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IN VITRO ANTIBACTERIAL ACTIVITY OF ETHANOLIC EXTRACT DERIVED FROM LEAVES OF *SANSEVIERIA AETHIOPICA* THUNB. (ASPARAGACEAE)

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This study was performed to assess the antibacterial properties of ethanolic extract prepared from *Sansevieria aethiopica* leaves against *Escherichia coli*, *Staphylococcus aureus*, and *Pseudomonas aeruginosa* strains, clinically important bacteria, which are indicator organisms commonly used in various projects in order to monitor antibiotic resistance. For this study, a panel of organisms including *Staphylococcus aureus* ATCC 25923 (mecA negative), *S. aureus* ATCC 29213 (mecA negative, Oxacillin sensitive, weak β-lactamase-producing strain), *S. aureus* NCTC 12493 (mecA positive, Methicillin-resistant, EUCAST QC strain for cefoxitin), *Escherichia coli* ATCC 25922, *E. coli* ATCC 35218, *Pseudomonas aeruginosa* ATCC 27583 were used. The results of antibacterial assays showed that plant extract has exhibited the highest antibacterial activity against *S. aureus* as compared to the *E. coli* and *P. aeruginosa* strains. The diameters of inhibition zones were (26.35 ±1.26) mm, (16.15 ±1.47) mm, and (21.6 ±1.23) mm for *S. aureus* ATCC 25923, *S. aureus* ATCC 29213, and *S. aureus* NCTC 12493, respectively. Conversely, the extract has shown less antimicrobial activities against *P. aeruginosa*. The mean of the inhibition zone was (12.49 ±1.09) mm. Finally, the ethanolic extract of *S. aethiopica* leaves exhibited mild antibacterial activity against *E. coli* [mean of inhibition zone ranged (18.62 ±1.32) mm for *E. coli* ATCC 25922 and (16.38 ±1.02) mm for *E. coli* ATCC 35218]. Thus, the extract obtained by leaves of *Sansevieria aethiopica* showed potent antimicrobial activity. It can be assumed that the presence of the plant extracts could be used for the treatment of various infections because of its effective zone of inhibition of bacteria growth. However, isolation and characterization of the active ingredients in this plant together with their mechanisms of actions on pathogens are still open for further investigations.

Keywords: *Sansevieria aethiopica* Thunb., leaf extract, *Escherichia coli*, *Staphylococcus aureus*, and *Pseudomonas aeruginosa* strains, antibacterial activity, disc diffusion technique, ethanolic extracts

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Introduction

Genus *Sansevieria* Thunb., belonging to Asparagaceae family (Lu and Morden, 2014), comprises ca. 70 species worldwide, distributed mainly in dry or arid areas of the Old World tropics and subtropics (Staples and Herbst, 2005), with a distribution range from Africa to South-East Asia and the islands of the Indian Ocean (Alfani et al., 1989; Carlquist and Schneider, 2007). Representatives of this genus are usually xerophytic perennial rhizomatous plants that occur in dry tropical and subtropical parts of the world (Staples and Herbst, 2005). The habitats of *Sansevieria* in the Old World are often described as open, sunny places, but frequently with subsurface moisture availability (Carlquist and Schneider, 2007). It is assumed that species in this genus represent an important example of the evolution of Asparagaceae for their rapid adaptation to a diversity of habitats (Lu and Morden, 2014). The recent classification has treated *Sansevieria* as a synonym of Dracaena based on their overlapping morphological characteristics (Bos, 1998; Lu and Morden, 2014).

Sansevieria, a genus with diverse ethnobotanical uses in its geographical distribution range, has occupied an important place among plant genera applied for the treatment of a broad spectrum of diseases and disorders (Khalumba and Mbugua, 2005; Staples and Herbst, 2005; Takawira-Nyenya et al., 2014). Members of *Sansevieria* are of great economic importance as ornamental plants mainly due to the multicolored and mottled leaves and the interesting wide variation in leaf shapes (Nazeer and Khoshoo, 1984). *Sansevieria* species are also used as a source of fiber and in traditional African medicine. For example, in Africa (i.e., Tanzania, South Africa, and Zimbabwe), leaves and rhizomes of *S. hyacinthoides* (L.) Druce is squeezed and the juice is used in the treatment of ear infections, earaches, toothache, hemorrhoids, ulcers and intestinal worms, stomach disorders and diarrhea (Wyk and Gericke, 2000). Plant preparations of the *Sansevieria liberica* Gerome and Labroy are commonly used across Nigeria for the treatment of inflammatory conditions (Akindele et al., 2015), while the aqueous root extract of *S. liberica* is used in traditional African medicine (TAM) for the treatment of diarrhea (Adeyemi et al., 2009). Moreover, the anticancer activity of root extracts of *S. liberica* using a combination of *in vitro* and *in vivo* models has been reported (Akindele et al., 2015). It was reported that the whole plant of *S. roxburghiana* Schult. & Schult. f. is traditionally used as cardiotonic, expectorant, febrifuge, purgative, tonic, in glandular enlargement and rheumatism (cited by Haldar et al., 2010). Antitumor activity of *S. roxburghiana* rhizome against Ehrlich ascites carcinoma in mice was evaluated by Haldar et al. (2010).

