3 mL/min.^[16]

Statistical analysis

All experiments were carried out in triplicate and results were expressed as Mean ± standard deviation these data were subjected to analysis of variance using SPSS for Windows, Version 16.0. Chicago, SPSS Inc. was obtained at $P < 0.05$.

RESULTS

Antimicrobial activities of methanolic extract of *Solanum lycopersicum* and *S. pimpinellifolium* on some test organisms

The antimicrobial effects of the leaves extracts are shown as zones of inhibition in millimetres (mm) on some selected microorganisms; 7 bacteria, 3 fungi, and 1 yeast, which includes, *P. aeruginosa*, *P. putida*, *B. cereus*, *K. pneumoniae*, *B. subtilis*, *E. coli*, *S. aureus*, *A. niger*, *A. flavus*, *C. albicans*, and *S. cerevisiae* are presented in Figure 1a and b. The antimicrobial activity of the leaf extract of *S. Pimpinellifolium* was found to be the highest at 5 mg/ml against *E. coli* which produced an inhibition zone of 12 mm [Figure 1a] while that of *S. lycopersicum* is highest at 5 and 25 mg/ml against *C. albicans* with a zone of inhibition of 12 mm [Figure 1b].

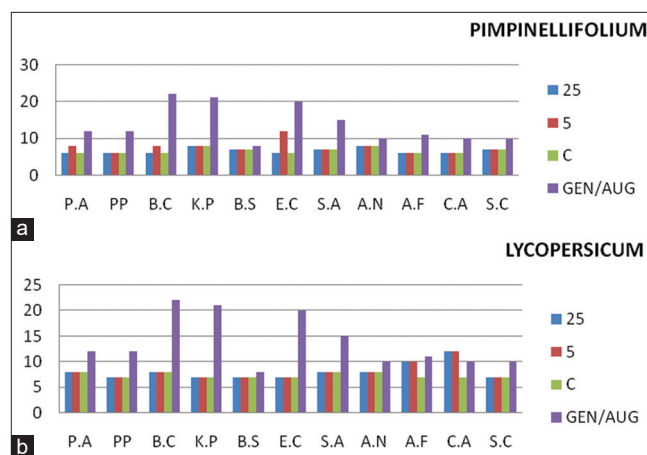


Figure 1: (a) Effect of methanolic extract of *Solanum Pimpinellifolium* extract on the test organisms. (b) Effect of methanolic extract of *S. Solanum lycopersicum* extract on the test organisms. Keys: PA – *Pseudomonas aeruginosa*, P.P – *Pseudomonas putida*, B.C – *Bacillus cereus*, K.P – *Klebsiella pneumoniae*, B.S – *Bacillus subtilis*, E.C – *Escherichia coli*, S.A – *Staphylococcus aureus*, A.N – *Aspergillus niger*, A.F – *Aspergillus flavus*, C.A – *Candida albicans* and S.C – *Saccharomyces cerevisiae*, 25% – 25% conc., 5% – 5% conc., GEN/AUG – Gentamicin/Augumentin, C - Control

The foliar organic compounds in the species of *Solanum* through gas chromatography-mass spectroscopy

Table 1 shows the results of the GC-MS analysis conducted on the leaves of the species of *Solanum* studied. A total of 6 organic compounds were detected and they belong to 2 different groups of chemicals namely, ester and alkanol. 5 of the organic compounds were esters while just one belonged to an alkanol [Table 1]. Hexadecanoic acid methyl ester (HEAME), 9-octadecenoic acid methyl ester (E-) and Phytol were identified as the chief chemical compounds ranging from 15.55% to 38.33% while the other three were present in minor quantities with peak areas ranging from 1.39% to 5.91%.

Phytochemicals in the leaves of the species of *Solanum* studied

Table 2 shows the presence of some metabolites in the leaf extract of the *Solanum* species studied. The methanolic extract of *S. lycopersicum* and *S. pimpinellifolium* leaves contained alkaloids, saponin, tannin, cardiac glycosides, flavonoids, phenols, phlobatannin and terpenoids.

