UNIVERSITI PUTRA MALAYSIA

ANTIMICROBIAL ACTIVITY OF SOLANUM TORVUM SWARTZ: SYSTEMATIC REVIEW

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FPSK2 2021 35

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A THESIS SUBMITTED AS PARTIAL REQUIREMENTS FOR THE DEGREE OF BACHELOR OF SCIENCE (BIOMEDICAL SCIENCES)

DEPARTMENT OF BIOMEDICAL SCIENCES
FACULTY OF MEDICINE AND HEALTH SCIENCES
UNIVERSITI PUTRA MALAYSIA

2021

ABSTRACT

Antimicrobial Activities of *Solanum torvum* Swartz: Systematic Review

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Introduction: Uncontrollable use of antibiotic drugs causes antibiotic resistance. Pathogenic bacteria use a variety of techniques to establish inherent tolerance to antibiotics, including changing target sites, active drug efflux and enzymatic degradation. Medicinal plant extracts are becoming increasingly popular for combating a variety of diseases. *Solanum torvum* Sw. are used in traditional medicine to treat toothaches, cracks in the foot and stomachache. The fruits are served as one of the dishes due to their rich in nutritions. *S. torvum* Sw. are reported to perform antimicrobial activities, but the findings were inconsistent. **Objectives:** The study aims to do systematic review in order to identify the types of extracts and parts of *S. torvum* Sw. which have reported to have antimicrobial activities. Besides, the study aims to identify the species targeted and to review the zone of inhibition, minimum inhibitory concentration, minimum bactericidal concentration, minimum fungicidal concentration and percentage of inhibitions that have been reported in each study. **Methodology:** Studies related to *S. torvum* Sw. and antimicrobial activities were searched from five databases, that is Google Scholar, Pubmed, SpringerLink, ScienceDirect and Scopus according to the inclusion criteria. 36 studies were included in the systematic review. **Result:** There were 47.8% of studies reported the antimicrobial activities that used leaf, and 28.3% of studies that used fruit, 8.7% of studies that used stem, 6.5% of studies that used whole plant, 4.3% of studies that used root and 2.2% of studies that used inflorescence and flower, respectively. There were 23% studies reported the antimicrobial activities that used Methanol extract, 23% from Aqueous extract, 5.4% from Absolute Ethanol extract, 12.2% studies that used different percentage of Ethanol extract, 8.1% from Chloroform extract, 6.8% from Acetone extract and 21.6% from other types of extracts. The leaf and the fruit were effective towards 79 and 76 species, respectively. The stem was effective towards 22 species. The whole plant and the root were effective towards 13 and 11 species, respectively. The flower and the inflorescence were effective towards 2 and 4 species, respectively. **Discussion:** The presence of phytochemical constituents makes the leaf and fruit widely used in the studies. Most polar groups containing antimicrobial activities are more soluble in Methanol and Aqueous extracts. **Conclusion**: The systematic review showed that the leaf had the highest effectiveness against microorganisms, and this is corresponding to the highest number of studies using it. Methanol and Aqueous extract were highly used in most of the studies.

All the parts of *S. torvum* Sw. were able to inhibit or kill effectively to most of the species such as *E. coli*, *P. aeruginosa*, *S. aureus*, *B. cereus*, *A. niger*, *C. albicans*, *C. lunata* and *A. fumigatus*. It is recommended that specific species of microorganisms especially often found in human diseases are used to evaluate antimicrobial activities of *S. torvum* Sw..

Keywords: *Solanum torvum* Sw., antimicrobial activities, systematic review

ABSTRAK

Aktiviti Antimikrobial untuk *Solanum torvum* Swartz: Analisis-Sistematik

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Pengenalan: Penggunaan ubat antibiotik tanpa kawalan telah menyebabkan rintangan antibiotik. Bakteria patogen menggunakan beberapa teknik untuk menunjukkan toleransi kepada antibiotik, termasuk menukarkan kedudukan sasaran, mengaktifkan ubat mengalir keluar dari bakteria, dan enzimatik merosot. Tumbuhan-tumbuhan ubatan menjadi semakin terkenal kerana mereka digunakan untuk memerangi kebanyakan penyakit. *Solanum torvum* Sw. telah digunakan dalam perubatan tradisional untuk merawat sakit gigi, kaki pecah-pecah dan sakit perut. Buah-buahannya merupakan salah satu hidangan kerana kaya dengan khasiat. *S. torvum* Sw. dilaporkan dengan aktiviti antimikrobial, tetapi dapatan adalah tidak konsisten. **Objektif:** Kajian ini bertujuan untuk membuat analisis sistematik dengan mengenal pasti jenis-jenis ekstrak dan bahagian S. torvum Sw. yang dilaporkan mendapati aktiviti antimikrobial. Di samping itu, kajian ini juga bertujuan untuk mengenal pasti spesies yang disasarkan dan mengulas zon perencatan, minimum konsentrasi perencatan, minimum konsentrasi bakteria, minimum konsentrasi kulat dan perencatan peratusan yang telah dilaporkan dalam kajian masing-masing. **Metodologi:** Kajian yang berkaitan dengan *S. torvum* Sw. dan aktiviti antimikrobial telah dicari daripada lima pangkalan data, iaitu Google Scholar, Pubmed, SpringerLink, ScienceDirect dan Scopus berdasarkan dengan kriteria pemilihan. 36 kajian telah termasuk dalam analisis-sistematik. **Keputusan:** Terdapat 47.8% kajian yang dilaporkan dengan aktiviti antimikrobial dengan menggunakan daun, terdapat 28.3% kajian yang menggunakan buah-buahan, terdapat 8.7% kajian yang menggunakan batang, terdapat 6.5% kajian yang menggunakan keseluruhan tanaman, terdapat 4.3% kajian yang menggunakan akar, dan terdapat 2.2% kajian yang menggunakan perbungaan dan bunga masing-masing. Terdapat 23% kajian yang dilaporkan dengan aktiviti antimikrobial dengan menggunakan ekstrak Metanol, 23% kajian yang menggunakan ekstrak berair, 5.4% kajian yang menggunakan ekstrak etanol mutlak, 12.2% kajian yang menggunakan etanol ekstrak peratusan yang tidak sama, 8.1% kajian yang menggunakan ekstrak kloroform, 6.8% kajian yang menggunakan ekstrak aseton, dan 21.6% yang menggunakan ekstrak lain-lain. Daun dan buah-buahan menunjukkan kesan kepada 79 dan 76 spesies masing-masing. Batang adalah berkesan terhadap 22 spesies. Keseluruhan tanaman dan akar adalah berkesan terhadap 13 dan 11 spesies masing-masing. Bunga dan perbungaan adalah berkesan terhadap 2 dan 4 spesies masing-masing. **Perbincangan:** Kewujudan fitokimia menyebabkan penggunaan daun dan buah-buahan dalam kebanyakan kajian. Kebanyakan polar berkutub yang mempunyai aktiviti antimikrobial akan lebih larut dalam ekstrak metanol dan ekstrak berair. **Konklusi:** Analisis-sistematik menunjukkan bahawa daun mempunyai keberkesanan yang paling tinggi terhadap mikroorganisma dan ia sepadan dengan nombor yang paling banyak digunakan dalam kajian. Ekstrak Metanol dan Berair merupakan ekstrak yang paling banyak digunakan dalam kajian. Semua bahagian *S. torvum* Sw. dapat menghalang dan membunuh dengan berkesan terhadap kebanyakan spesies seperti *E. coli*, *P. aeruginosa*, *S. aureus*, *B. cereus*, *A. niger*, *C. albicans*, *C. lunata* and *A. fumigatus*. Cadangan terhadap kajian masa depan adalah mengkaji spesies tertentu yang sentiasa didiagnosi di penyakit manusia untuk menilai aktiviti antimikrobial *S. torvum* Sw..

Kunci Utama: *S. torvum* Sw., aktiviti antimikrobial, analisis-sistematik

ACKNOWLEDGMENT

First of all, I would like to express my utmost gratitude towards my co-supervisor, Associate Prof Dr Yong Yoke Keong for supporting me to switch from wet lab to dry lab during this pandemic, so that I could work on my Final Year Project without being affected by the pandemic. I am glad that I have a chance to learn how to do a systematic review. I would also like to express my gratitude towards Associate Prof Dr Lim Vuanghao for teaching and guiding me to do a systematic review and suggested some websites that helped me a lot while doing data extraction and thesis writing.

I would also like to thank a Postgraduate student, Liew Kong Yen, for giving me some feedback and suggestions to improve my thesis writing. I am also grateful that one of my seniors was willing to lend me her thesis writing for reference. I would also like to say thank you to my coursemates because they provided me so much strength and motivation during this pandemic.

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LIST OF ABBREVIATIONS

DNA	Deoxyribonucleic Acid
MIC	Minimum Inhibitory Concentration
MBC	Minimum Bactericidal Concentration
MFC	Minimum Fungicidal Concentration
β	Beta
mm	Millimeter
cm	Centimeter
µg/mL	Microgram per milliliter
±	Plus-minus sign
%	Percentage
˚C	Degree Celsius
PRISMA	Preferred Reporting Items for Systematic Reviews and Meta-analyse
i.e.	That is
MTCC	Microbial Type Culture Collection and Gene Bank
ATCC	American Type Culture Collection
ITCC	Indian Type Culture Collection
CIP	Institute Pasteur Collection
LMG	Laboratory of Microbiology Gent
ESBL	Extended spectrum beta-lactamase
MRSA	Methicillin-resistant *Staphylococcus aureus*
MSSA	Methicillin-susceptible *Staphylococcus aureus*

BHI	Brain heart infusion (growth media)
sp.	Species

CHAPTER 1

INTRODUCTION

1.1 Background

Antibiotics simply means "against life," and in this case refers to microorganisms. Antibiotics come in a variety of forms, including antibacterials, antivirals, antifungals, and antiparasitics. Broad-spectrum antibiotics are antibiotics that are selective against a wide range of bacteria. Others, like small range antibiotics, are selective against only a few bacteria. Antibiotics are the most widely used antimicrobials. Antimicrobial medicines (antibiotics) were invented during the twentieth century. The body's own defences acquired a strong ally with the discovery of penicillin and the beginning of the antibiotic age (Felson, 2019). In the 1920s, British scientist Alexander Fleming found a naturally occurring agent that has the potential to destroy some bacteria in his laboratory at St. Mary's Hospital in London. He discovered colonies of Staphylococcus aureus were inhibited or destroyed by a kind of mold that grew on the same agar plate. He discovered that the mould produced a substance capable of destroying bacteria. Penicillin was the name he gave to the drug. Low doses of Penicillin could still treat severe infections and save a lot of people’s lives. However, the uncontrollable use of antibiotic drugs causes antibiotic resistance. It raises public health concern as it gives negative impacts in the medical field. Some severe infections have been more difficult to treat, requiring healthcare personnel to administer a second or even third antibiotic if the first fails (HealthChildren.org, 2019).

Plasmids are small fragments of DNA which provide genetic instructions from one germ to another, containing resistance genes. Then certain bacteria will transmit their DNA to other bacteria, making them resistant as well. Pathogenic bacteria use a variety of techniques to establish inherent tolerance to antibiotics, including changing target sites, active drug efflux, and enzymatic degradation (Centers for Disease Control and Prevention, 2020). Medicinal plant extracts exhibit a diverse range of biological functions which can be effectively used to treat diseases. Combining dietary and medicinal perspectives may result in a potent tool for combating a variety of diseases (Anand et. al, 2019). The antimicrobial function of plant extracts can be exerted not just by destroying the microorganism but also by disrupting key events in the pathogenic phase. Plant products can alter or suppress protein–protein interactions, making them efficient modulators of immune response, mitosis, apoptosis, and signal transduction. Microorganisms might not quickly develop resistance towards the phytochemicals in plant extracts (Gupta and Birdi, 2017).

1.2 Objectives

1.2.1 General Objective

The general objective of this study is to review the antimicrobial activities of *S. torvum* Sw..

1.2.2 Specific Objective

i. To identify the parts of *S. torvum* Sw. which have been reported to have antibacterial and antifungal activities.

ii. To identify the types of extracts of *S. torvum* Sw. which have been reported to have antibacterial and antifungal activities.

iii. To identify the bacteria and fungi species targeted by different types of extracts and parts of *S. torvum* Sw.

iv. To review the zone of inhibition, MIC, MBC, MFC and percentage of inhibitions that have been reported in each study.

1.3 Hypothesis

It is hypothesized that the systematic review may determine the effectiveness of *S. torvum* Sw. towards the bacteria and fungi species via zone of inhibition, MIC, MBC, MFC and percentage of inhibitions.

CHAPTER 2

LITERATURE REVIEW

2.1 *S. torvum* Sw.

S. torvum Sw., also known as Turkey Berry, Devil's Fig, eggplant and sundakkai, is from the Solanaceae family (National Parks, n.d.). It is a slender, evergreen shrub with sparsely armed branches that grows from 1 to 4 metres long. The stems have stout, recurved prickles that are 2.5 - 10 mm long and 2 - 10 mm high, and are reddish or light yellow in color. *S. torvum* Sw. can be found in a variety of ecosystems around the tropics and subtropics. It can be found all around the world such as India, Malaysia, Thailand, China, and South America. This plant consists of roots, stems, leaves, flowers, and fruits (cabi.org, 2019). The plant is harvested in the wild for local usage as a food and medicinal. It becomes more common as a food, and it is planted as a home garden crop (Useful Tropical Plants, 2019). However, make sure the plant is ripe before consuming it, since unripe fruit might induce unpleasant neurological and digestive problems (Hill, 2020).

Figure 2.1.1 The image of the fruits and flowers of *S. torvum* Sw. (Ansley, 2020)

Figure 2.1.2 The image of the leaf of *S. torvum* Sw. (IPlantz, n.d.)