There are some studies that revealed the antimicrobial activity of *Sansevieria* species (Onah et al., 1994; Aliero et al., 2008; Philip Deepa et al., 2011; Sheela et al., 2012). Similarly, in our previous study, we have evaluated the antibacterial capacity of ten species of *Sansevieria* genus against *Staphylococcus aureus* in order to validate scientifically the inhibitory activity for microbial growth attributed by their popular use and to propose new sources of antimicrobial agents (Buyun et al., 2016). The selected bacterial strain *S. aureus* is widespread and causes serious problems due to their pathogenicities and high levels of drug resistance. This has caused many clinical problems in the treatment of infectious diseases because the commercially available antibiotics commonly used are sometimes associated with adverse effects such as hypersensitivity, allergic reaction, and immunosuppression in the host. Thus,

the search for the discovery of new antimicrobial agents is an urgent need. The results proved that the inhibition zones ranged between 16 and 34 mm. *S. fischeri* and *S. francisii* extracts were particularly active against tested strain (diameters of inhibition zones were 34 mm). This was followed by the activities of *S. parva*, *S. kirkii*, *S. aethiopica*, *S. caulescens*, *S. metallica* leaf extracts (diameters of inhibition zones ranged from 25 to 31 mm). The ethanolic extracts of *S. canaliculata* and *S. trifasciata* showed less antimicrobial activities (16.0 to 16.5 mm). The results proved that the ethanolic extracts of *S. fischeri*, *S. francisii*, *S. parva*, *S. kirkii*, *S. aethiopica*, *S. caulescens*, *S. metallica* exhibited a favorable antibacterial activity against *S. aureus*. By the agar diffusion method, the ethanolic extracts of *S. fischeri*, *S. francisii*, *S. parva*, *S. kirkii*, *S. aethiopica*, *S. caulescens*, and *S. metallica* leaves showed anti-*S. aureus* activity, evidencing that ethanol is an efficient organic solvent to be used for the extraction of bioactive plant materials (Buyun et al., 2016). As previously mentioned, our results also revealed that the ethanolic extracts obtained from leaves of *S. kirkii*, *S. arborescens*, *S. roxburghiana*, *S. francisii*, *S. forskaliana*, *S. cylindrica*, *S. trifasciata*, *S. canaliculata*, *S. caulescens*, *S. metallica*, *S. aethiopica* possess antibacterial potency against *Escherichia coli* isolates and may be used as natural antiseptics and antimicrobial agents in medicine (Tkachenko et al., 2017).

Sansevieria aethiopica Thunb. is an evergreen, succulent, perennial plant producing long, narrow, erect or slightly spreading sword-shaped leaves up to 75 cm long from a rhizomatous rootstock (Figure 1). The plant can spread to form colonies. Good quality fiber is obtained from the leaves of wild plants, which are also used for local medicinal purposes for the treatment of oral, ear and other fungal infections (Tropical Plants Database, Ken Fern). The leaf fibers of *S. aethiopica* are used to make strong twines and ropes. Like several other species of the genus it is especially valued to make bowstrings, hence the vernacular name. The Himba of Namibia uses the fiber to make clothing. In Botswana, it is used to make fishing lines and nets and the rope is used to make sleeping mats by tying thick papyrus stems together (Kirby, 1963; Obermeyer, 1992; Newton, 2001; Praptosuwiryo, 2003; Takawira-Nyenya, 2006).