Saponins have also been reported in *Senna alata* and *Cajanus cajan* by Lawal et al.,^[23] in *Lophira lanceolata* seeds by Lohlum et al.^[24] and also in cultivars of *Capsicum* by Adepoju et al.^[15] These phytochemicals have been associated with antimicrobial activities.^[25,26] Apart from their antimicrobial activities, the secondary metabolites observed in this study such as tannins are known to have astringent properties, useful in treatment of inflamed tissue and in prevention of cancer. Flavonoids, saponins and cardiac glycosides act as antiparasitic agents, antiviral agents, can inhibit tumor growth and are useful as antidepressant.^[3,27,28] The content of tannin in the extract of *S. lycopersicum* and *S. pimpinellifolium* was not significantly different at $P \leq 0.05$ while that of alkaloids, saponin, cardiac glycosides, flavonoids, phenols, phlobatannin, and terpenoids differed significantly at $P \leq 0.05$. The mean quantities of the phytochemicals ranged from 0.12-0.92, with Cardiac glycosides having the highest constituent (0.92) and Phenols the lowest (0.12).

The biochemical composition of the leaves extracts of *Solanum lycopersicum* and *Solanum pimpinellifolium*

The percentage proximate composition of the methanolic extract of *S. lycopersicum* and *S. pimpinellifolium* leaves is presented in Table 3. The results of the proximate composition of the leaf extracts showed the presence of crude fiber, crude fat, crude carbohydrate, moisture content, total ash, dry matter, and crude protein. Moisture content and crude protein occurred in appreciable amounts.

The content of crude fiber and total ash were also high, this thereby suggesting the high nutritive value of these plant materials. The high total ash values are an indication of high mineral content. Of all the nutrients detected, the leaves were particularly high in moisture content (36%–37%) but low in dry matter (2.3%).

The composition of crude fiber, crude carbohydrate, moisture content, crude protein, and total ash is higher in *S. lycopersicum*

Table 1: The percentage peak area values of some organic compounds quantified in the leaves of the *Solanum* species studied

Chemical compound	Molecular formula	LYCONR NR (area percentage)	PIMP (area percentage)
9-OCME	C ₁₉ H ₃₆ O ₂	29.19	29.19
OCME-910	C ₁₉ H ₃₆ C ₁₂ O ₂	2.00	1.39
710-OCME	C ₁₉ H ₃₄ O ₂	5.64	3.76
H-16-MME	C ₁₉ H ₃₈ O ₂	4.11	5.91
HEAME	C ₁₇ H ₃₄ O ₂	38.33	36.53
Phytol	C ₂₀ H ₄₀ O	21.55	15.55

HEAME: Hexadecanoic acid methyl ester, H-16-MME: Heptadecanoic acid, 16-methyl-, methyl ester, 710-OCME: 7,10-Octadecadienoic acid, methyl ester, OCME-910: Octadecanoic acid, 9, 10-dichloro-methyl ester, 9-OCME: 9-octadecenoic acid methyl ester (E-), LYCONR: *Solanum lycopersicum* cultivar with No Ribs[®], PIMP: *Solanum pimpinellifolium*

Table 2: Mean quantities of some secondary metabolites (ppm) in the leaves of the *Solanum* species studied

Metabolites	PIMP	LYCONR
Alkaloids	0.62 ^b	0.71 ^b
Saponin	0.81 ^a	0.83 ^a
Phenol	0.12 ^a	0.13 ^a
Tannin	0.30 ^a	0.31 ^a
Flavonoid	0.41 ^a	0.41 ^a
Terpenoid	0.83 ^a	0.75 ^b
Cardiac glycoside	0.91 ^a	0.92 ^a
Phlobatannin	0.33 ^a	0.31 ^a

Mean values in rows with different superscripts of alphabets are significantly different at $P \leq 0.05$ while those with the same alphabets are not significantly different at $P \leq 0.05$. PIMP: *Solanum pimpinellifolium*, LYCONR: *Solanum lycopersicum* Not-ribbed cultivar