2.2 Usage of *S. torvum* Sw. in Different Countries

The leaves of *S. torvum* Sw. are reported to have tannins, flavonoids, reducing sugars, saponin glycosides, alkaloids, phytosteroids and terpenoids (Brobbey et al., 2016). The fruits of *S. torvum* Sw. contain alkaloids, flavonoids and diterpene which are having antimicrobial properties (Jaabir, 2010). *S. torvum* Sw. is commonly used in traditional medicine. There are different usages of *S. torvum* Sw. in different countries or different tribes. The tribes in Bangladesh and Indonesia serve the fruits as one of their dishes in their diets. The fruits of *S. torvum* Sw. are densely filled with high-quality proteins, dietary fibres, vitamins, minerals, and antioxidants. It also has a low carbohydrate, calories and fat content, making it excellent for weight reduction regimens. The fruits are high in vitamin A and carotenoids, helps to enhance eyesight, skin texture, and prevent chronic diseases. It has a lot of vitamin C, which helps to boost immunity and wash out damaging free radicals from the body. Besides, the fruits are high in iron, which helps to improve red blood cell production, as well as calcium, which helps to build strong bones. They are also high in sodium and potassium, two essential components for maintaining electrolyte balance in the body (Bharat, 2020).

The green fruits will be soaked in buttermilk, sun-dried, and served as dried sundakkai vathal in Tamil Nadu, India. It is commercially packed and marketed in this shrivelled state as a digestive aid or cooked as sundakkai vatha kuzhambu with a strong tamarind base (Bharat, 2020). In Malaysia, the seeds are burned to treat toothaches and the roots are used to treat the cracks in the foot (Bari et. al, 2010). In China, the roots are used to ease the discomfort while in India, the extract can become an antidote after bees sting and the fruits are believed to treat stomach ache (National Parks, n.d). The fruits and leaves can be used to regulate a variety of microbial activity. Solasodine, a glycoalkaloid present in the leaves and fruits, is used to produce steroidal sex hormones for oral contraceptives in India. The leaves can be used as a treatment in the diabetic medicine after the leaves are dried and ground into powder form. Besides, the leaves are used to heal burns, bruises, and skin diseases (Useful Tropical Plants, 2019).

2.3 Mechanism of Antimicrobial Activities

Antimicrobial is an agent against the life of microorganisms. The term antimicrobial is different from antibiotics because it is effective against microorganisms including bacteria, fungi, virus and protozoa (Michigan State University, n.d). The most common antibiotics include Penicillins, Fluoroquinolones, and Tetracycline (Lewis, 2021). The example of antifungal agents are Polyenes, Allylamines, Azoles and Triazole Agents (Seladi-Schulman, 2019). The examples of antiviral agents are Ribavirin, Rimantadine and Simeprevir. The examples of antiprotozoal agents are Chloroquine, Mepacrine and Sulfadiazine (OpenStax, n.d.).

Antibacterial action is mostly linked to two methods: interfering chemically with the function of essential components of bacteria or evading traditional antibacterial resistance mechanisms. The targets of antimicrobial agents could be bacterial protein biosynthesis, cell wall, cell membrane and bacterial DNA. For bacterial protein biosynthesis, inhibiting protein synthesis by targeting ribosomal subunits so that no initiation, elongation, and termination of protein building. Cell wall of the bacteria consists of a network of covalently cross-linked peptide and glycan strands that can offer greater mechanical strength for osmotic lysis. Transglycosylases and transpeptidases are two types of family enzymes that play important roles in the development of this layer. There are some antibiotics such as Penicillins that are able to target these two enzymes in order to prevent a reaction and hence weaken the cell wall. Besides, antimicrobial agents are able to destroy the bacterial cell membrane by causing alteration of the phospholipid bilayer. It leads to an osmotic imbalance and causes bactericidal activity. Another target of antimicrobial agents is DNA synthesis of bacteria. DNA gyrase is an enzyme that is important for replication, repair and transcription of the DNA. However, DNA gyrase is targeted so that all those important processes could be inhibited (Khameneh et al, 2019).

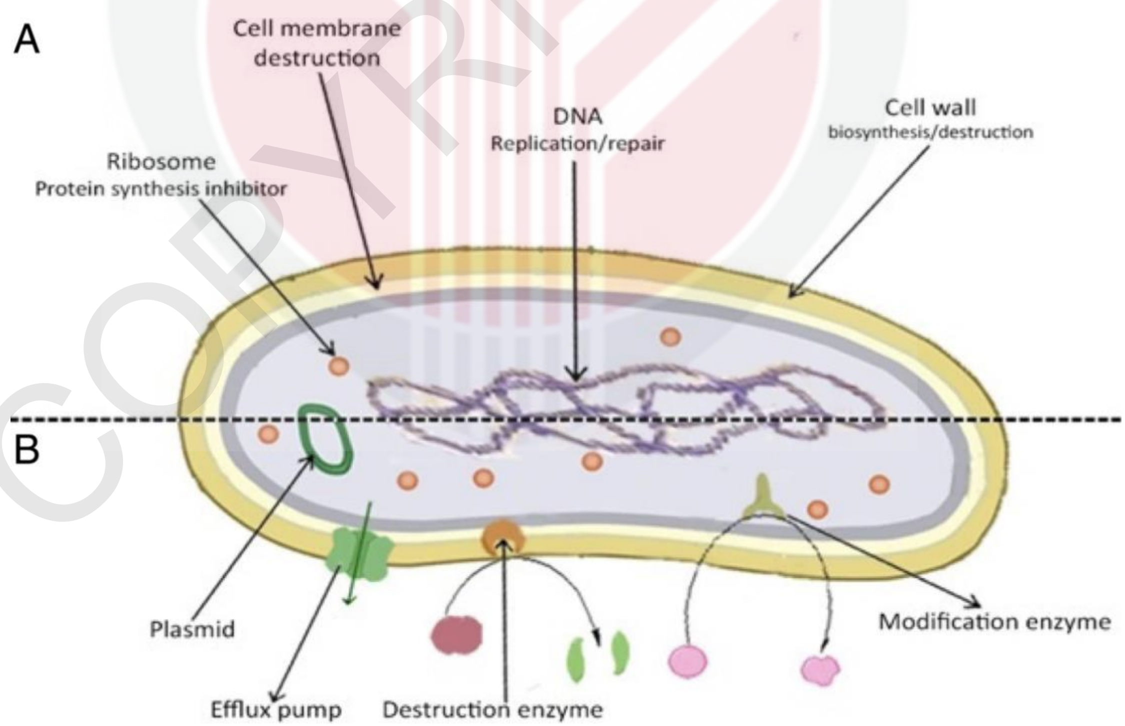


Figure 2.3.1 shows the structure of a bacteria. Part A demonstrates how antibacterial agents could inhibit the growth of a bacteria or cause a bactericidal activity, these include altering the protein synthesis in ribosomes, destruction on cell membrane, inhibit nucleic acid synthesis and destruction on cell wall. Part B demonstrates the mechanisms of antibiotic resistance in bacteria, these include efflux pumps, degradation of antibacterial agents, modification of enzymes to do conformational alteration on antimicrobial agents (Khameneh et al, 2019).

Antifungal agents are prescribed to treat fungal infections. The breakdown of the cell membrane is the most prevalent mechanism of action for antifungal agents. The difference of the metabolic pathways between fungi and humans is that fungi produce sterols. Sterols are necessary for maintaining appropriate membrane fluidity so that the cell membrane of the fungi could function well. Ergosterol is the most common membrane sterol in fungus. Antifungal agents that target ergosterol production are selectively harmful because human cell membranes employ cholesterol rather than ergosterol. They either inhibit the production of ergosterol or bind the ergosterol in the fungal membrane to create pores and hence alter the membrane. Apart from that, there are some antifungal agents such as Echinocandins that block β (1→3) glucan of the cell walls (OpenStax, n.d.).

2.4 Zone of Inhibition

The Kirby-Bauer test, also known as the disc diffusion antibiotic sensitivity test, is used to determine if an antimicrobial agent is effective against specific bacteria or fungi. The sample collected is cultured on the agar plate. The dish is then covered with a piece of filter paper impregnated with a variety of antibiotics applied in various locations. The antimicrobial agent diffuses into the agar, and its concentration diminishes radially from the point where the antimicrobial agent was administered outwards. The bacteria or fungi is not able to grow around the antimicrobial agent if the agent is effective to inhibit microorganisms. The region that does not have bacteria growth is known as the zone of inhibition. The effectiveness of the antimicrobial agent can be evaluated through the diameter of the zone of inhibition and the unit is mm or cm (Bhargav et al., 2016). This method is quick and cheap. It can be used to screen a large number of samples for antimicrobial properties. This approach is used to evaluate a wide range of antimicrobial agents such as liquids, coated antimicrobial surfaces, and antimicrobial-impregnated solid products (Microchem Laboratory, n.d.).

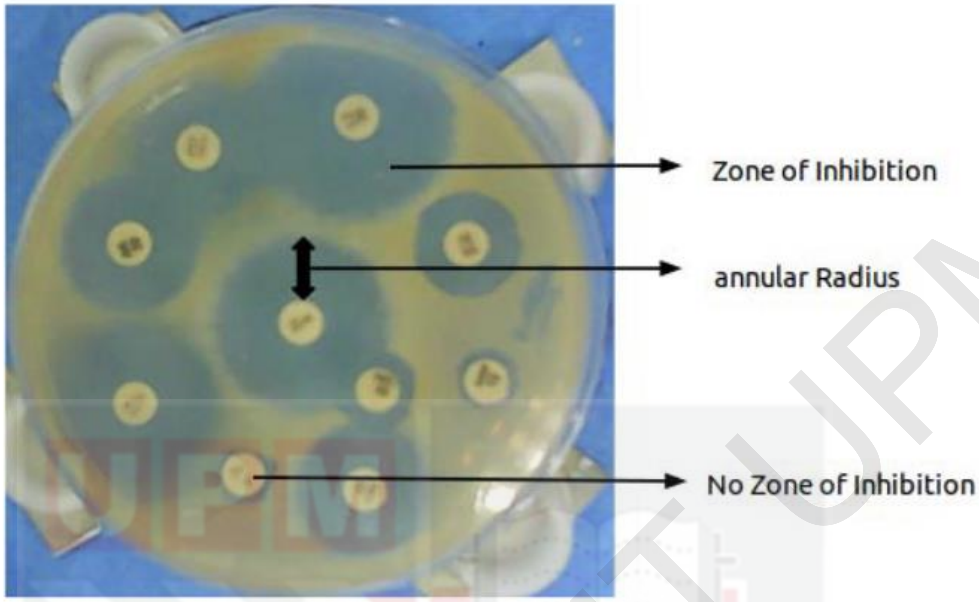


Figure 2.4.1 shows the antimicrobial activity of an antimicrobial agent. The zone of inhibition can be examined by measuring the diameter of circular region that does not have growth. The greater the diameter of the zone of inhibition, the antimicrobial agent is more effective. No inhibition towards microorganisms if the microorganisms are resistant to the antimicrobial agents (Bhargav et al., 2016).

2.5 Minimum Inhibitory Concentration, Minimum Bactericidal Concentration, Minimum Fungicidal Concentration

Minimum Inhibitory Concentration (MIC) is used to determine the lowest concentration of an antimicrobial agent to inhibit the growth of the microorganisms. The serial dilutions of the tested antimicrobial agents are prepared in a microdilution plate. A few colonies are taken to do an inoculum. Then dispense the inoculum into each well of the microdilution plate and then incubate the plate. Then the MIC value can be evaluated by reading the microdilution plate (Emery Pharma, n.d.). The turbidity of each well is observed. If it is cloudy, it indicates that there is a growth of microorganisms where that particular concentration cannot inhibit the growth. The MIC test is straightforward and can be done with only a small volume of antimicrobial agents (Microchem Laboratory, n.d).

Minimum Bactericidal Concentration (MBC) is used to determine the lowest concentration of an antibacterial agent to kill bacteria under a precise set of settings for a defined, relatively lengthy period, such as 18 hours or 24 hours. Minimum Fungicidal Concentration (MFC) is also the same as MBC to determine the minimum concentration of an antifungal agent to reduce the viability of fungi by more than 99%. MBC and MFC are tested after the MIC test has been taken. Antimicrobial agents are considered bactericidal and/or fungicidal if their MBC and/or MFC value is less than four times the MIC. An antimicrobial agent's MBC or MFC may be near to the MIC. If the tested agent's MBC or MFC against the tested microbe is greater than 32 times the MIC, the microorganism has acquired resistance to the tested antimicrobial agent (Pacific BioLabs, n.d.).

S. torvum Sw. has antimicrobial properties. Hence, *S. torvum* Sw. is reviewed with its antimicrobial activity and the performance of the antimicrobial activity.

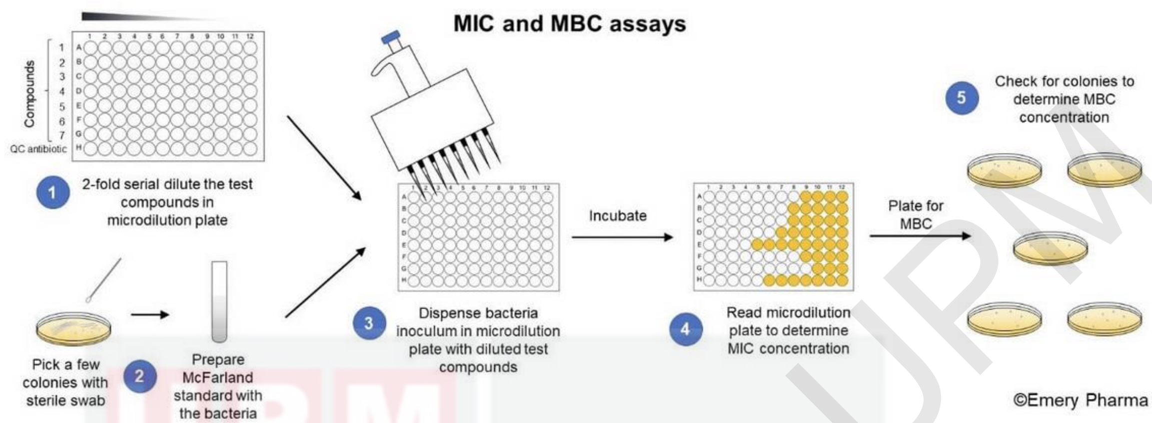


Figure 2.5.1 shows how the MIC and MBC assays are performed. The serial dilutions of the tested antimicrobial agents are prepared in a microdilution plate. A few colonies are taken to do an inoculum. Then dispense the inoculum into each well of the microdilution plate and then incubate the plate. Then the MIC value can be evaluated by reading the microdilution plate. MBC assay can be performed by plating on the agar plates. Incubate the agar plates. Lastly check the colonies on the agar plates to determine the MBC values (Emery Pharma, n.d.).