The rhizomes are a source of drinking water obtained by chewing and spitting out the fibers. *S. aethiopica* is planted as an ornamental in pots and gardens. The medicinal use of rhizomes and leaves is widespread in southern Africa. This plant is used for the treatment of oral, ear and other fungal infections (Hutchings et al., 1996). In Zimbabwe, the leaves are heated and the sap is squeezed into the ear to treat ear infections, while the rhizome is warmed and used for treating toothache (Newton, 2001; Praptosuwiryo, 2003; Takawira-Nyenya, 2006). The leaves are bruised, then heated for a short time. They are then twisted by hand and the fluid thus obtained is dripped into the ear as a cure for ear problems (Leffers, 2003). Fresh or boiled rhizomes are eaten to treat hemorrhoids, stomach-ache, ulcers, diarrhea, and internal parasites. In Namibia, Bushmen apply the heated, pounded leaves to a stiff neck to give relief. Leaf sap is applied to wounds to accelerate healing and to maternal breasts to stimulate milk production (Newton, 2001; Praptosuwiryo, 2003; Takawira-Nyenya, 2006).

These data have prompted us to focus on the assessment of antibacterial activities of the leaves of *Sansevieria aethiopica* plants growing in the M.M. Gryshko National Botanic Garden (Kyiv, Ukraine). Thus, the current study was designed to test the antibacterial efficacy of ethanolic extract prepared from *Sansevieria aethiopica* leaves against *Escherichia coli*, *Staphylococcus*

aureus, and *Pseudomonas aeruginosa* strains, clinically important bacteria, which are indicator organisms commonly used in various projects in order to monitor antibiotic resistance.

Figure 1 *Sansevieria aethiopica* Thunb.
A – specimen of *S. aethiopica* cultivated under glasshouse conditions at NBG (Kyiv, Ukraine) (photo by Denis Krupoderov); B – Growth habit of *S. aethiopica* (cultivated plants with inflorescences developing under glasshouse conditions at M.M. Gryshko National Botanical Garden, Kyiv, Ukraine) (Photo: Lyudmyla Buyun)

Materials and methodology

Collection of Plant Material

The leaves of *S. aethiopica* were sampled in M.M. Gryshko National Botanic Garden (Kyiv, Ukraine) (Figure 1). The whole collection of tropical and subtropical plants at M.M. Gryshko National Botanic Garden (Kyiv, Ukraine) has the status of a National Heritage Collection of Ukraine. The sampled leaves were brought into the laboratory for antimicrobial studies.

It should be noted that in the updated version of the World Checklist of Selected Plant Families (WCSP) *Sansevieria aethiopica* Thunb. (Asparagaceae) is considered as a synonym of currently accepted *Dracaena aethiopica* (Thunb.) Byng & Christenh [http://wcsp.science.kew.org/].

Preparation of Plant Extracts

The leaves were brought into the laboratory for antimicrobial studies. Freshly crushed leaves and pseudobulbs were washed, weighed, and homogenized in 96% ethanol (in proportion

1 : 19) at room temperature. The extracts were then filtered and investigated for their antimicrobial activity.

Bacterial test strain and growth conditions

For this study, a panel of organisms including *Staphylococcus aureus* ATCC 25923 (mecA negative), *S. aureus* ATCC 29213 (mecA negative, Oxacillin sensitive, weak β-lactamase-producing strain), *S. aureus* NCTC 12493 (mecA positive, Methicillin-resistant, EUCAST QC strain for cefoxitin), *Escherichia coli* ATCC 25922, *E. coli* ATCC 35218, *Pseudomonas aeruginosa* ATCC 27583 were used. The cultivation medium was trypticase soy agar (Oxoid, UK), supplemented with 10% defibrinated sheep blood. Cultures were grown aerobically for 24 h at 37 °C. The cultures were later diluted with a sterile solution of 0.9% normal saline to approximate the density of 0.5 McFarland standard. The McFarland standard was prepared by inoculating colonies of the bacterial test strain in sterile saline and adjusting the cell density to the specified concentration.

Determination of the antibacterial activity of plant extracts by the disk diffusion method

Antimicrobial activity was determined using the agar disk diffusion assay (Bauer et al., 1966). Strains were inoculated onto Mueller-Hinton (MH) agar plates. Sterile filter paper discs impregnated with extract were applied over each of the culture plates. Isolates of bacteria were then incubated at 37 °C for 24 h. The plates were then observed for the zone of inhibition produced by the antibacterial activity of ethanolic extract obtained from the leaves of *S. aethiopica*. A negative control disc impregnated with sterile ethanol was used in each experiment. At the end of the period, the inhibition zones formed were measured in millimeters using the vernier. For each extract, eight replicates were assayed. The plates were observed and photographs were taken. The susceptibility of the test organisms to the plant extracts was indicated by a clear zone of inhibition around the holes containing the plant extracts and the diameter of the clear zone was taken as an indicator of susceptibility. Zone diameters were determined and averaged.