Table 3: Percentage proximate composition of the species of *Solanum* studied

Parameters (%)	PIMP	LYCONR
Crude fibre	17.31 ^a	17.03 ^b
Crude carbohydrate	7.40 ^a	6.65 ^b
Dry matter	2.306 ^b	2.32 ^a
Crude fat	12.281 ^b	13.001 ^a
Moisture content	37.50 ^a	36.20 ^b
Crude protein	33.50 ^a	32.61 ^b
Total ash	16.211 ^a	16.000 ^b

Mean values in rows with different superscripts of alphabets are significantly different at $P \leq 0.05$ while those with no alphabet are not significantly different at $P \leq 0.05$. PIMP: *Solanum pimpinellifolium*, LYCONR: *Solanum lycopersicum* Not-ribbed cultivar

than in *S. pimpinellifolium*. The result shows a significant difference at $P \leq 0.05$ only in the composition of crude fibre, crude carbohydrate, moisture content and crude protein in the species of *Solanum* studied. The quantities of the proximate composition of the *Solanum* species studied can be listed from the highest to the lowest in this order—moisture content > protein > crude-fiber > total ash > crude fat > crude carbohydrate > dry matter.

Mineral element composition of the extracts of *Solanum lycopersicum* and *Solanum pimpinellifolium*

Table 4 shows the mineral element composition of the species of *Solanum* plants studied.

The result of the mineral composition of the leaf extracts showed the presence of Manganese, Zinc, Copper, Sodium, Potassium, Magnesium, Calcium, Iron, and Phosphorus. Potassium (27.4%–27.6%), Calcium (27.1%–27.3%) and Magnesium (13.1%–13.3%) were detected in appreciable quantities while the remaining six elements were in trace amounts. On the whole, the quantities of the mineral elements in the plants studied can be enumerated from the highest to the lowest as Potassium > Calcium > Magnesium > Sodium > Zinc > Copper > Phosphorus > Iron and Manganese.

Calcium is essential for growth and maintenance of bones, teeth, and muscles. Potassium is an important extracellular cation while Magnesium is a component of chlorophyll and is both required for chemical reactions in the body and intestinal absorption.^[29-32] The high levels and collective presence of these three elements are known to reduce hypertension and blood pressure. They are therefore essential in the prevention and treatment of hypertension.^[17,29]

Significance of organic, proximate, mineral, and phytochemical contents on antimicrobial efficacy of the extracts

In this study, five of the identified volatile compounds belong to the class ester and one to the class alkanol, and these have been reported to be pharmacologically active. HEAME is said to have potential antibacterial and antifungal activities as well as antioxidant properties.^[33,34] Crude fibers are necessary in diet for digestion and effective to eliminate the risks of coronary heart disease, hypertension, constipation and breast cancer. There is said to be a strong correlation between crude fibre and moisture content, as the fiber is easily digested and disintegrated which could be of high interest in human nutrition. Since both nutrients are high in

these plants, they are therefore valuable sources of dietary fiber needed for human health.^[35,36] Also the high total ash values are an indication of high mineral content which was later observed in the study.

Minerals are required for normal growth, muscular activities, and skeletal development. The high levels and collective presence of Calcium, Potassium, and Magnesium are known to reduce hypertension and blood pressure. They are therefore essential in the prevention and treatment of hypertension.^[17,29] Copper, Iron, and Manganese although observed in trace amounts are still essential for cellular activity, oxygen transport, and intestinal absorption and chemical reaction in the body respectively.^[15,37]

The presence of alkaloids, saponins, tannin, phlobatannins, anthraquinones, cardiac glycosides, flavonoids, and phenol in these extracts may be responsible for the good antibacterial activity. Phenolic compounds are known to have antimicrobial effects.^[38] Flavonoid derivatives were reported to be effective antimicrobial substances against different microorganisms. Their mode of action may be due to their ability to complex with extracellular and soluble proteins and bacterial cell wall. In addition to having antibacterial activity, flavonoids are also effective against viruses and parasites.^[38]