CHAPTER 3

METHODOLOGY

3.1 Protocol

This review was based on the Preferred Reporting Items for Systematic Reviews and Meta-analyse, (PRISMA) report guidelines.

3.2 Eligibility Criteria

3.2.1 Type of Study

In vitro study were agar disc diffusion method and broth microdilution with different concentration of extractions.

3.2.2 Type of Population

The type of population consists of bacteria and fungi. There is no restriction of species, strains and isolates of bacteria and fungi.

3.2.3 Type of Intervention

Different parts of *S. torvum* Sw., i.e., leaves, stems, fruits, roots, flowers, pericarps, and whole plants were included in systematic review. Besides, different types of extractions of *S. torvum* Sw. were also included.

3.2.4 Type of Outcome Measures

The outcome measures were the zone of inhibitions, minimum inhibitory concentration (MIC), minimum bactericidal concentration (MBC), minimum fungicidal concentration (MFC) and percentage of inhibition of *S. torvum* Sw.. The parameters must be in measurable diameter (mm) and concentration (µg/mL).

3.3 Search Strategy and Data Source

We conducted a search from several databases such as Google Scholar, Pubmed, SpringerLink, ScienceDirect and Scopus. The publication dates are restricted between 2010 to 2021. The last search on the databases was performed on 31st March 2021. The following search term were used: ("*Solanum torvum*" OR "turkey berry" OR "eggplant" OR "sundakkai") and ("antimicrobial" OR "antibacterial" OR "antimycobacterial" OR "antifungal"). The inclusion criteria are: (1) all types of antimicrobial activities (antibacterial, antifungal) involved in *Solanum torvum* Sw.; (2) everything that involves *Solanum torvum* Sw. (i.e formulations); (3) in vitro, in vivo, clinical and in silico; (4) only English articles. The exclusion criteria are: (1) data and results that are unclear; (2) articles that are about the microorganisms that cause harm to *Solanum torvum*; (3) posters, abstracts, proceedings and thesis. The articles were screened according to the criteria stated above by the first reviewer, Ling Liong Fang. The articles were confirmed by the second reviewers, Associate Prof Dr Yong Yoke Keong and Associate Prof Dr Lim Vuanghao.

3.4 Study Selection

Results from five databases were sorted out in the excel. Duplicates were removed if the articles contain the same authors and titles. The articles were screened according to eligibility criteria. The reviewers screened the articles according to the eligibility assessment. The titles and abstracts were screened first followed by the full-text screening. Articles that do not meet the criteria were removed. The flow of study selection was done by referring to the PRISMA flow diagram. The reasons for excluded articles were also recorded.

3.5 Data Extraction

The following data was extracted for each article: parts of plants, extracts of plants, bacteria species, fungi species, concentration of extract, zone of inhibition, minimum inhibition concentration, minimum bactericidal concentration, minimum fungicidal concentration and percentage of inhibition.

CHAPTER 4

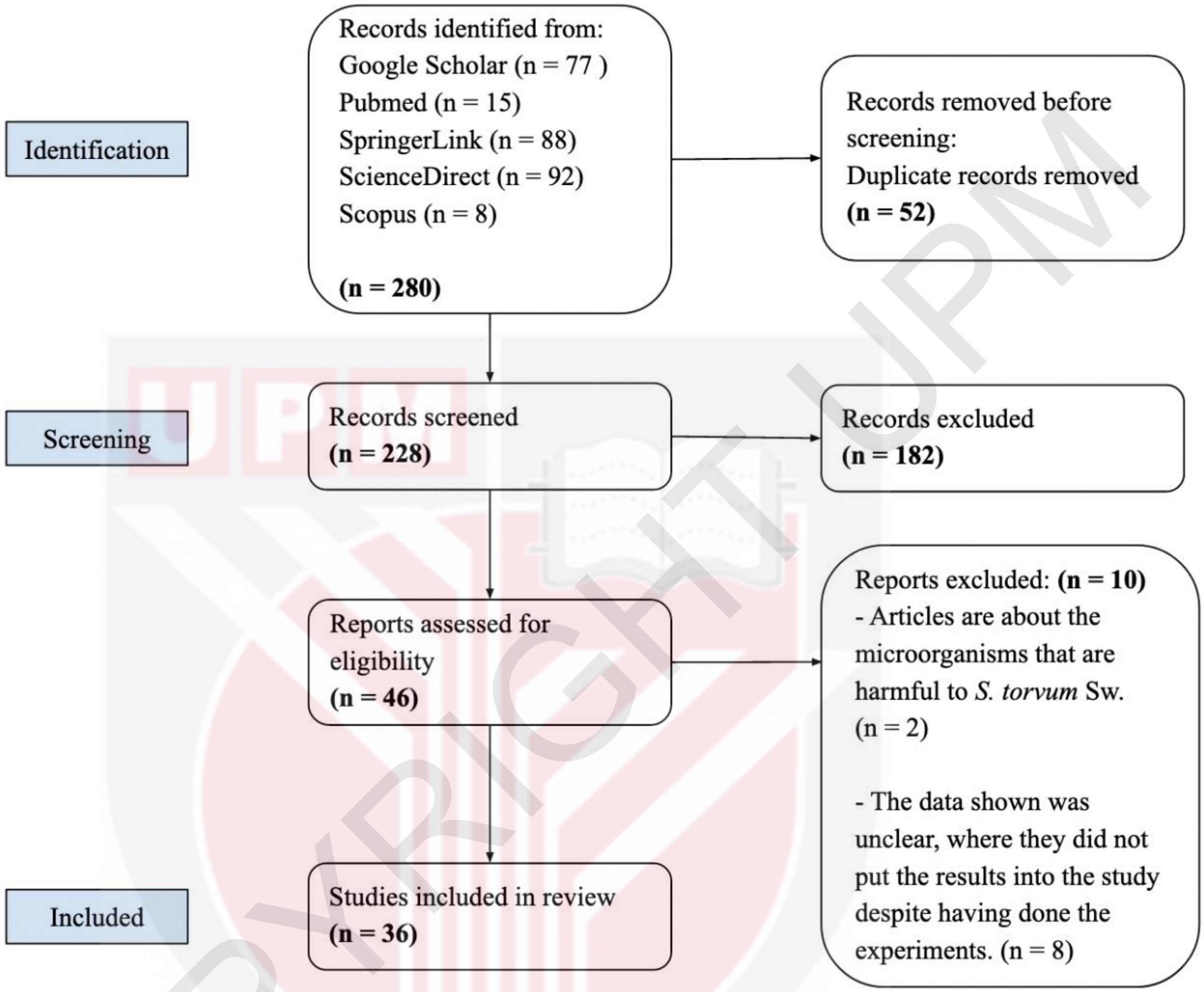
RESULT

Systematic Review

4.1 Literature Search

The following search term were used: ("*Solanum torvum*" OR "turkey berry" OR "eggplant" OR "sundakkai") and ("antimicrobial" OR "antibacterial" OR "antimycobacterial" OR "antifungal"). A total of 280 articles were identified through a combination of search terms. Figure 1 shows the flowchart of the study selection strategy. After removing 52 duplicates, 182 studies were excluded in the screening process based on titles and abstracts. Lastly, only 36 articles were eligible after assessing them.

Figure 4.1 Flow of literature search according to the PRISMA guidelines



4.2 Data Extraction and Organization

The zone of inhibition, MIC, MBC, MFC and percentage of inhibition of different parts and different extracts of *S. torvum* Sw. on bacterial and fungal species were included. Note that "-" in the tables means that there were no observable changes, while leaving blank means that the experiment was not performed.

Table 4.1 Summary of antibacterial properties on different bacterial species.

References	Parts	Extracts	Bacterial Species	Concentration of extract (µg/mL)	Zone of Inhibitions (mm)	MIC (µg/mL)	MBC (µg/mL)
Ahmed et al., 2019	Leaf	Methanol	*Escherichia coli*		15.25 ± 0.5		
			Pseudomonas aeruginosa		13.5 ± 0.58		
			Klebsiella pneumoniae		15 ± 0.82		
			Salmonella sp.		13 ± 0.82		
			Staphylococcus aureus		15.5 ± 0.58		
Anatole et al., 2019	Leaf	Aqueous	*Shigella. sp 076 CO/17*	2.5 x 10^4	6	-	
				5 x 10^4	6		

				10×10^4	6		
			Salmonella para typhi B 150 PI/17	2.5×10^4	6		
				5×10^4	6		
				10×10^4	6		
			Salmonella flexneri 214 CA/17	2.5×10^4	6		
				5×10^4	6		
				10×10^4	6		
			Escherichia coli 118 UB/17	2.5×10^4	6		
				5×10^4	6		
				10×10^4	6		
			Escherichia coli 135 UB/17	2.5×10^4	6		
				5×10^4	14		
				10×10^4	18		
			Escherichia coli 146 PI/17	2.5×10^4	6	1.25×10^4	5×10^4

				5 x 10^4	6		
				10 x 10^4	6		
			Escherichia coli 238 UB/17	2.5 x 10^4	6		
				5 x 10^4	6	-	
				10 x 10^4	6		
			Staphylococcus aureus 129 UB/17	2.5 x 10^4	6		
				5 x 10^4	6		
				10 x 10^4	6		
			Staphylococcus aureus 234 UB/17	2.5 x 10^4	6	6.25 x 10^3	2.5 x 10^4
				5 x 10^4	6		
				10 x 10^4	13.33		
			Staphylococcus aureus 241 UB/17	2.5 x 10^4	6	-	
				5 x 10^4	6		
				10 x 10^4	6		
Balachandran et al., 2012	Fruit		*Staphylococcus aureus MTCC 96*	2000	20 ± 0.71	250	

		Methanol (Methyl Caffeate)	*Micrococcus luteus*		9 ± 0.45	100	
			Proteus vulgaris MTCC 1771		22 ± 0.71	50	
			Klebsiella pneumoniae MTCC 109		9 ± 0.45	100	
			Salmonella typhimurium MTCC 1251		12 ± 0.71	500	
			Salmonella paratyphi-B		16 ± 0.45	100	
			Pseudomonas aeruginosa MTCC 741		20 ± 0.71	100	
			Bacillus subtilis MTCC 441		19 ± 0.71	250	
			Escherichia coli (ESBL-3984)			250	
			Escherichia coli (ESBL-3904)			500	
			Klebsiella pneumoniae (ESBL-3971)			25	
			Klebsiella pneumoniae (ESBL-75799)			100	
			Klebsiella pneumoniae (ESBL-3894)			500	

			Klebsiella pneumoniae (ESBL-3967)			250	
			Staphylococcus aureus (MRSA-methicillin resistant, clinical pathogen)			500	
			Mycobacterium tuberculosis H37Rv (HR-Sen) (ATCC 27294)			8	
			Mycobacterium tuberculosis Rif R			8	
Bari et al., 2010	Leaf	Chloroform	*Salmonella typhi*	5 x 10^3	-		
				20 x 10^3	11		
	Stem	Chloroform	*Staphylococcus aureus*	5 x 10^3	7		
				20 x 10^3	9		
			Bacillus cereus	5 x 10^3	-		
				20 x 10^3	9		
			Salmonella typhi	5 x 10^3	7		
				20 x 10^3	14		
	Root	Chloroform	*Staphylococcus aureus*	5 x 10^3	7		

				20×10^3	13		
			Bacillus cereus	5×10^3	6		
				20×10^3	14		
			Bacillus megaterium	5×10^3	7		
				20×10^3	12		
			Bacillus subtilis	5×10^3	7		
				20×10^3	18		
			Streptococcus-β-haemolyticus	5×10^3	9		
				20×10^3	21		
			Salmonella typhi	5×10^3	7		
				20×10^3	19		
			Shigella dysenteriae	5×10^3	7		
				20×10^3	18		
	Inflorescence	Chloroform	*Staphylococcus aureus*	5×10^3	7		
				20×10^3	12		
			Bacillus cereus	5×10^3	7		

				20×10^3	13		
			Salmonella typhi	5×10^3	7		
				20×10^3	13		
			Shigella dysenteriae	5×10^3	-		
				20×10^3	17		
	Leaf	Methanol	*Salmonella typhi*	5×10^3	-		
				20×10^3	16		
	Stem	Methanol	*Staphylococcus aureus*	5×10^3	7		
				20×10^3	19		
			Bacillus cereus	5×10^3	-		
				20×10^3	19		
			Salmonella typhi	5×10^3	7		
				20×10^3	20		
	Root	Methanol	*Staphylococcus aureus*	5×10^3	7		
				20×10^3	22		
			Bacillus cereus	5×10^3	8	128	

				20 x 10^3	22		
			Bacillus megaterium	5 x 10^3	8		
				20 x 10^3	19		
			Bacillus subtilis	5 x 10^3	8	64	
				20 x 10^3	21		
			Streptococcus-β-haemolyticus	5 x 10^3	9	64	
				20 x 10^3	24		
			Salmonella typhi	5 x 10^3	7	64	
				20 x 10^3	21		
			Shigella dysenteriae	5 x 10^3	7	128	
				20 x 10^3	20		
	Inflorescence	Methanol	*Staphylococcus aureus*	5 x 10^3	7		
				20 x 10^3	21		
			Bacillus cereus	5 x 10^3	-		
				20 x 10^3	21		
			Salmonella typhi	5 x 10^3	7		

				20×10^3	21		
			Shigella dysenteriae	5×10^3	-		
				20×10^3	18		
De Britto et al., 2011	Leaf	Aqueous	*Xanthomonas campestris*	100	10.33 ± 0.57	-	
			Aeromonas hydrophila		11.33 ± 1.15		
		Methanol	*Xanthomonas campestris*	100	12.66 ± 1.52	128.00 ± 0.00	
			Aeromonas hydrophila		14.66 ± 0.57	128.00 ± 0.00	
Djoueudam et al., 2019	Leaf	95% Ethanol	*Salmonella Typhimurium*	1×10^5		32	256
			Salmonella Paratyphi A			64	512
			Salmonella Paratyphi B			64	512
			Salmonella Typhi			32	512
			Salmonella Typhi (ATCC 6539)			32	256
		70% Ethanol	*Salmonella Typhimurium*			128	1024
			Salmonella Paratyphi A			64	1024
			Salmonella Paratyphi B			64	1024
			Salmonella Typhi			32	512