Statistical analysis

Zone diameters were determined and averaged. Statistical analysis of the data obtained was performed by employing the mean ± standard error of the mean (S.E.M.). All variables were randomized according to the phytochemical activity of extracts tested. All statistical calculation was performed on separate data from each strain. The data were analyzed using a one-way analysis of variance (ANOVA) using Statistica software, version 8.0 (StatSoft, Poland) (Zar, 1999). The following zone diameter criteria were used to assign susceptibility or resistance of bacteria to the phytochemicals tested: Susceptible (*S*) ≥15 mm, Intermediate (*I*) = 10–15 mm, and Resistant (*R*) ≤10 mm (Okoth et al., 2013).

Results and discussion

The aim of our study was to examine the antibacterial properties of *Sansevieria aethiopica* leaves against *Escherichia coli*, *Staphylococcus aureus*, and *Pseudomonas aeruginosa* strains. The results of antibacterial activity screening are given in Figure 2 and 3, which clearly indicate that the extract has shown antibacterial activity against the entire tested organisms. The extract has shown better activity against *S. aureus* compared to the *E. coli* and *P. aeruginosa* strains. The diameters of inhibition zones were (26.35 ±1.26) mm, (16.15 ±1.47) mm, and (21.6 ±1.23) mm for *S. aureus* ATCC 25923, *S. aureus* ATCC 29213, and *S. aureus* NCTC 12493, respectively. The extract has shown less antimicrobial activities against *P. aeruginosa*. The mean of the inhibition zone was (12.49 ±1.09) mm. Finally, the ethanolic extract of *S. aethiopica* leaves exhibited mild antibacterial activity against *E. coli* [mean of inhibition zone ranged (18.62 ±1.32) mm for *E. coli* ATCC 25922 and (16.38 ±1.02) mm for *E. coli* ATCC 35218] (Figure 2 and 3).

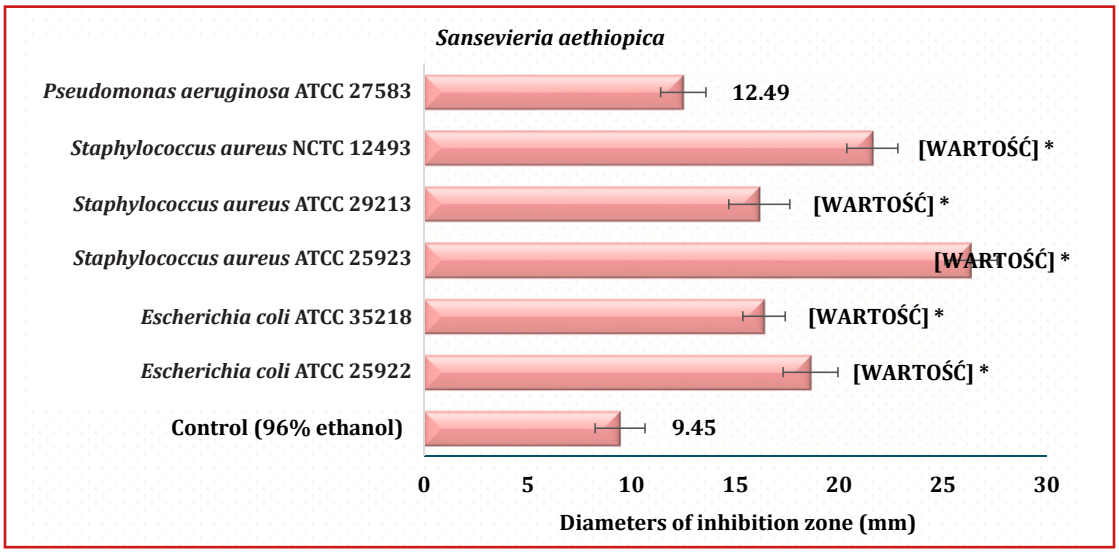

Figure 2 The mean inhibition zone diameters of ethanolic extracts obtained from leaves of *Sansevieria aethiopica* against *S. aureus* (ATCC 25923, ATCC 29213, NCTC 12493), *Escherichia coli* (ATCC 25922, ATCC 35218), and *Pseudomonas aeruginosa* (ATCC 27583) (M ±m, *n* = 8)

Consequently, in this study, the antibacterial activity of *S. aethiopica* leaf extract (Figure 2 and 3) was investigated against the standard Gram-positive strains: *Staphylococcus aureus* (ATCC 25923, ATCC 29213, NCTC 12493) and Gram-negative strains: *Pseudomonas aeruginosa* (ATCC 27583) and *Escherichia coli* (ATCC 25922, ATCC 35218) by the disc diffusion technique. The mean of inhibition zone diameters of ethanolic extracts obtained from leaves of *S. aethiopica* was statistically increased against *S. aureus* by 179% (ATCC 25923), by 71% (ATCC 29213), and by 129% (NCTC 12493), respectively as well as against *E. coli* strains by 97% (ATCC 25922) and by 73% (ATCC 35218) compared to control sample (96% ethanol) (Figure 2).