In earlier studies, the antimicrobial, proximate, organic, mineral, and phytochemical analyses of the extract of the tomato plant have been carried out but very few have been done on the foliar extract of the plant.^[7,13,26,39] According to Kim *et al.* (2014), the tomato leaves include a higher content of antimicrobial metabolites than tomato fruits and also contain more phenolic compounds and alkaloids than other tomato parts. It is therefore important that further studies be carried out on the foliar extract of these plants.^[39]

The significant antimicrobial activity of methanolic extracts of *Solanum* species might be due to the synergistic effects of compounds identified in the proximate, organic, mineral, and phytochemical analyses of the plant part. Something striking to note is that *S. lycopersicum* extract was found to be most active against *C. albicans* at 5 and 25% concentration with a zone of inhibition that suggests a better performance than the test drugs.

Based on this study, it can be observed that the leaves of the plant material (*S. lycopersicum* and *S. Pimpinellifolium*) are of high nutritive value, as they contain an appreciable amount of nutrients which are important requirements in human and animal diet. The high total ash composition is an indicator of a high mineral content which is evident in the result of the mineral element composition. The extracts contain several phytochemicals; alkaloids, saponins, cardiac glycosides, tannins, phlobatannin, phenol, flavonoids, and terpenoids. The presence of these detected phytochemicals is responsible for the antimicrobial activity of these species of *Solanum* studied as the test organisms were resistant to most of the broad-spectrum antibiotics investigated, while no resistivity

Table 4: Mineral element composition (ppm) of the species of *Solanum* plants studied

Taxa	PIMP	LYCONR
Mn	0.320 ^a	0.323 ^a
Zn	0.515 ^b	0.591 ^a
Cu	0.449 ^a	0.432 ^b
Na	1.708 ^a	1.721 ^a
K	27.600 ^a	27.402 ^b
Mg	13.306 ^a	13.107 ^b
Ca	27.303 ^a	27.192 ^b
Fe	0.348 ^a	0.311 ^b
P	0.323 ^b	0.684 ^a

^aValues are the mean per treatment. Means in a row without common superscript alphabets differ significantly ($P \leq 0.05$), as analyzed by one-way ANOVA. Mn: Manganese, Zn: Zinc, Cu: Copper, Na: Sodium, K: Potassium, Mg: Magnesium, Ca: Calcium, Fe: Iron, P: Phosphorus, PIMP: *Solanum pimpinellifolium*, LYCONR: *Solanum lycopersicum* 'No Rib' cultivar

was observed against the extracts of the plant materials used. Cardiac glycosides were observed to be the highest constituent of the phytochemicals detected and it has been reported to work by inhibiting sodium and potassium pump which in turn cause an increase in the amount of calcium ions and are thus useful in the treatment of heart failure and cardiac arrhythmia. A high composition of cardiac glycosides (which was discovered in the plants hereby studied) is relative to high calcium content.

CONCLUSION

This study has proved that methanolic extract of the leaves of *S. lycopersicum* and *S. pimpinellifolium* possess microbe inhibitory properties, owing to their constituents and can therefore be employed in the production of broad-spectrum antimicrobial agents for use in medicine and pharmaceutical industries. This suggests that the plants are good alternative source of antimicrobial agents and show more promising antimicrobial potentials than some drugs. The authors wish to recommend that *S. lycopersicum* and *S. pimpinellifolium* should be further studied for their potentials towards utilization in drug production.

Financial support and sponsorship

Nil.

Conflicts of interest

There are no conflicts of interest.