			Salmonella Typhi (ATCC 6539)			64	512
		50% Ethanol	*Salmonella Typhimurium*			512	1024
			Salmonella Paratyphi A			256	1024
			Salmonella Paratyphi B			512	1024
			Salmonella Typhi			512	-
			Salmonella Typhi (ATCC 6539)			1024	-
		30% Ethanol	*Salmonella Typhimurium*			64	256
			Salmonella Paratyphi A			64	-
			Salmonella Paratyphi B			128	512
			Salmonella Typhi			32	512
			Salmonella Typhi (ATCC 6539)			64	256
		Infused extract	*Salmonella Typhimurium*			256	1024
			Salmonella Paratyphi A			256	-
			Salmonella Paratyphi B			256	1024

			Salmonella Typhi			512	-
			Salmonella Typhi (ATCC 6539)			256	1024
		Decocted extract	*Salmonella Typhimurium*			64	256
			Salmonella Paratyphi A			128	512
			Salmonella Paratyphi B			64	256
			Salmonella Typhi			128	512
			Salmonella Typhi (ATCC 6539)			128	512
		Macerated extract	*Salmonella Typhimurium*			256	-
			Salmonella Paratyphi A			256	1024
			Salmonella Paratyphi B			256	1024
			Salmonella Typhi			512	1024
			Salmonella Typhi (ATCC 6539)			512	-
Fosso et al., 2017	Leaf	Methanol	*Bacillus subtilis*			256	-
			Escherichia coli			2048	-
			Pseudomonas aeruginosa			2048	-

			Shigella flexneri			2048	-
			Staphylococcus aureus MSSA 01			2048	-
	Fruit	Methanol	*Shigella flexneri*			2048	-
Govindaraju et al., 2010	Leaf	Silver nanoparticles (Aqueous)	*Pseudomonas aeruginosa*	10 µL (3400 µg/mL)	4.7		
				50 µL	12.5		
				100 µL	16.9		
			Staphylococcus aureus	10 µL (3400 µg/mL)	5.2		
				50 µL	11.9		
				100 µL	17.6		
GuPta & Tripathi, 2011	Leaf	Aqueous	*Escherichia coli*		10.4 ± 47		
			Bacillus subtilis		12.7 ± 32		
Hsu et al., 2010	Whole plant	Aqueous	*Helicobacter pylori*	5 x 10^4	13		
			Helicobacter pylori 26695	5 x 10^4	13		
			Helicobacter pylori V633		12		
			Helicobacter pylori V1254		13.75		

			Helicobacter pylori V1354		16.75		
			Helicobacter pylori V2356		20.5		
		Methanol	*Helicobacter pylori*	5×10^4	10		
				2.5×10^4	9.5		
			Helicobacter pylori 26695	5×10^4	10		
			Helicobacter pylori V633		10.5		
			Helicobacter pylori V1254		11		
			Helicobacter pylori V1354		9.5		
			Helicobacter pylori V2356		10		
		Acetone	*Helicobacter pylori*	5×10^4	9		
				2.5×10^4	9		
			Helicobacter pylori 26695	5×10^4	9		
			Helicobacter pylori V633		9.5		
			Helicobacter pylori V1254		11		
			Helicobacter pylori V1354		10		
			Helicobacter pylori V2356		11		

		Chloroform	*Helicobacter pylori*	5×10^4	17		
				2.5×10^4	16.5		
				1×10^4	12.5		
				5×10^3	9		
			Helicobacter pylori 26695	5×10^4	17		
			Helicobacter pylori V633		12		
			Helicobacter pylori V1254		14		
			Helicobacter pylori V1354		13		
			Helicobacter pylori V2356		12.5		
Jaabir et al., 2010	Fruit	Absolute Ethanol	*Klebsiella pneumoniae*	2.5×10^4	8		
				5×10^4	9		
				10×10^4	11		
			Bacillus subtilis	2.5×10^4	8		
				5×10^4	10		
				10×10^4	12		
			Escherichia coli	2.5×10^4	10		

				5 x 10^4	12		
				10 x 10^4	13		
			Staphylococcus aureus	2.5 x 10^4	12		
				5 x 10^4	13		
				10 x 10^4	15		
Kannan et al., 2012	Leaf	Methanol	*Staphylococcus aureus (MTCCAcc.No.7443)*	100%	25		
				80%	17.6		
				60%	15.2		
				40%	9.6		
				20%	3.6		
			Bacillus subtilis (MTCC Acc.No.441)	100%	18.3		
				80%	16		
				60%	14.7		
				40%	10.5		
				20%	4.2		
				100%	28.2		

			Escherichia coli (MTCC Acc.No.476)	80%	23.1		
				60%	18.5		
				40%	8		
				20%	5.7		
			Salmonella species (MTCC Acc.No.53)	100%	15.8		
				80%	13		
				60%	10.3		
				40%	4.1		
				20%	2.6		
			Pseudomonas aeruginosa (MTCC Acc.No.424)	100%	30		
				80%	18.4		
				60%	15		
				40%	10.7		
				20%	4.8		
Lalitha et al., 2010	Leaf	Methanol	*Xanthomonas oryzae*	10 µL (1 x 10^6 µg/mL)	10		
				20 µL	12		

				30 µL	12		
				40 µL	15		
				50 µL	15		
				60 µL	15		
				70 µL	18		
				80 µL	18		
				90 µL	18		
				100 µL	18		
		Absolute Ethanol	*Xanthomonas oryzae*	10 µL (1 x 10^6 µg/mL)	12		
				20 µL	19		
				30 µL	19		
				40 µL	20		
				50 µL	20		
				60 µL	22		
				70 µL	26		
				80 µL	26		

				90 µL	28		
				100 µL	30		
Maser et al., 2015.	Fruit	80% Methanol	*Staphylococcus aureus*	60 µL	4.50 ± 0.50		
					4.00 ± 0.00		
					4.33 ± 0.57		
					4.33 ± 0.57		
					4.50 ± 0.50		
		Chloroform	*Staphylococcus aureus*		6.67 ± 0.57		
					6.67 ± 0.57		
					6.50 ± 0.50		
					6.67 ± 0.28		
					6.83 ± 0.28		
Mohamad et al., 2011	Fruit	80% Methanol	*Mycobacterium tuberculosis*	3200		1600	
Naimon et al., 2015	Leaf	95% Ethanol	*Bacillus cereus*			1.95×10^3	1.95×10^3
			Staphylococcus epidermidis			1.563×10^4	1.563×10^4
			Staphylococcus aureus			1.563×10^4	1.563×10^4

			Staphylococcus intermedius			1.563×10^4	1.563×10^4
			Pseudomonas aeruginosa			3.125×10^4	3.125×10^4
Nguta et al.,2016	Leaf	80% Ethanol	*Mycobacterium tuberculosis subsp.tuberculosis (ATCC® 27294™)*			1.25×10^3	
			Mycobacterium smegmatis (ATCC®19420™)			2.5×10^3	
			Mycobacterium tuberculosis Strain H37Ra (ATCC® 25177™)			156.3	
Nithiyanantham et al., 2012	Fruit	Raw	*Staphylococcus aureus (MTCC 3160)*	2000	8		
			Klebsiella pneumoniae (MTCC 3384)		6		
			Pseudomonas aeruginosa (MTCC 424)		13		
		80% Methanol	*Staphylococcus aureus (MTCC 3160)*		7		
			Klebsiella pneumoniae (MTCC 3384)		6		
			Pseudomonas aeruginosa (MTCC 424)		11		

Obiang et al., 2019	Fruit	Aqueous	*Escherichia coli 0157 ATCC*	1×10^5 (10 µL)	11 ± 2.0	1.25×10^3	2.50×10^3
			Escherichia coli 105182 CIP		10 ± 0.0	2.5×10^3	5×10^3
			Listeria innocua LMG 135668 BHI		8 ± 1.5	-	-
			Staphylococcus aureus ATCC 25293 BHI		9 ± 0.0	5×10^3	-
			Enterococcus faecalis 103907 CIP		10 ± 0.0	2.5×10^3	5×10^3
			Bacillus cereus LMG 13569 BHI		19 ± 1.0	1.25×10^3	2.5×10^3
			Shigella dysenteriae 5451 CIP		14 ± 2.0	2.5×10^3	5×10^3
			Pseudomonas aeruginosa		7 ± 1.0	2.5×10^3	-
			Salmonella enterica		10 ± 1.0	5×10^3	5×10^3
			Salmonella typhimurium		11 ± 2.0	5×10^3	5×10^3
			Shigella flexneri		12 ± 1.0	620	2.5×10^3
			Shigella dysenteriae		20 ± 2.0	1.25 x 10^3	2.5×10^3
			Neisseria gonorrhoeae		14 ± 1.0	2.5 x 10^3	5×10^3

			Escherichia coli		9 ± 1.0	-	-
			Enterococcus faecalis		16 ± 2.0	620	2.5 x 10^3
			Staphylococcus aureus		11 ± 0.0	2.5 x 10^3	-
			Acinetobacter baumannii		10 ± 1.0	5 x 10^3	5 x 10^3
			Enterobacter aerogenes		9 ± 0.0	-	-
			Salmonella sp.		10 ± 1.0	5 x 10^3	5 x 10^3
			Neisseria meningitidis		10 ± 0.0	-	-
		Water ethanol	*Escherichia coli 0157 ATCC*	1 x 10^5 (10 µL)	12 ± 2.0	1.25 x 10^3	1.25 x 10^3
			Escherichia coli 105182 CIP		12 ± 0.0	2.5 x 10^3	2.5 x 10^3
			Listeria innocua LMG 135668 BHI		11 ± 0.0	2.5 x 10^3	5 x 10^3
			Staphylococcus aureus ATCC 25293 BHI		15 ± 1.0	2.5 x 10^3	5 x 10^3
			Enterococcus faecalis 103907 CIP		13 ± 0.5	1.25 x 10^3	2.5 x 10^3
			Bacillus cereus LMG 13569 BHI		24 ± 1.0	620	1.25 x10^3

			Shigella dysenteriae 5451 CIP		18 ± 1.0	1.25 x 10^3	1.25 x 10^3
			Pseudomonas aeruginosa		10 ± 0.0	1.25 x 10^3	-
			Salmonella enterica		13 ± 0.0	1.25 x 10^3	2.5 x 10^3
			Salmonella typhimurium		15 ± 0.0	2.5 x 10^3	5 x 10^3
			Shigella flexneri		11 ± 2.0	1.25 x 10^3	2.5 x 10^3
			Shigella dysenteriae		23 ± 1.0	1.25 x 10^3	2.5 x 10^3
			Neisseria gonorrhoeae		17 ± 1.0	1.25 x 10^3	2.5 x 10^3
			Escherichia coli		10 ± 2.0	2.5 x 10^3	-
			Enterococcus faecalis		16 ± 1.0	620	2.5 x 10^3
			Staphylococcus aureus		11 ± 1.0	1.25 x 10^3	2.5 x 10^3
			Klebsiella pneumoniae		10 ± 0.0	5 x 10^3	-
			Acinetobacter baumannii		13 ± 2.0	1.25 x 10^3	2.5 x 10^3
			Enterobacter aerogenes		10 ± 2.0	5 x 10^3	5 x 10^3
			Salmonella sp.		14 ± 2.0	2.5 x 10^3	5 x 10^3
			Neisseria meningitidis		12 ± 1.0	2.5 x 10^3	5 x 10^3

		Water acetone	*Escherichia coli 0157 ATCC*	1×10^5 (10 µL)	13 ± 0.0	1.25×10^3	2.5×10^3
			Escherichia coli 105182 CIP		11 ± 1.0	2.5×10^3	2.5×10^3
			Listeria innocua LMG 135668 BHI		11 ± 2.0	5×10^3	5×10^3
			Staphylococcus aureus ATCC 25293 BHI		13 ± 0.0	2.5×10^3	2.5×10^3
			Enterococcus faecalis 103907 CIP		13 ± 2.0	1.25×10^3	2.5×10^3
			Bacillus cereus LMG 13569 BHI		24 ± 0.0	1.25×10^3	1.25×10^3
			Shigella dysenteriae 5451 CIP		17 ± 0.0	1.25×10^3	2.5×10^3
			Pseudomonas aeruginosa		9 ± 1.0	1.25×10^3	2.5×10^3
			Salmonella enterica		12 ± 2.0	1.25×10^3	2.5×10^3
			Salmonella typhimurium		13 ± 0.0	2.5×10^3	2.5×10^3
			Shigella flexneri		11 ± 2.0	2.5×10^3	-
			Shigella dysenteriae		24 ± 0.0	1.25×10^3	2.5×10^3
			Neisseria gonorrhoeae		18 ± 0.0	1.25×10^3	2.5×10^3

			Escherichia coli		13 ± 1.0	2.5 x 10^3	5 x 10^3
			Enterococcus faecalis		15 ± 1.0	620	2.5 x 10^3
			Staphylococcus aureus		12 ± 1.0	2.5 x 10^3	-
			Klebsiella pneumoniae		9 ± 0.0	-	-
			Acinetobacter baumannii		13 ± 1.0	2.5 x 10^3	5 x 10^3
			Enterobacter aerogenes		12 ± 2.0	2.5 x 10^3	2.5 x 10^3
			Salmonella sp.		13 ± 0.0	2.5 x 10^3	2.5 x 10^3
			Neisseria meningitidis		12 ± 2.0	1.25 x 10^3	2.5 x 10^3
Porchelvi & Ramakrishnan, 2016	Flower	Aqueous (Iron nanoparticle)	*Pseudomonas sp.*	5 x 10^4	22-24		
			Proteus sp.		22-24		
Ramadas & Deivendran, 2015	Leaf	Acetone	*Escherichia coli*	15 µL	5		
			Klebsiella pneumoniae		6		
			Pseudomonas aeruginosa		4		
			Staphylococcus aureus		5		
			Escherichia coli	30 µL	7		
			Klebsiella pneumoniae		5		

			Pseudomonas aeruginosa		12		
			Staphylococcus aureus		9		
			Escherichia coli	45 µL	13		
			Klebsiella pneumoniae		9		
			Pseudomonas aeruginosa		7		
			Staphylococcus aureus		10		
			Escherichia coli	60 µL	10		
			Klebsiella pneumoniae		11		
			Pseudomonas aeruginosa		15		
			Staphylococcus aureus		14		
Ramamurthy et al., 2013	Fruit	Aqueous (Silver nanoparticles)	*Bacillus subtilis*	1	5		
				10	8		
				100	9		
				1000	10		
			Pseudomonas aeruginosa	1	3		