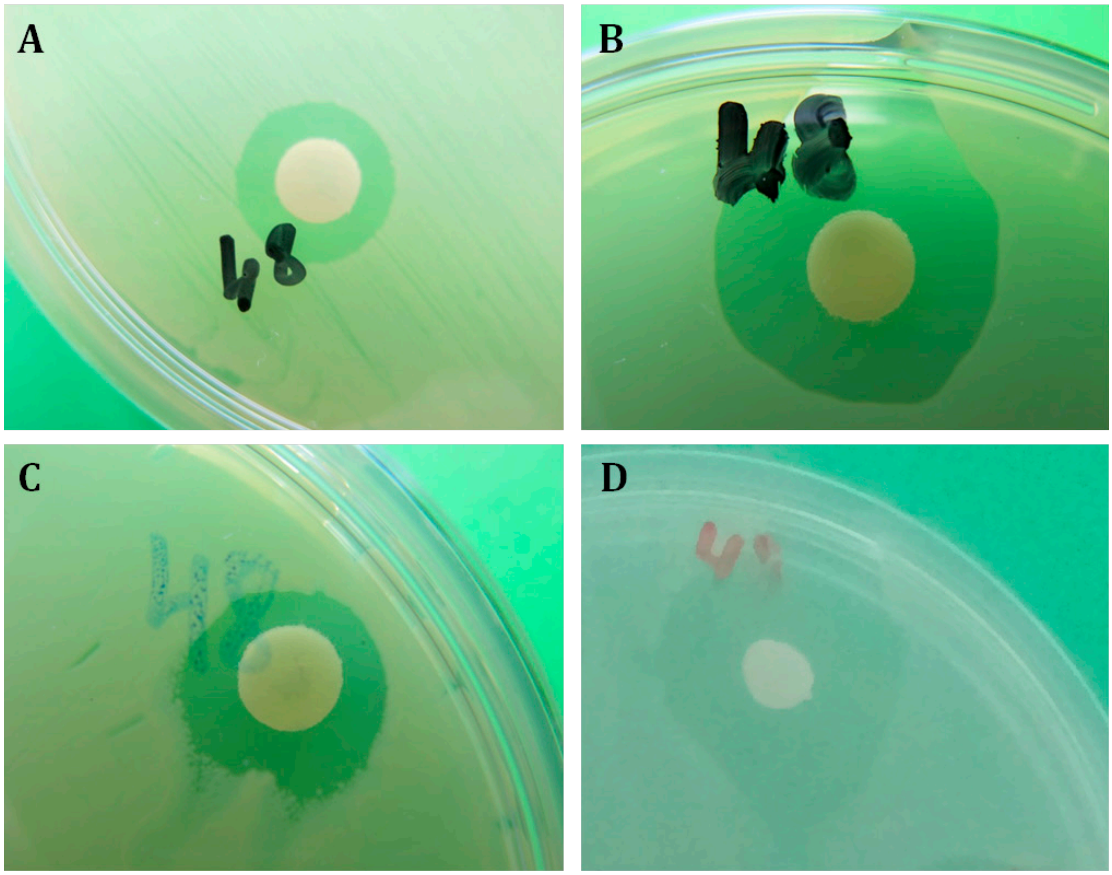

Figure 3 Antimicrobial activity of ethanolic extract obtained from leaves of *S. aethiopica* against *Escherichia coli* ATCC 25922 (A), *Escherichia coli* ATCC 35218 (B), *Pseudomonas aeruginosa* ATCC 27583 (C), and *Staphylococcus aureus* NTCC 12493 (D) measured as inhibition zone diameter