REFERENCES

- Tajkarimi M, Ibrahim S, Cliver D. Antimicrobial herb and spice compounds in food. *Food Control* 2010;21:1199-218.
- Joshi RK. Role of natural products against microorganisms. *Am J Clin Microbiol Antimicrob* 2018;1:1005.
- Osuntokun OT, Akanji OC, Adesoji AJ. Antimicrobial activity and phytochemical composition of Crude ethyl acetate extracts of *Anisopus manniion* some selected clinically important microorganisms. *Int J Pharm Sci Res* 2016;7:231-9.
- Khusro A, Aarti C, Preetamraj JP, Panicker SG. *In vitro* studies on antibacterial activity of aqueous extracts of spices and vegetables against *Bacillus licheniformis* strain 018 and *Bacillus tequilensis* strain ARMATI. *Int J Curr Microbiol Appl Sci* 2013;2:79-88.
- Venkatadri B, Khusro A, Aarti C, Rameshkumar MR, Agastian P. *In vitro* assessment on medicinal properties and chemical composition of *Michelia nilagirica* bark. *Asian Pac J Trop Biomed* 2017;7:782-90.
- Sarah CD, Sandra K, Iris EP. Taxonomy of tomatoes in the Gal'apagos Islands: Native and introduced species of *Solanum* section *Lycopersicon* (Solanaceae). *J Syst Biodivers* 2003;1:29-53.
- Umar M, Zubairu A, Hamisu HS, Mohammed IB, Oko JO, Abdulkarim IM, *et al.* Evaluation of phytochemical and *in vitro* antimicrobial effects of *Solanum lycopersicum* Linn. (Tomato) on oral thrush and human cariogenic pathogens. *Journal of Advances in Medical and Pharmaceutical Sciences*. 2016:1-9.
- Acquaah G. *Horticulture: Principles and Practices*. New Jersey: Prentice Hall; 2002.
- Dilis V, Trichopoulou A. Antioxidant intakes and food sources in Greek adults. *J Nutr* 2010;140:1274-9.
- Krishna MJ, Bhaumik A, Kumar SP. Phytochemical analysis and antimicrobial studies of various extracts of tomato (*Solanum lycopersicum* L.). *Scholars Acad J Biosci* 2013;1:34-8.
- Srinivasan R. *Safer Tomato Production Methods: A Field Guide for Soil Fertility and Pest Management*. Vol. 2. AVRDC The World Vegetable Center, Shanhua, Taiwan: AVRDC Publication; 2010. p. 10-740.
- Aune D, Chan DS, Vieira AR, Navarro Rosenblatt DA, Vieira R, Greenwood DC, *et al.* Dietary compared with blood concentrations of carotenoids and breast cancer risk: A systematic review and meta-analysis of prospective studies. *Am J Clin Nutr* 2012;96:356-73.
- Kim DS, Na H, Kwack Y, Chun C. Secondary metabolite profiling in various parts of tomato plants. *Korean J Hort Sci Technol* 2014;32:252-60.
- Adepoju AO, Ogunkunle AT, Azeze MA, Femi-Adepoju AG. Value of seed protein profile in the taxonomy of cultivars of *Capsicum* in Nigeria. *Niger J Biotechnol* 2019;36:1-8.
- Adepoju AO, Omotosho IO, Femi-Adepoju G, Karim AB. Comparative studies on the antimicrobial, chemical and biochemical contents of *Capsicum frutescens* L. varieties. *Afr J Biotechnol* 2020;19:836-45.
- Adepoju AO, Fadiji AE, Femi-Adepoju AG, Akinyemi AS, Durodola FA. Comparative antimicrobial, phytochemical, nutritional and Gc-MS profiling of methanolic extracts of solanum Sect. *Melongena*. *Int J Agr Biol Sci* 2021;4:82-91.
- Asuk AA, Agiang M, Dasofunjo K, Willie AJ. The biomedical significance of the phytochemical, proximate and mineral compositions of the leaf, stem bark and root of *Jatropha curcas*. *Asian Pac J Trop Biomed* 2015;7:1-8.
- Liener IE. *Toxic Constituents of Plant Foodstuffs*. New York: Academic Press; 1969.
- Hudson BJ, El-Difrawi EA. The sapogenins of the seeds of four lupin species. *J Plant Foods* 1979;3:181-6.