				10	9		
				100	10		
				1000	11		
			Escherichia coli	1	4		
				10	9		
				100	10		
				1000	12		
		Silver nitrate	*Bacillus subtilis*	1	4		
				10	5		
				100	8		
				1000	9		
			Pseudomonas aeruginosa	1	2		
				10	6		

				100	8		
				1000	10		
			Escherichia coli	1	3		
				10	5		
				100	9		
				1000	10		
Sabarinath et al., 2018	Leaf	Petroleum ether	*Staphylococcus aureus*	1000	10		
				2000	11		
				3000	12		
				4000	14		
				5000	16		
Santhi et al., n.d	Whole plant	Aqueous and methanol	*Escherichia coli (MTCC 585)*		7		
			Xanthomonas campestris (MTCC 2286)		14		
			Bacillus subtilis		10		

			Mycobacterium (MTCC 994)		8		
			Klebsiella aerogenes		13		
		Dry	*Escherichia coli (MTCC 585)*		8		
			Xanthomonas campestris (MTCC 2286)		11		
			Bacillus subtilis		9		
			Mycobacterium (MTCC 994)		7		
			Klebsiella aerogenes		11		
Senizza et al., 2021	Fruit	Methanol, Aqueous, Acetone	*Staphylococcus aureus (ATCC 6538)*			900 ± 0.00	1200 ± 0.00
			Bacillus cereus (clinical isolate)			200 ± 0.00	300 ± 0.00
			Proteus mirabilis			500 ± 0.00	600 ± 0.00
			Mariniluteicoccus flavus			300 ± 0.00	600 ± 0.00
			Pseudomonas aeruginosa (ATCC 27853)			100 ± 0.00	200 ± 0.00

			Escherichia coli (ATCC 35210)			500 ± 0.00	600 ± 0.00
			Salmonella typhimurium (ATCC 13311)			600 ± 0.00	200 ± 0.00
			Enterobacter cloacae (human isolate)			300 ± 0.00	200 ± 0.00
	Leaf		*Staphylococcus aureus (ATCC 6538)*			500 ± 0.00	600 ± 0.00
			Bacillus cereus (clinical isolate)			500 ± 0.00	600 ± 0.00
			Proteus mirabilis			200 ± 0.00	300 ± 0.00
			Mariniluteicoccus flavus			500 ± 0.00	600 ± 0.00
			Pseudomonas aeruginosa (ATCC 27853)			100 ± 0.00	200 ± 0.00
			Escherichia coli (ATCC 35210)			500 ± 0.00	600 ± 0.00
			Salmonella typhimurium (ATCC 13311)			200 ± 0.00	600 ± 0.00
			Enterobacter cloacae (human isolate)			200 ± 0.00	300 ± 0.00

	Stem bark		*Staphylococcus aureus (ATCC 6538)*			500 ± 0.00	600 ± 0.00
			Bacillus cereus (clinical isolate)			300 ± 0.00	600 ± 0.00
			Proteus mirabilis			100 ± 0.00	200 ± 0.00
			Mariniluteicoccus flavus			300 ± 0.00	600 ± 0.00
			Pseudomonas aeruginosa (ATCC 27853)			100 ± 0.00	200 ± 0.00
			Escherichia coli (ATCC 35210)			300 ± 0.00	600 ± 0.00
			Salmonella typhimurium (ATCC 13311)			200 ± 0.00	600 ± 0.00
			Enterobacter cloacae (human isolate)			200 ± 0.00	300 ± 0.00
Singh et al., 2019	Leaf	Aqueous	*Staphylococcus aureus*	100	7.66 ± 0.98		
			Bacillus subtilis		9.33 ± 0.54		
			Escherichia coli		4.33 ± 0.98		
			Salmonella typhi		3.66 ± 0.27		
			Proteus vulgaris		3.0 ± 0.47		

		Methanol	*Staphylococcus aureus*		16.66 ± 0.72		
			Bacillus subtilis		13.0 ± 1.24		
			Escherichia coli		6.66 ± 0.72		
			Salmonella typhi		7.66 ± 0.27		
			Proteus vulgaris		7.66 ± 0.98		
		Acetone	*Staphylococcus aureus*		13.0 ± 0.47		
			Bacillus subtilis		10.66 ± 0.72		
			Escherichia coli		5.33 ± 0.98		
			Salmonella typhi		5.0 ± 0.47		
			Proteus vulgaris		6.0 ± 0.47		
		n-Hexane	*Staphylococcus aureus*		8.66 ± 0.98		
			Bacillus subtilis		6.33 ± 0.72		
			Escherichia coli		3.33 ± 0.72		

			Salmonella typhi		3.0 ± 0.47		
			Proteus vulgaris		5.0 ± 0.00		
Sivapriya et al., 2011	Fruit coat	Aqueous	*Escherichia coli*	1 x 10^4	21 ± 1	16.8 ± 0.1	
			Vibrio cholerae		21 ± 2	16.8 ± 0.2	
			Staphylococcus aureus		21 ± 1	16.8 ± 0.7	
			Streptococcus		19 ± 2	-	
			Bacillus subtilis		24 ± 2	19.2 ± 0.5	
			Klebsiella pneumoniae		16 ± 1	12.8 ± 0.7	
			Salmonella cibrum		21 ± 2	16.8 ± 0.3	
			Salmonella typhimurium		20 ± 1	15.6 ± 0.2	
			Pseudomonas		19 ± 2	15.2 ± 0.6	
			Proteus vulgaris		15 ± 1	15.0 ± 0.2	
		Ethanol Water	*Escherichia coli*	1 x 10^4	23 ± 1	18.4 ± 0.2	
			Vibrio cholerae		22 ± 1	17.3 ± 0.5	
			Staphylococcus aureus		23 ± 2	18.4 ± 0.3	
			Streptococcus		21 ± 1	-	

			Bacillus subtilis		26 ± 1	20.8 ± 0.7	
			Klebsiella pneumoniae		19 ± 2	15.2 ± 0.2	
			Salmonella cibrum		24 ± 1	19.2 ± 0.4	
			Salmonella typhimurium		22 ± 2	17.6 ± 0.7	
			Pseudomonas		23 ± 1	18.4 ± 0.2	
			Proteus vulgaris		17 ± 1	13.6 ± 0.5	
		Absolute Ethanol	*Escherichia coli*	1 x 10^4	14 ± 2	11.2 ± 0.3	
			Vibrio cholerae		12 ± 2	9.6 ± 0.5	
			Staphylococcus aureus		15 ± 1	12.0 ± 0.6	
			Streptococcus		16 ± 2	-	
			Bacillus subtilis		17 ± 1	21.2 ± 0.4	
			Klebsiella pneumoniae		16 ± 2	12.8 ± 0.2	
			Salmonella cibrum		16 ± 1	12.8 ± 0.1	
			Salmonella typhimurium		14 ± 2	11.2 ± 0.3	
			Pseudomonas		15 ± 1	12.0 ± 0.3	
			Proteus vulgaris		12 ± 2	9.6 ± 0.2	

		Acetone	*Escherichia coli*	1 x 10^4	14 ± 3	11.2 ± 0.8	
			Bacillus subtilis		12 ± 2	9.6 ± 0.7	
		Hexane	*Escherichia coli*	1 x 10^4	11 ± 2	8.8 ± 0.9	
			Bacillus subtilis		12 ± 3	9.6 ± 0.4	
Vanti et al., 2020	Fruit	Aqueous (Silver nanoparticles)	*Xanthomonas axonopodis pv. punicae*	50	18.1 ± 1	6.25	12.5
			Ralstonia solanacearum.		11.4 ± 1	12.5	25
Ve et al., 2018	Fruit	Aqueous	*Staphylococcus aureus*	100	12		
				200	16		
			Streptococcus pyogenes	100	12		
				200	15		
			Bacillus subtilis	100	14		
				200	16		
			Enterococcus faecalis	100	12		
				200	16		

			Salmonella typhi	100	7		
				200	12		
			Serratia	100	9		
				200	14		
			Pseudomonas aeruginosa	100	9		
				200	15		
			Proteus mirabilis	100	7		
				200	10		
		Methanol	*Staphylococcus aureus*	100	9		
				200	16		
			Streptococcus pyogenes	100	9		
				200	12		
			Bacillus subtilis	100	10		
				200	12		
			Enterococcus faecalis	100	10		

				200	13		
			Salmonella typhi	100	10		
				200	13		
			Serratia	100	10		
				200	13		
			Pseudomonas aeruginosa	100	6		
				200	12		
			Proteus mirabilis	100	10		
				200	12		

Table 4.2 Summary of antifungal properties on different fungal species.

References	Parts	Extracts	Fungal Species	Concentration of extract (μg/mL)	Zone of Inhibitions (mm)	MIC (μg/mL)	MFC (μg/mL)	Percent Inhibition (%)
Abhishek et al., 2015	Leaf	Chloroform	*Aspergillus flavus*			250	1000	28.00 ± 0·14
			Fusarium verticillioides			125	250	76.42 ± 0·27
Balachandran et al., 2012	Fruit	Methanol (Methyl Caffeate)	*Candida albicans MTCC 227*	2000	20 ± 0.71	250		
			Malassezia pachydermatis			500		
			Trichophyton mentagrophytes 66/01			100		
			Aspergillus flavus		22 ± 0.81	100		
Bari et al., 2010	Stem	Chloroform	*Aspergillus fumigatus*	5×10^3	-			
				20×10^3	9			
			Candida albicans	5×10^3	-			
				20×10^3	8			
	Root		*Aspergillus fumigatus*	5×10^3	7			
				20×10^3	10			

			Vasin factum	5 x 10^3	9				
				20 x 10^3	13				
			Candida albicans	5 x 10^3	7				
				20 x 10^3	11				
	Stem	Methanol	*Aspergillus fumigatus*	5 x 10^3	-				
				20 x 10^3	12				
			Candida albicans	5 x 10^3	7				
				20 x 10^3	11				
	Root		*Aspergillus fumigatus*	5 x 10^3	7				
				20 x 10^3	13				
			Vasin factum	5 x 10^3	11				
				20 x 10^3	15				
			Candida albicans	5 x 10^3	9				

				20 x 10^3	13				
Govindaraju et al., 2010	Leaf	Aqueous (Silver nanoparticles)	*Aspergillus flavus*	10 µL	4.3				
				50 µL	10.7				
				100 µL	15.2				
			Aspergillus niger	10 µL	4.9				
				50 µL	11.5				
				100 µL	14.8				
GuPta & Tripathi, 2011	Leaf	Aqueous	*Alternaria alternata (Fr.) Keissler (MTCC 3880)*						66.46 ± 0.36
			Alternaria solani (Ell. & Mart.) Jones & Grout. (MTCC 2101)						53.22 ± 0.91
			Aspergillus niger Van Tieghem (MTCC 2425)						60.44 ± 1.08
			Ceratocystis paradoxa (Dade) C Moreau (MTCC 2122)						51.42 ± 0.21
			Colletotrichum falcatum Went. (ITCC 430)						42.54 ± 0.72
			Curvularia lunata (Walker) Boedijn. (MTCC 2030)						73.56 ± 0.63

			Fusarium verticillioides (Sacc.) Nirenberg (MTCC 3322)					100
			Fusarium udum Butler (MTCC 4238)					58.24 ± 0.95
			Helminthosporium oryzae Breda de Haan. (ITCC 2537)					54.82 ± 0.75
			Penicillium italicum Wehmer (ITCC 6424)					57.75 ± 0.42
			Pythium aphanidermatum (Edson) Fitz. (ITCC 4746)					22.56 ± 1.59
			Rhizoctonia solani Kuhn. (MTCC 4633)					100
Hernández-Rodríguez et al., 2018	Root	Methanol	*Curvularia lunata*			225		
	Stem					112.5		
	Leaf					112.5		
	Fruit					450		
Kaushik et al., 2014	Leaf	Absolute Ethanol	*Fusarium oxysporum*	200 µL	10.2 ± 1.0			
			Aspergillus parasiticus		4.6 ± 0.30			
		Methanol	*Fusarium oxysporum*		8.7 ± 0.20			

			Aspergillus parasiticus		5.2 ± 0.20				
		Ethanol-Methanol	*Fusarium oxysporum*		9.5 ± 0.50				
			Aspergillus parasiticus		4.4 ± 0.12				
Santhi et al., n.d	Whole plant	Aqueous and methanol	*Candida albicans*		15				
			Aspergillus niger		9				
Lalitha et al., 2010	Leaf	Aqueous	*Pyricularia oryzae*	25%				100	
			Bipolaris oryzae					47.44 ± 0.39	
			Alternaria alternata					60.47 ± 0.47	
			Tricoconis padwickii					71.50 ± 0.60	
			Curvularia lunata					56.11 ± 0.42	
			Drechslera tetramera					63.33 ± 0.83	
			Drechslera halodes					78.62 ± 0.42	
			Fusarium moniliforme					66.66 ± 0.71	
			Fusarium oxysporum					47.44 ± 0.39	
			Fusarium solani					46.27 ± 0.39	

		Chloroform	*Pyricularia oryzae*	500				69.10 ± 0.81
			Bipolaris oryzae					22.08 ± 0.40
			Alternaria alternata					44.05 ± 0.69
			Tricoconis padwickii					29.52 ± 0.95
			Curvularia lunata					40.44 ± 0.44
			Drechslera tetramera					77.43 ± 0.51
			Drechslera halodes					53.45 ± 0.62
			Fusarium moniliforme					54.66 ± 0.66
			Fusarium oxysporum					63.80 ± 0.95
			Fusarium solani					26.66 ± 0.41
			Pyricularia oryzae	1000				68.97 ± 0.68
			Bipolaris oryzae					24.49 ± 0.40
			Alternaria alternata					44.66 ± 0.66
			Tricoconis padwickii					50.47 ± 0.47
			Curvularia lunata					52.44 ± 0.44
			Drechslera tetramera					77.43 ± 0.51