The comparison of our data, with those published by other authors, reveals that these results support the reports of other researchers that plant extracts are very effective in the treatment of bacterial infection. For example, David and Jide Afolayan (2017) have studied the effect of extracts of *S. aethiopica* on *C. albicans* ATCC 10231 and their possible mechanisms of actions were proposed. The minimum inhibitory concentrations (MICs) and minimum fungicidal concentrations (MFCs) of the extracts were determined using the macro broth dilution method while the structural changes in the fungus after treatment with the extract were determined by an electron microscope. Standard methods were used to determine the effects of the extracts on the proton pumping, internal pH and ergosterol synthesis. The MIC of the extracts ranged between 1.5625 and 3.125 mg/ml. Acetone extract had the highest MIC of 3.125 mg/ml and both Acetone and ethanolic extracts had MFC of 6.250 mg/ml. Acetone and methanolic extracts had fungicidal effects on the test yeast. The extracts-treated cells showed alterations in the morphology; wrinkled surfaces, shrinkages, tears, and holes. Proton pumping activity was lower in the treatment group compared to the control while the internal pH of test fungus ranged

between 5.40 and 6.03. These researchers have observed a decrease in ergosterol content in the candidal cells treated with the plant extracts. At ½MIC of acetone, methanol and ethanol extracts of the plants the amount of 24(28)-dihydroergosterol to ergosterol was 0.0972/0.5128, 0.0939/0.3571 and 0.1032/0.3702 g/dry weight respectively. The extracts were able to inhibit the growth, affect the intracellular pH (by extension the membrane integrity) and interfere with the sterol metabolism in *C. albicans* ATCC 10231 (David and Jide Afolayan, 2017).

David and Afolayan (2013a) have also investigated the *in vitro* interactions between extracts of *S. aethiopica* and gentamicin and the activities of the resultant iso-effective combinations against biofilm of *Enterobacter faecalis* ATCC 29212 and *E. faecalis* KZN. *In vitro* interactions between the plant extracts and gentamicin were studied using the checkerboard microdilution method and anti-biofilm activity of the iso-effective combinations was determined by semi-quantitative adherence assay. Acetone extract of *S. aethiopica* has the highest inhibitory activity. The minimum concentration of gentamicin that inhibited the two isolates was the same (0.016 mg/ml). Different isoeffective points were observed with fractional inhibitory concentration indexes ranged between 0.375 and 1.9313. The maximum biofilm reduction was observed when the two antibacterial agents were combined. The combinations of the agents were able to break the barrier created by the biofilm. This is necessary before dental pathogen embedded in the biofilm could be eradicated or reduced. The efficacy of the extracts of *S. aethiopica* (singly and in combination with gentamicin) justifies its usage in oral hygiene and also suggests it as an important candidate for the formulation of paste or tincture for oral hygiene and treatment of enterococcal infections (David and Afolayan, 2013a).

In another study, David and Afolayan (2013b) have screened *S. aethiopica* leaf extracts for antifungal activity against *Candida albicans* ATCC 10231. A micro broth dilution method was used to determine the minimum inhibitory concentrations (MICs) and a biofilm enumeration assay was employed to determine the minimum biofilm inhibition concentrations (MBICs) and minimum biofilm eradication concentrations (MBECs) of the extracts. Electron microscopy was used to determine the effects of the extracts on the ultrastructure of the biofilm of the test fungus. Acetone extract had the least effect on *C. albicans* ATCC 10231 with MIC of 3.125 mg/ml. For the extracts, the MBICs and MBECs were higher than the corresponding MICs. The MBEC : MIC and MBIC : MIC were 8 : 1 and 2 : 1, 4 : 1 and 2 : 1, and 8 : 1 and 8 : 1 for acetone, ethanolic and methanolic extracts, respectively. Extract treated cells showed a change in the morphology of the cells. Extracts of *S. aethiopica* were able to affect the proliferation of both planktonic and sessile cells of *C. albicans* (David and Afolayan, 2013b).

Moreover, in our previous study, we also have assessed the *in vitro* antibacterial activity of ethanolic extract prepared from *S. cylindrica* leaves against *Escherichia coli*, *Staphylococcus aureus*, and *Pseudomonas aeruginosa* strains. *S. aureus* ATCC 25923, *S. aureus* ATCC 29213, *S. aureus* NCTC 12493, *E. coli* ATCC 25922, *E. coli* ATCC 35218, *P. aeruginosa* ATCC 27583 were used to screen for antibacterial activity of leaf extract by the disc diffusion assay (Kirby–Bauer method). The results of antibacterial activity clearly showed that the extract has shown antibacterial activity against the entire tested organisms. The extract has shown better activity against *S. aureus* and *P. aeruginosa* strains compared to the *E. coli* strains. The diameters of inhibition zones were (22.5 ±1.24) mm, (20.5 ±1.3) mm, and (16.4 ±0.95) mm for *S. aureus*