- Harborne JB. *Phytochemical Methods: A Guide to Modern Techniques of Plant Analysis*. 3rd ed. New Delhi: Springer Pvt Ltd; 2008.
- James CS. *Analytical Chemistry of Food*. New York: Chapman & Hall; 1995.
- Association of Official Analytical Chemists. *Official Methods of Analysis of AOAC International*. 18th ed. Washington DC: Association of Official Analytical Chemists; 2010.
- Lawal IO, Grierson DS, Afolayan AJ. Phytotherapeutic information on plants used for the treatment of tuberculosis in Eastern Cape Province, South Africa. *Evid Based Complement Alternat Med* 2014;2014:735423.
- Lohlum SA, Maikidi GH, Solomon M. Proximate composition, amino acid profile and phytochemical screening of *Lophira lanceolata* seeds. *Afr J Food Agric Nutr Dev* 2010;10:2012-23.
- Aliyu AB, Musa AM, Abdullahi MS, Oyewale AO, Gwarzo US. Activity of plant extracts used in Northern Nigerian traditional medicine against Methicillin-resistant *Staphylococcus aureus* (MRSA). *Niger J Pharm Sci* 2008;7:1-8.
- Umar M, Zubair A, Hamisu HS, Mohammed IB, Oko JO, Abdulkrim IM, *et al.* Evaluation of phytochemical and *in-vitro* antimicrobial effects of *Solanum lycopersicum* Linn. (Tomato) on oral thrush and human cariogenic pathogens. *J Adv Med Pharm Sci* 2017;11:1-931456.
- Shimada T. Salivary proteins as a defense against dietary tannins. *J Chem Ecol* 2006;32:1149-63.
- Ebbo AA, Sani D, Suleiman MM, Ahmed A, Hassan AZ. Phytochemical, proximate analysis, antimicrobial screening, methanolic extract, *Diospyros mespiliformis* Hochst ex a. Dc (ebenaceae). *Pharmacogn J* 2019;11:362-8.
- Wardlaw GM, Hampl JS, DiSilvestro RA. *Perspectives in Nutrition*. 6th ed. New York: McGraw Hill; 2004.
- Akpanyung EO. Proximate and mineral composition of bouillon cubes produced in Nigeria. *Pak J Nutr* 2005;4:327-9.
- Okaka JC, Enoch NT, Okaka NC. *Food and Human Nutrition*. Enugu, Nigeria: O.J.C Academic Publishers; 2006. p. 135-53.
- Susanto DF, Aparamarta HW, Widjaja A, Gunawan S. Identification of phytochemical compounds in *Calophyllum inophyllum* leaves. *Asian Pac J Trop Biomed* 2017;7:773-81.
- McGaw LJ, Jäger AK, van Staden J. Isolation of antibacterial fatty acids from *Schotia brachypetala*. *Fitoterapia* 2002;73:431-3.
- Wei LS, Wee W, Siong JY, Syamsumir DF. Characterization of anticancer, antimicrobial, antioxidant properties and chemical compositions of *Peperomia pellucida* leaf extract. *Acta Med Iran* 2011;49:670-4.
- Hussain J, Ullah R, Rehman N, Khan AL, Muhammad Z, Khan FU. Endogenous transitional metal and proximate analysis of selected medicinal plants from Pakistan. *J Med Plants Resour* 2010;4:267-70.
- Ishida H, Suzuno H, Sugiyama N, Innami S, Todokoro T, Maekawa A.

- Nutritional evaluation of chemical component of leaves stalks and stems of sweet potatoes (*Ipomoea batatas* poir). Food Chem 2000;68:359-67.
37. Muhammad A, Dangoggo SM, Tsafe AI, Itodo AU, Atiku FA. Proximate, minerals and anti-nutritional factors of *Gardenia aqualla* (Gauden dutse) fruit pulp. Pak J Nutr 2011;10:577-81.
38. Aduloju V, Ezegbe CC, Aduloju TA. Antibacterial activity of *Solanum lycopersicum* var. ceraciforme on aerobic microbial isolates of meat. Afr J Food Sci Technol 2018;9:1-7.
39. Kim EH, Lee SY, Baek DY, Park SY, Lee SG, Ryu TH, *et al.* A comparison of the nutrient composition and statistical profile in red pepper fruits (*Capsicums annuum* L.) based on genetic and environmental factors. Appl Biol Chem 2019;62:48.