			Drechslera halodes					65.07 ± 0.79
			Fusarium moniliforme					62.66 ± 0.66
			Fusarium oxysporum					92.37 ± 0.95
			Fusarium solani					31.66 ± 0.41
		Methanol	*Pyricularia oryzae*	500				80.95 ± 0.95
			Bipolaris oryzae					49.80 ± 0.39
			Alternaria alternata					68.94 ± 0.45
			Tricoconis padwickii					71.85 ± 0.74
			Curvularia lunata					44.08 ± 0.54
			Drechslera tetramera					50.83 ± 0.83
			Drechslera halodes					78.97 ± 0.51
			Fusarium moniliforme					75.55 ± 0.55
			Fusarium oxysporum					35.68 ± 0.39
			Fusarium solani					42.03 ± 0.80
			Pyricularia oryzae	1000				100

			Bipolaris oryzae					65.68 ± 0.39
			Alternaria alternata					74.42 ± 0.45
			Tricoconis padwickii					100
			Curvularia lunata					60.31 ± 0.49
			Drechslera tetramera					63.33 ± 0.83
			Drechslera halodes					87.62 ± 0.53
			Fusarium moniliforme					76.01 ± 0.58
			Fusarium oxysporum					59.21 ± 0.39
			Fusarium solani					43.91 ± 0.39
		Absolute Ethanol	*Pyricularia oryzae*	500				79.79 ± 0.86
			Bipolaris oryzae					16.96 ± 0.60
			Alternaria alternata					38.19 ± 0.69
			Tricoconis padwickii					17.77 ± 0.11
			Curvularia lunata					27.77 ± 0.69
			Drechslera tetramera					57.77 ± 0.11

			Drechslera halodes					35.65 ± 0.77
			Fusarium moniliforme					48.60 ± 0.69
			Fusarium oxysporum					48.44 ± 0.44
			Fusarium solani					30.41 ± 0.41
			Pyricularia oryzae	1000				100
			Bipolaris oryzae					67.87 ± 0.60
			Alternaria alternata					50.69 ± 0.69
			Tricoconis padwickii					44.44 ± 0.11
			Curvularia lunata					81.66 ± 0.83
			Drechslera tetramera					82.22 ± 0.11
			Drechslera halodes					77.51 ± 0.77
			Fusarium moniliforme					71.52 ± 0.69
			Fusarium oxysporum					67.10 ± 0.44
			Fusarium solani					44.16 ± 0.41

Obiang et al., 2019	Fruit	Aqueous	*Candida albicans ATCC 10231*	1 x 10^5 (10 µL)	7 ± 1.0	-	-	
			Candida albicans ATCC 90028		9 ± 0.0	5 x 10^3	-	
			Candida albicans		13 ± 1.0	1.25 x 10^3	1.25 x 10^3	
		Water ethanol	*Candida albicans ATCC 10231*	1 x 10^5 (10 µL)	10 ± 1.0	2.5 x 10^3	5 x 10^3	
			Candida albicans ATCC 90028		14 ± 0.0	2.5 x 10^3	2.5 x 10^3	
			Candida albicans		12 ± 2.0	620	1.25 x 10^3	
		Water acetone	*Candida albicans ATCC 10231*	1 x 10^5 (10 µL)	9 ± 1.0	2.5 x 10^3	5 x 10^3	
			Candida albicans ATCC 90028		12 ± 1.0	2.5 x 10^3	2.5 x 10^3	
			Candida albicans		13 ± 0.0	1.25 x 10^3	1.25 x 10^3	
Senizza et al., 2021	Fruit	Methanol, Aqueous, Acetone	*Aspergillus fumigatus (human isolate)*			200 ± 0.00	300 ± 0.00	
			Aspergillus niger (ATCC 6275)			300 ± 0.00	600 ± 0.00	
			Aspergillus versicolor (ATCC 11730)			200 ± 0.00	300 ± 0.00	

			Aspergillus flavus			200 ± 0.00	300 ± 0.00	
			Penicillium funiculosum (ATCC 36839)			100 ± 0.00	200 ± 0.00	
			Penicillium ochrochloron (ATCC 9112)			300 ± 0.00	600 ± 0.00	
			Penicillium verrucosum var. cyclopium (food isolate)			200 ± 0.00	300 ± 0.00	
	Leaf		*Aspergillus fumigatus (human isolate)*			200 ± 0.00	300 ± 0.00	
			Aspergillus niger (ATCC 6275)			200 ± 0.00	300 ± 0.00	
			Aspergillus versicolor (ATCC 11730)			120 ± 0.00	300 ± 0.00	
			Aspergillus flavus			200 ± 0.00	300 ± 0.00	
			Penicillium funiculosum (ATCC 36839)			100 ± 0.00	200 ± 0.00	
			Penicillium ochrochloron (ATCC 9112)			100 ± 0.00	200 ± 0.00	
			Penicillium verrucosum var. cyclopium (food isolate)			200 ± 0.00	300 ± 0.00	

	Stem bark		*Aspergillus fumigatus (human isolate)*			300 ± 0.00	600 ± 0.00	
			Aspergillus niger (ATCC 6275)			200 ± 0.00	300 ± 0.00	
			Aspergillus versicolor (ATCC 11730)			200 ± 0.00	300 ± 0.00	
			Aspergillus flavus			200 ± 0.00	300 ± 0.00	
			Penicillium funiculosum (ATCC 36839)			200 ± 0.00	300 ± 0.00	
			Penicillium ochrochloron (ATCC 9112)			200 ± 0.00	300 ± 0.00	
			Penicillium verrucosum var. cyclopium (food isolate)			300 ± 0.00	600 ± 0.00	
Thippeswamy et al., 2013	Leaf	Chloroform	*Fusarium verticillioides*	2000		250		67.2 ± 0.21
Yomgam et al., 2017	Leaf	Ethyl acetate	*Aspergillus niger*		15.75			
	Stem	Ethyl acetate + water			7.5			
Ve et al., 2018	Fruit	Aqueous	*Aspergillus flavus*	100	12			
				200	17			
			Candida albicans	100	13			

				200	11			
		Methanol	*Aspergillus flavus*	100	13			
				200	18			
			Candida albicans	100	12			
				200	17			

4.3 Data Analysis

The data analysis was done by doing pie charts to identify the most popular parts and extracts of *S. torvum* Sw. used by the studies. Besides, a bar chart was included to do the comparisons between the effectiveness of each part of *S. torvum* Sw. towards bacterial and fungal species. Tables were included to identify the species that could be inhibited by *S. torvum* Sw.. The same species with different strains were highlighted if they were inhibited or killed effectively by most of the parts of *S. torvum* Sw..

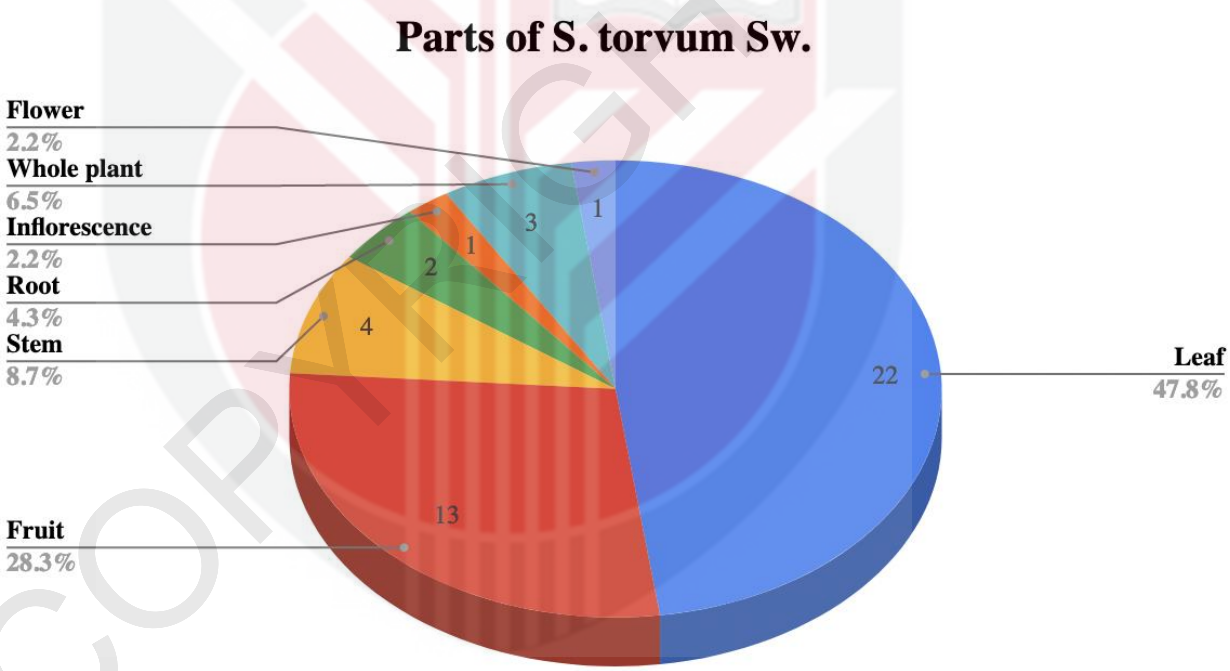


Figure 4.3.1 shows the number of parts of *S. torvum* Sw. used in 36 studies. Among 36 studies which reported the antimicrobial activities of *S. torvum* Sw., there were 47.8% (22) of studies that used leaf, 28.3% (13) of studies that used fruit, 8.7% (4) of studies that used stem, 6.5% (3) of studies that used whole plant, 4.3% (2) of studies that used root, 2.2% (1) of studies that used inflorescence and 2.2% (1) of studies used flower.

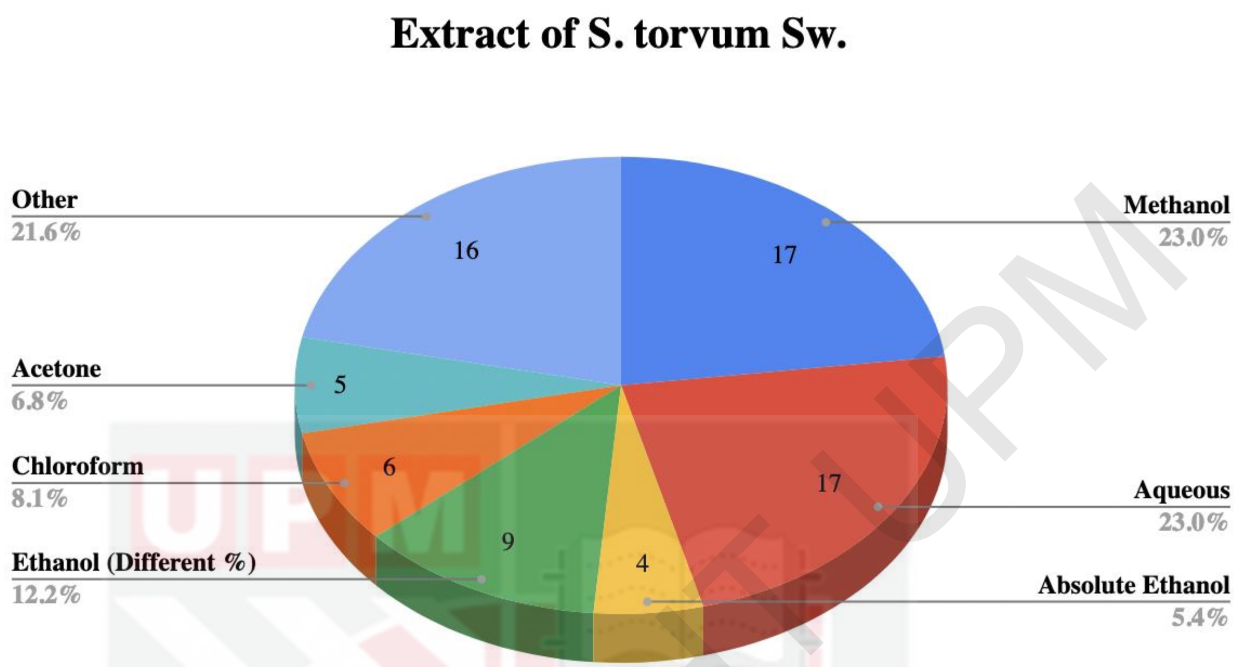


Figure 4.3.2 shows the number of extracts of *S. torvum* Sw. used in 36 studies. Among 36 studies which reported the antimicrobial activities of S. torvum Sw., there were 23% (17) studies that used Methanol extract, 23% (17) studies that used Aqueous extract, 5.4% (4) studies that used Absolute Ethanol extract, 12.2% (9) studies that used other percentage of Ethanol extract, 8.1% (6) that used Chloroform extract, 6.8% (5) studies that used Acetone extract and 21.6% (16) that used other types of extracts.