ATCC 25923, *S. aureus* ATCC 29213, and *S. aureus* NCTC 12493, respectively. The extract has shown less antimicrobial activities against *P. aeruginosa*. Finally, the ethanolic extract exhibited mild antibacterial activity against *E. coli* (Buyun et al., 2018). The preliminary screening assay indicated that the leaves of *S. parva* with antibacterial properties may offer alternative therapeutic agents against bacterial infections. The results proved that the leaf extract from *S. parva* exhibits a favorable antibacterial activity against Gram-positive strains: *Staphylococcus aureus* (ATCC 25923, ATCC 29213, NCTC 12493) and Gram-negative strains: *Pseudomonas aeruginosa* (ATCC 27583) and *Escherichia coli* (ATCC 25922, ATCC 35218) (Tkachenko et al., 2019).

By the agar diffusion method, the ethanolic extracts from *S. fischeri*, *S. francisii*, *S. parva*, *S. kirkii*, *S. aethiopica*, *S. caulescens*, and *S. metallica* showed anti-*S. aureus* activity, evidencing that ethanol is an efficient organic solvent to be used for the extraction of bioactive plant materials. It would be reasonable to suggest that the bioactivity of *Sansevieria* plant extracts is attributed to phytochemical constituents. The microbial growth inhibition capacity relies on the rich variety of phytochemicals including carbohydrates, saponin, flavonoids, phenols, alkaloid, anthocyanin and cyanine, glycosides, proteins, and phytosterols (Deepa Philip et al., 2011).

Prakoso et al. (2018) have explored the role of *Aloe vera* (L.) Burm.f. (AV), *Ananas comosus* (L.) Merr. (AC), and *Sansevieria masoniana* Chahin. (SM) on the skin wound infected with methicillin-resistant *Staphylococcus aureus* (MRSA). Forty-five adult female Sprague Dawley rats weighing 250–300 grams were divided into 5 groups. All the groups were exposed to two round full-thickness punch biopsy and infected with MRSA. The group C was the control group/untreated; group BC was treated with base cream/without extract; group AV was treated with 75% AV cream; group AC was treated with 75% AC cream, and group SM was treated with 75% SM cream. The wounds were observed on days 5, 10, and 15. The base cream formulation in this study has no potential effect on wound healing. The treatment groups (AV, AC, and SM) showed a better result of healing on the wound that was infected with MRSA in all parameters compared with groups C and BC (P <0.05). The topical application of AV, AC, and SM increased the wound contraction, skin tensile strength, angiogenesis, fibroblast, and collagen deposition in wound tissue, and it starts on day 5 (P <0.05). The healing of skin wounds was measured by a percentage of closure, skin tensile strength, and histopathology. The result showed that AV, AC, and SM have a similar potential effect on healing in the wound that was infected with MRSA compared to the groups C and BC (P <0.05). The study of Prakoso et al. (2018) proved that AV, AC, and SM are widely used as traditional medicine and have a potential role in activating cluster of differentiation 8 [$CD8^+$, a transmembrane glycoprotein that serves as a co-receptor for the T cell receptor (TCR)] to infiltrate the wound tissue as the mechanism to eliminate MRSA infection (Wu and Xu, 2014). As T-cells are cytotoxic, $CD8^+$ plays an important role not only in controlling the infection but also in eliminating the infected cells (Prakoso et al., 2014).

The resin extracts of *Dracaena cinnabari* Balf. f. (Asparagaceae) and its solution in methanol were investigated for their *in vitro* antifungal activities against six human pathogenic fungal strains by the agar diffusion method, for antioxidant activities using the DPPH assay and for cytotoxic activity using the neutral red uptake assay by Al-Fatimi (2018). The test organisms: *Candida krusei* (ATCC 90878), *Absidia corymbifera* (100798), *Aspergillus fumigatus* (13550/99),

Trichophyton mentagrophytes (05/2004) *Microsporum gypseum* and *Mucor* sp. were used. In comparison with different resin extracts, the methanolic solution of the whole resin showed the strongest biological activities. The best antifungal activity was demonstrated by the methanolic solution of the crude resin (20–30 mm) against *Aspergillus fumigatus*, *Microsporum gypseum* and *Trichophyton mentagrophytes* followed by less polar dichloromethane and ethyl acetate extracts (18 to 20 mm), compared with the antifungal reference nystatin. In contrast, the residue of the resin dissolved in methanol showed weak activity. The methanolic solution of the whole resin was evaluated for the MIC. The resin solution showed a MIC at 500 µg/mL with inhibition zones 8 mm and 10 mm towards *M. gypseum* and *T. mentagrophytes*, respectively. It showed strong antifungal activity, especially against *Microsporum gypseum* and *Trichophyton mentagrophytes* besides antioxidant activities and toxicity against FL-cells, a human amniotic epithelial cell line (Al-Fatimi, 2018).

The antibacterial activity of the *S. aethiopica* extract may be due to the presence of various active metabolites. The phytochemicals, antioxidants and antibacterial potential of acetone and methanolic extracts of *S. aethiopica* leaf against bacterial pathogens responsible for otitis were evaluated by David and Afolayan (2016). The phenolic contents of the extracts were 57.13 and 19.06 mg tannic acid/g in acetone and methanolic extracts respectively. Flavonols and proanthocyanidin recorded the least values in methanolic and acetone extracts respectively. The extracts have good antioxidant properties although lower than the standard chemicals used as controls. The extracts expressed antibacterial effects on both Gram-negative and Gram-positive bacteria however, their activity was more pronounced on Gram-negative organisms. Although slightly toxic, the extracts have both bacteriostatic and bactericidal effects on the selected bacteria associated with otitis, especially Gram-negative (David and Afolayan, 2016). For example, the phytochemical screening revealed the high presence of alkaloids in the methanolic extract of *S. roxburghiana* compared to acetone, chloroform, and ether. Flavonoids were present in ethanolic and ether extracts in moderate proportions; saponins were present in ethanolic and methanolic extracts in moderate proportions. Steroids were shown in higher proportions in methanol, chloroform and ether and moderate in acetone; terpenoids presence were was shown in chloroform and absent in all rest of the extracts. Tannins were high in acetone and methanol and moderate in ethanol and chloroform. Phenols were only in methanol fractions, while quinones were presented in methanol, chloroform, and ether at moderate levels (Kumar and Kumari, 2015).

Phytochemical analysis revealed the presence of oils, reducing sugars, alkaloids, saponins, anthraquinones, and tannins in the root extract of *S. liberica* (Adeyemi et al., 2009).

S. roxburghiana Schult. & Schult.f. and *S. trifasciata* Prain plants were used to screen pharmacologically important phytochemical constituents against Gram-positive and Gram-negative bacterial strains in the study of Kingsley et al. (2013). The methanol extract from the leaves of *S. roxburghiana* and *S. trifasciata* plants showed good inhibition against all the pathogens. *S. roxburghiana* exhibited good inhibition effect against *S. aureus* and *P. aeruginosa* whereas *S. trifasciata* manifested good antimicrobial effect against *E. coli*, *S. aureus*, and *P. aeruginosa*. The combined effect of antibiotics and plant extract has enhanced the antimicrobial effect of the extracts obtained against pathogenic microorganisms. The

percentage inhibition of combined effect was calculated and it was observed that the leaves of *S. roxburghiana* possess antimicrobial effect (50%) against *S. aureus* combined with norfloxacin whereas the leaf extract of *S. trifasciata* when combined with tetracycline it showed 36% of inhibition against *S. aureus*. Both of the plant extracts were effective against Gram-positive and Gram-negative pathogenic microorganisms. The components present in the plant extracts are responsible for the inhibition effects as all the antimicrobial and phytochemical agents are being carried by the nature of the solvent used. The compounds separated through thin layer chromatography of *S. roxburghiana* and *S. trifasciata* with 50 mg/mL concentration exhibited good antimicrobial effect against pathogenic microorganisms (Kingsley et al., 2013).

Therefore, based on data derived from previous and recent studies, the therapeutic actions of extracts derived from *Sansevieria* spp. plants are more likely related to the antibacterial properties of their constituents.

Conclusions

The extract obtained by leaves of *Sansevieria aethiotica* showed potent antimicrobial activity. The extract has shown better activity against *S. aureus* compared to the *E. coli* and *P. aeruginosa* strains. It can be assumed that the presence of the plant extracts could be used for the treatment of various infections, caused by the tested organisms, because of its effective zone of inhibition of bacteria growth. The result lends credence to the ethnobotanical use of this plant in treating microbial infection and shows that *Sansevieria aethiotica* could be exploited for new potent antimicrobial agents. However, isolation and characterization of the active ingredients in this plant together with their mechanisms of actions on pathogens are still open for further investigations.

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