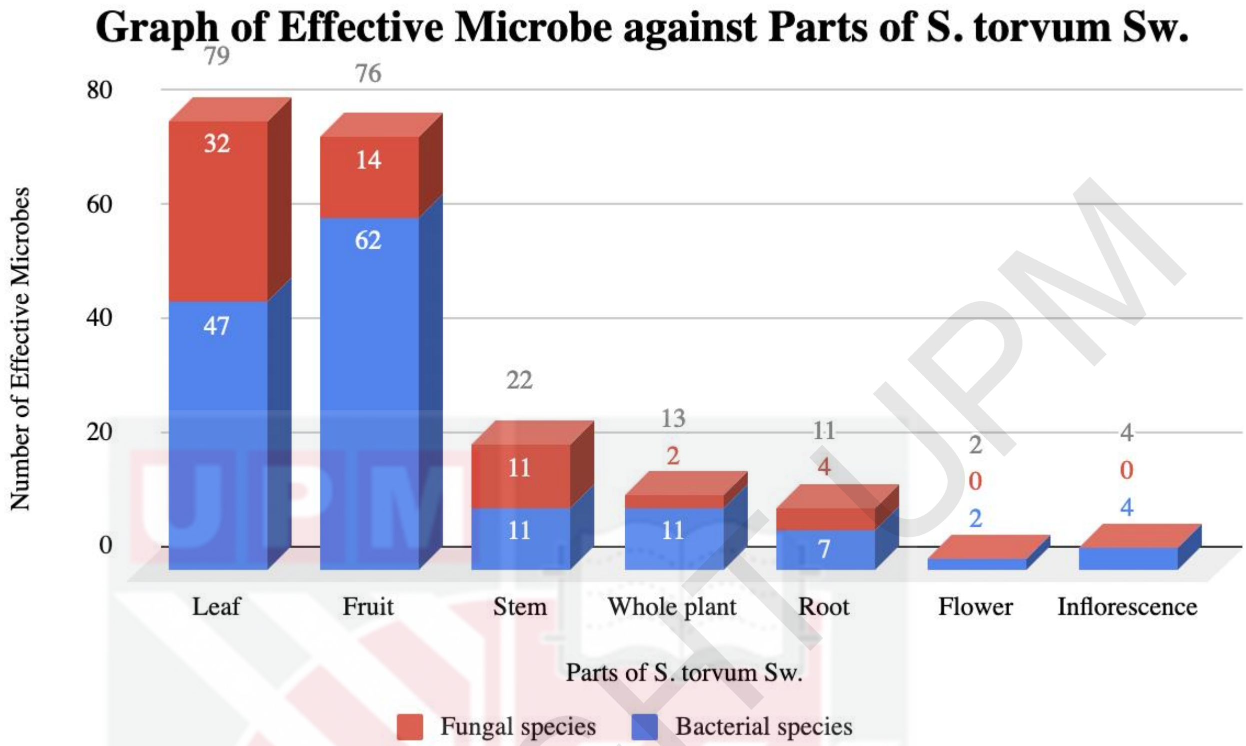


Figure 4.3.3 shows the effective number of microorganisms against parts of plants. Among 36 studies, the leaf had the highest effectiveness towards 79 species, where 32 fungal species and 47 bacterial species. The fruit was effective towards 76 species, where 14 fungal species and 62 bacterial species. The stem was effective towards 22 species, where 11 fungal species and 11 bacterial species. The whole plant was effective towards 13 species, where 2 fungal species and 11 bacterial species. The root was effective towards 11 species, where 4 fungal species and 7 bacterial species. The flower was effective towards 2 bacterial species and the inflorescence was effective towards 4 bacterial species.

Table 4.3.1 Bacterial species that could be inhibited or killed effectively in most of the parts were highlighted.

Leaf	Fruit	Stem	Whole Plant	Root	Inflorescence	Flower
Escherichia coli, *Pseudomonas aeruginosa,* *Klebsiella pneumoniae,* *Salmonella sp.,* *Staphylococcus aureus,* *Shigella. sp 076 CO/17,* *Salmonella para typhi B 150 PI/17,* *Salmonella flexneri 214 CA/17,* *Escherichia coli 118 UB/17,* *Escherichia coli 135 UB/17,* *Escherichia coli 146 PI/17,* *Escherichia coli 238 UB/17,* *Staphylococcus aureus 129 UB/17,* *Staphylococcus aureus 234 UB/17,* *Staphylococcus aureus 241 UB/17,* *Salmonella typhi,* *Xanthomonas campestris,* *Aeromonas hydrophila,* *Salmonella Typhimurium,* *Salmonella Paratyphi A,* *Salmonella Paratyphi B,*	*Staphylococcus aureus MTCC 96,* *Micrococcus luteus,* *Proteus vulgaris MTCC 1771,* *Klebsiella pneumoniae MTCC 109,* *Salmonella typhimurium MTCC 1251,* *Salmonella paratyphi-B,* *Pseudomonas aeruginosa MTCC 741,* *Bacillus subtilis MTCC 441,* *Escherichia coli (ESBL-3984),* *Escherichia coli (ESBL-3904),* *Klebsiella pneumoniae (ESBL-3971),* *Klebsiella pneumoniae (ESBL-75799),* *Klebsiella pneumoniae (ESBL-3894),* *Klebsiella pneumoniae (ESBL-3967),* *Staphylococcus aureus (MRSA-methicillin resistant, clinical pathogen),*	*Staphylococcus aureus,* *Bacillus cereus,* *Salmonella typhi,* *Staphylococcus aureus (ATCC 6538),* *Bacillus cereus (clinical isolate),* *Proteus mirabilis,* *Mariniluteicoccus flavus,* *Pseudomonas aeruginosa (ATCC 27853),* *Escherichia coli (ATCC 35210),* *Salmonella typhimurium (ATCC 13311),* *Enterobacter cloacae (human isolate)*	*Helicobacter pylori,* *Helicobacter pylori 26695,* *Helicobacter pylori V633,* *Helicobacter pylori V1254,* *Helicobacter pylori V1354,* *Helicobacter pylori V2356,* *Escherichia coli (MTCC 585),* *Xanthomonas campestris (MTCC 2286),* *Bacillus subtilis,* *Mycobacterium (MTCC 994),* *Klebsiella aerogenes*	*Staphylococcus aureus,* *Bacillus cereus,* *Bacillus megaterium,* *Bacillus subtilis,* *Streptococcus-β-haemolyticus,* *Salmonella typhi,* *Shigella dysenteriae*	*Staphylococcus aureus,* *Bacillus cereus,* *Salmonella typhi,* *Shigella dysenteriae*	*Pseudomonas sp.,* *Proteus sp.*

Salmonella Typhi (ATCC 6539), Bacillus subtilis, Shigella flexneri, Staphylococcus aureus MSSA 01, Staphylococcus aureus (MTCCAcc.No.7443), Bacillus subtilis (MTCC Acc.No.441), Escherichia coli (MTCC Acc.No.476), Salmonella species (MTCC Acc.No.53), Pseudomonas aeruginosa (MTCC Acc.No.424), Xanthomonas oryzae, Bacillus cereus, Staphylococcus epidermidis, Staphylococcus intermedius, Mycobacterium tuberculosis subsp.tuberculosis (ATCC® 27294™), Mycobacterium smegmatis (ATCC®19420™), Mycobacterium tuberculosis, Strain H37Ra (ATCC® 25177™), Pseudomonas aeruginosa,	*Mycobacterium tuberculosis H37Rv (HR-Sen) (ATCC 27294), Mycobacterium tuberculosis Rif R, Shigella flexneri, Klebsiella pneumoniae, Bacillus subtilis, Escherichia coli, Staphylococcus aureus, Mycobacterium tuberculosis, Staphylococcus aureus (MTCC 3160), Klebsiella pneumoniae (MTCC 3384), Pseudomonas aeruginosa (MTCC 424), Escherichia coli 0157 ATCC, Escherichia coli 105182 CIP, Listeria innocua LMG 135668 BHI, Staphylococcus aureus ATCC 25293 BHI, Enterococcus faecalis 103907 CIP, Bacillus cereus LMG 13569 BHI, Shigella dysenteriae 5451 CIP, Pseudomonas aeruginosa,*					

Staphylococcus aureus (ATCC 6538), Bacillus cereus (clinical isolate), Proteus mirabilis, Mariniluteicoccus flavus, Pseudomonas aeruginosa (ATCC 27853), Escherichia coli (ATCC 35210), Salmonella typhimurium (ATCC 13311), Enterobacter cloacae (human isolate), Proteus vulgaris	*Salmonella enterica, Salmonella typhimurium, Shigella flexneri, Shigella dysenteriae, Neisseria gonorrhoeae, Enterococcus faecalis, Acinetobacter baumannii, Enterobacter aerogenes, Salmonella sp., Neisseria meningitidis, Staphylococcus aureus (ATCC 6538), Bacillus cereus (clinical isolate), Proteus mirabilis, Mariniluteicoccus flavus, Pseudomonas aeruginosa (ATCC 27853), Escherichia coli (ATCC 35210), Salmonella typhimurium (ATCC 13311), Enterobacter cloacae (human isolate), Vibrio cholerae, Streptococcus, Salmonella cibrum, Pseudomonas, Proteus vulgaris,*					

	Xanthomonas axonopodis pv. punicae, *Ralstonia solanacearum.,* *Streptococcus pyogenes,* *Salmonella typhi,* *Serratia*					

Table 4.3.2 Fungal species that could be inhibited or killed effectively in most of the parts were highlighted.

Leaf	Fruit	Stem	Whole Plant	Root
Aspergillus flavus, *Fusarium verticillioides,* *Aspergillus niger,* *Alternaria alternata (Fr.) Keissler (MTCC 3880),* *Alternaria solani (Ell. & Mart.), Jones & Grout. (MTCC 2101),* *Aspergillus niger Van Tieghem (MTCC 2425),* *Ceratocystis paradoxa (Dade) C Moreau (MTCC 2122),* *Colletotrichum falcatum Went. (ITCC 430),* *Curvularia lunata (Walker)*	*Candida albicans MTCC 227,* *Malassezia pachydermatis,* *Trichophyton mentagrophytes 66/01,* *Aspergillus flavus,* *Curvularia lunata,* *Candida albicans ATCC 10231,* *Candida albicans ATCC 90028,* *Candida albicans,* *Aspergillus fumigatus (human isolate),* *Aspergillus niger (ATCC*	*Aspergillus fumigatus,* *Candida albicans,* *Curvularia lunata,* *Aspergillus fumigatus (human isolate),* *Aspergillus niger (ATCC 6275),* *Aspergillus versicolor (ATCC 11730),* *Aspergillus flavus,* *Penicillium funiculosum (ATCC 36839),* *Penicillium ochrochloron (ATCC 9112),*	*Candida albicans,* *Aspergillus niger*	*Aspergillus fumigatus,* *Vasin factum,* *Candida albicans,* *Curvularia lunata*

Boedijn. (MTCC 2030), Fusarium verticillioides (Sacc.) Nirenberg (MTCC 3322), Fusarium udum Butler (MTCC 4238), Helminthosporium oryzae Breda de Haan. (ITCC 2537), Penicillium italicum Wehmer (ITCC 6424), Pythium aphanidermatum (Edson) Fitz. (ITCC 4746), Rhizoctonia solani Kuhn. (MTCC 4633), Curvularia lunata, Fusarium oxysporum, Aspergillus parasiticus, Pyricularia oryzae, Bipolaris oryzae, Alternaria alternata, Tricoconis padwickii, Drechslera tetramera, Drechslera halodes, Fusarium moniliforme, Fusarium solani, Aspergillus fumigatus (human isolate), Aspergillus niger (ATCC 6275), Aspergillus versicolor (ATCC 11730), Penicillium funiculosum (ATCC 36839),	*6275), Aspergillus versicolor (ATCC 11730), Penicillium funiculosum (ATCC 36839), Penicillium ochrochloron (ATCC 9112), Penicillium verrucosum var. cyclopium (food isolate),*	*Penicillium verrucosum var. cyclopium (food isolate), Aspergillus niger*		

Penicillium ochrochloron (ATCC 9112), Penicillium verrucosum var. cyclopium (food isolate)				

CHAPTER 5

DISCUSSION

S. torvum Sw. is well-known because it is one of the vegetables or ingredients in the food and it has been widely used as an herbal remedy. Traditionally, the whole plant is used as a digestive, diuretic, and sedative. Coughing and liver and spleen enlargement are treated with fruit and leaf decoctions. Hemostasis and anti-inflammation properties are also found in the leaves. Plant extracts and metabolites from different parts of *S. torvum* Sw. have been widely studied using various solvents and extraction processes (Naimon, 2015). Among different parts of the plant, the leaf is found to be widely used by most of the studies and followed by fruit. The percentage of journals using the leaf and fruit as their study is 47.8% (22) and 28.3% (13) respectively. This is due to the presence of a variety of phytochemical constituents such as steroids, glycosides, saponins, flavonoid, phenol, vitamin C and E, iron salt and steroid alkaloids (Naimon, 2015). Immune-modulator organs benefit from phenol and flavonoids, which destroy bacteria (Kang, 2011). Besides, most of the tribes and traditional medicine use leaf and fruit as their treatments.

Extraction is used in the chemical lab for a variety of reasons. It is a common technique for separating chemicals from a plant. Extraction is the process of transferring chemicals from one liquid to another to make them easier to be manipulated or concentrated. It also allows for the removal of certain components from a mixture. Different extracts will give different degrees of inhibition against microorganisms. The most common extracts that are used in studies are Methanol and Aqueous. This is because most polar groups, such as phenolics, alkaloids, terpenes, and glycosides, have good antibacterial activity and are soluble in methanol. However, some phytochemicals, such as glycoside, are so polar that they are poorly soluble in these solvents (Zunjar, 2014) and hence, aqueous extraction is able to yield glycosides (Ekambaram, 2014). Besides, methanol has the highest usage in most of the studies because the boiling point of methanol is 64.7˚C only, which means the methanol extraction requires lower temperature to evaporate the solvent in the rotary vapor compared to ethanol extraction. It causes little damage compared to ethanol extraction (Bader, 2014). According to the FDA, ethanol is effective, efficient, and safe. It is dependable, constantly providing effective extractions with little effort (High Purity Extraction, n.d). Some extractions such as petroleum ether extraction is used to extract non-polar compounds (Ekambaram, 2014).

According to Graph 4.3.3, the leaf of *S. torvum* Sw. was the most effective towards the microorganisms, and followed by fruit, stem and whole plant. This is corresponding to Graph 4.3.1 which shows that the leaf, fruit, stem and whole plant are the top popular parts of *S. torvum* Sw.. This indicates that each part of *S. torvum* Sw. is effectively inhibits the growth of microorganisms. From most of the studies, a few species were highlighted because they were inhibited or killed effectively by the leaf, fruit, stem, root, flower, inflorescence and even the whole plant of *S. torvum* Sw.. Those bacterial species include

E. coli, *P. aeruginosa*, *S. aureus* and *B. cereus*, while the fungal species include *A. niger*, *C. albicans*, *C. lunata* and *A. fumigatus*.

According to Table 4.1, the leaf of *S. torvum* Sw. with absolute ethanol extract and the concentration was 100 µL (1 x 10^6 µg/mL) had the highest zone of inhibition value towards *Xanthomonas oryzae*, 30 mm (Lalitha et al., 2010). Vanti et al. (2020) reported the lowest MIC towards *Xanthomonas axonopodis pv. punicae* (6.25 µg/mL) and *Ralstonia solanacearum* (12.5 µg/mL). In the same study, Vanti et al. (2020) also reported the lowest MBC towards *Xanthomonas axonopodis pv. punicae* (12.5 µg/mL) and *Ralstonia solanacearum* (25 µg/mL). According to Table 4.2, Balachandran et al. (2012) reported that the fruit of *S. torvum* Sw. with methanol extract and the concentration was 2000 µg/mL had the highest zone of inhibition value towards *Aspergillus flavus*, 22 ± 0.81 mm, and also with the lowest MIC value, 100 µg/mL. The same lowest MIC value was stated in *Trichophyton mentagrophytes* 66/01 (Balachandran et al., 2012), *Penicillium funiculosum* and *Penicillium ochrochloron* (Senizza et al., 2021). The lowest MFC value was 200 µg/mL and the species were *Penicillium funiculosum* and *Penicillium ochrochloron* (Senizza et al., 2021). The highest percentage of inhibition is 100% and the species were *Fusarium verticillioides (Sacc.) Nirenberg, Rhizoctonia solani Kuhn.* (GuPta & Tripathi, 2011) and *Pyricularia oryzae* (Lalitha et al., 2010).

The limitation is the number of studies to test the specific microbial species by using the same parts of plant and the same types of extracts are too little. The systematic review can only show that *S. torvum* Sw. has antimicrobial properties, and the popular species that were used in the studies. However, it is not able to specifically identify which species can be inhibited or killed by the plant. Hence, it is recommended to study more on specific species of microorganisms that are especially crucial in treating human diseases.

CHAPTER 6

CONCLUSION

In conclusion, the leaf is the most popular part of *S. torvum* Sw. as there were 47.8% (22) of studies using it to do research on antimicrobial activities and hence, the leaf had the highest effectiveness against the bacterial and fungal species. Methanol extract and Aqueous extract were highly used in the studies and the percentage was 23% respectively. The species that were inhibited or killed effectively by the leaf, fruit, stem, root, flower, inflorescence and whole plant of *S. torvum* Sw. were *E. coli*, *P. aeruginosa*, *S. aureus*, *B. cereus*, *A. niger*, *C. albicans*, *C. lunata* and *A. fumigatus*. In bacteria species, the highest zone of inhibition was 30 mm, the lowest MIC value was 6.25 µg/mL, and the lowest MBC value was 12.5 µg/mL. In fungal species, the highest zone of inhibition was 22 mm, the lowest MIC value was 100 µg/mL, the lowest MFC value was 200 µg/mL, and the highest percentage of inhibition was 100%. The number of research employing the same parts of the plant and the same types of extracts to evaluate specific microbial species is insufficient. Future studies should be performed on specific species of microorganisms to evaluate the antimicrobial activities of *S. torvum* Sw..

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APPENDICES

Tables show no observable changes in antimicrobial activities in the studies. Parts and extracts of *S. torvum* Sw., bacterial species and references were included.

Table A: Bacterial species that were not inhibited.

References	**Parts**	**Extracts**	**Bacterial Species**	**No activity found in (Zone of Inhibition / MIC / MBC / MFC / Percentage of Inhibition)**
Anatole et al., 2019	Leaf	Aqueous	*Shigella. sp 076 CO/17, Salmonella para typhi B 150 PI/17, Salmonella flexneri 214 CA/17, Escherichia coli 118 UB/17, Escherichia coli 135 UB/17, Escherichia coli 238 UB/17, Staphylococcus aureus 129 UB/17, Staphylococcus aureus 234 UB/17, Staphylococcus aureus 241 UB/17*	MIC
Balachandran et al., 2012	Fruit	Methanol (Methyl Caffeate)	*Enterobacter aerogenes MTCC 111, Staphylococcus epidermidis MTCC 3615, Shigella flexneri MTCC 1457*	Zone of Inhibition MIC

Bari et al., 2010	Leaf	Chloroform	*Staphylococcus aureus,* *Bacillus cereus,* *Bacillus megaterium,* *Bacillus subtilis,* *Sarcina lutea,* *Streptococcus-β-haemolyticus,* *Shigella dysenteriae,* *Shigella shiga,* *Shigella sonnei,* *Shigella boydii,* *Escherichia coli,* *Klebsiella sp.,* *Pseudomonas aeruginosa,* *Proteus sp.*	Zone of Inhibition (5×10^3 µg/mL and 20×10^3 µg/mL)
	Stem		*Bacillus megaterium,* *Bacillus subtilis,* *Sarcina lutea,* *Streptococcus-β-haemolyticus,* *Shigella dysenteriae,* *Shigella shiga,* *Shigella sonnei,* *Shigella boydii,* *Escherichia coli,* *Klebsiella sp.,* *Pseudomonas aeruginosa,* *Proteus sp.*	
	Root		*Sarcina lutea,* *Shigella shiga,* *Shigella sonnei,* *Shigella boydii,* *Escherichia coli,* *Klebsiella sp.,* *Pseudomonas aeruginosa,* *Proteus sp.*	
	Inflores cence		*Bacillus megaterium,* *Bacillus subtilis,* *Sarcina lutea,* *Streptococcus-β-haemolyticus,* *Shigella shiga,* *Shigella sonnei,* *Shigella boydii,* *Escherichia coli,* *Klebsiella sp.,* *Pseudomonas aeruginosa,* *Proteus sp.*	

	Leaf	Methanol	*Staphylococcus aureus,* *Bacillus cereus,* *Bacillus megaterium,* *Bacillus subtilis,* *Sarcina lutea,* *Streptococcus-β-haemolyticus,* *Shigella dysenteriae,* *Shigella shiga,* *Shigella sonnei,* *Shigella boydii,* *Escherichia coli,* *Klebsiella sp.,* *Pseudomonas aeruginosa,* *Proteus sp.*	
	Stem		*Bacillus megaterium,* *Bacillus subtilis,* *Sarcina lutea,* *Streptococcus-β-haemolyticus,* *Shigella dysenteriae,* *Shigella shiga,* *Shigella sonnei,* *Shigella boydii,* *Escherichia coli,* *Klebsiella sp.,* *Pseudomonas aeruginosa,* *Proteus sp.*	
	Root		*Sarcina lutea,* *Shigella shiga,* *Shigella sonnei,* *Shigella boydii,* *Escherichia coli,* *Klebsiella sp.,* *Pseudomonas aeruginosa,* *Proteus sp.*	
	Inflores cence		*Bacillus megaterium,* *Bacillus subtilis,* *Sarcina lutea,* *Streptococcus-β-haemolyticus,* *Shigella shiga,* *Shigella sonnei,* *Shigella boydii,* *Escherichia coli,* *Klebsiella sp.,* *Pseudomonas aeruginosa,* *Proteus sp.*	

De Britto et al., 2011	Leaf	Aqueous	*Xanthomonas campestris, Aeromonas hydrophila*	MIC
Djoueudam et al., 2019	Leaf	50% Ethanol	*Salmonella Typhi, Salmonella Typhi (ATCC 6539)*	MBC
		30% Ethanol	*Salmonella Paratyphi A*	
		Infused extract	*Salmonella Paratyphi A, Salmonella Typhi*	
		Macerated extract	*Salmonella Typhimurium, Salmonella Typhi (ATCC 6539)*	
Fosso et al., 2017	Leaf	Methanol	*Staphylococcus aureus ATCC 25923, Pseudomonas aeruginosa PA01, Staphylococcus aureus MRSA 03, Staphylococcus aureus MRSA 04*	MIC MBC
			Bacillus subtilis, Escherichia coli, Pseudomonas aeruginosa, Shigella flexneri, Staphylococcus aureus MSSA 01	MBC
	Fruit	Methanol	*Bacillus subtilis, Escherichia coli, Pseudomonas aeruginosa, Staphylococcus aureus ATCC 25923, Pseudomonas aeruginosa PA01, Staphylococcus aureus MSSA 01, Staphylococcus aureus MRSA 03, Staphylococcus aureus MRSA 04*	MIC MBC
			Shigella flexneri	MBC
Hsu et al., 2010	Whole plant	Aqueous	*Helicobacter pylori*	Zone of Inhibition (2.5×10^4 µg/mL, 1×10^4 µg/mL, 5×10^3 µg/mL, 2.5×10^3 µg/mL)

		Methanol	*Helicobacter pylori*	Zone of Inhibition (1×10^4 µg/mL, 5×10^3 µg/mL, 2.5×10^3 µg/mL)
		Acetone	*Helicobacter pylori*	Zone of Inhibition (1×10^4 µg/mL, 5×10^3 µg/mL, 2.5×10^3 µg/mL)
		Chloroform	*Helicobacter pylori*	Zone of Inhibition (2.5×10^3 µg/mL)
Jaabir et al., 2010	Fruit	Absolute Ethanol	*Salmonella typhi*, *Pseudomonas aeruginosa*	Zone of Inhibition (2.5×10^4 µg/mL, 5×10^4 µg/mL, 10×10^4 µg/mL)
Lalitha et al., 2010	Leaf	Petroleum ether, Benzene, Chloroform	*Xanthomonas oryzae*	Zone of Inhibition (10 µL, 20 µL, 30 µL, 40 µL, 50 µL, 60 µL, 70 µL, 80 µL, 90 µL, 100 µL)
Laskowitz, 2018	Whole plant	Methanol	*Listeria monocytogenes ATCC 19115*, *Listeria monocytogenes ATCC 7644*, *Escherichia coli ATCC BAA 2196*, *Escherichia coli ATCC BAA 2210*, *Escherichia coli ATCC 5053*, *Escherichia coli O157:H7 AU2 301*, *Salmonella Heidelberg*, *Salmonella Typhimurium*	Zone of Inhibition (5%, 10%, 20%)
Maser et al., 2015.	Fruit	Hexane, Ethyl acetate, Aqueous	*Staphylococcus aureus*	Zone of Inhibition
Nithiyanantham et al., 2012	Fruit	Raw, 80% Methanol	*Salmonella typhi (MTCC 3215)*, *Escherichia coli (MTCC 40)*	Zone of Inhibition
Obiang et al., 2019	Fruit	Aqueous	*Klebsiella pneumoniae*	Zone of Inhibition
			Listeria innocua LMG 135668 BHI, *Escherichia coli*, *Klebsiella pneumoniae*, *Enterobacter aerogenes*, *Neisseria meningitidis*	MIC

			Listeria innocua LMG 135668 BHI, *Staphylococcus aureus ATCC 25293 BHI,* *Pseudomonas aeruginosa,* *Escherichia coli,* *Staphylococcus aureus,* *Klebsiella pneumoniae,* *Enterobacter aerogenes,* *Neisseria meningitidis*	MBC
		Water ethanol	*Pseudomonas aeruginosa,* *Escherichia coli,* *Klebsiella pneumoniae*	MBC
		Water acetone	*Klebsiella pneumoniae*	MIC
			Shigella flexneri, *Staphylococcus aureus,* *Klebsiella pneumoniae*	MBC
Sabarinath et al., 2018	Leaf	Petroleum ether	*Salmonella typhimurium,* *Escherichia coli,* *Klebsiella pneumoniae,* *Pseudomonas aeruginosa,* *Proteus vulgaris*	Zone of Inhibition (1000 µg/mL, 2000 µg/mL, 3000 µg/mL, 4000 µg/mL, 5000 µg/mL)
Sivapriya et al., 2011	Fruit coat	Aqueous, Ethanol water, Absolute ethanol	*Streptococcus*	MIC
		Acetone	*Vibrio cholerae,* *Staphylococcus aureus,* *Streptococcus,* *Klebsiella pneumoniae,* *Salmonella cibrum,* *Salmonella typhimurium,* *Pseudomonas,* *Proteus vulgaris*	Zone of Inhibition and MIC
		Hexane	*Vibrio cholerae,* *Staphylococcus aureus,* *Streptococcus,* *Klebsiella pneumoniae,* *Salmonella cibrum,* *Salmonella typhimurium,* *Pseudomonas,* *Proteus vulgaris*	Zone of Inhibition and MIC

Table B: Fungal species that were not inhibited.

References	Parts	Extracts	Fungal Species	No activity on (Zone of Inhibition / MIC / MBC / MFC / Percentage of Inhibition)
Bari et al., 2010	Leaf	Chloroform	*Aspergillus fumigatus, Aspergillus niger, Aspergillus flavus, Vasin factum, Mucor sp. Candida albicans, Fusarium oxysporum, Colletotrichum falcatum*	Zone of Inhibition (5 x 10^3 µg/mL, 20 x 10^3 µg/mL)
	Stem		*Aspergillus niger, Aspergillus flavus, Vasin factum, Mucor sp., Fusarium oxysporum, Colletotrichum falcatum*	
	Root		*Aspergillus niger, Aspergillus flavus, Mucor sp., Fusarium oxysporum, Colletotrichum falcatum*	
	Inflores cence		*Aspergillus fumigatus, Aspergillus niger, Aspergillus flavus, Vasin factum, Mucor sp., Candida albicans, Fusarium oxysporum, Colletotrichum falcatum*	
	Leaf	Methanol	*Aspergillus fumigatus, Aspergillus niger, Aspergillus flavus, Vasin factum, Mucor sp., Candida albicans, Fusarium oxysporum, Colletotrichum falcatum*	

	Stem		*Aspergillus niger,* *Aspergillus flavus,* *Vasin factum,* *Mucor sp.,* *Fusarium oxysporum,* *Colletotrichum falcatum*	
	Root		*Aspergillus niger,* *Aspergillus flavus,* *Mucor sp.,* *Fusarium oxysporum,* *Colletotrichum falcatum*	
	Inflore- scence		*Aspergillus fumigatus,* *Aspergillus niger,* *Aspergillus flavus,* *Vasin factum,* *Mucor sp.,* *Candida albicans,* *Fusarium oxysporum,* *Colletotrichum falcatum*	
Jaabir et al., 2010	Fruit	Absolute Ethanol	*Aspergillus niger,* *Candida albicans*	Zone of Inhibition (25 mg/well, 50 mg/well, 100 mg/well)
Rao, 2015	Leaf	70% Ethanol	*Alternaria alternata,* *Aspergillus flavus,* *Aspergillus niger,* *Curvularia lunata,* *Fusarium moniliforme,* *Fusarium solani,* *Helminthosporium sativum,* *Penicillium sp.*	Percentage of Inhibition
Santhi et al., n.d	Whole plant	Aqueous and methanol	*Aspergillus fumigatus*	Zone of Inhibition
Obiang et al., 2019	Fruit	Aqueous	*Candida albicans ATCC 10231*	MIC
			Candida albicans ATCC 10231, *Candida albicans ATCC 90028*	MFC
Yomgam et al., 2017	Leaf	Aqueous	*Aspergillus niger*	Zone of Inhibition