CARPATHIAN JOURNAL OF FOOD SCIENCE AND TECHNOLOGY

journal homepage: **http://chimie-biologie.ubm.ro/carpathian_journal/index.html**

EVALUATION OF ANTIBACTERIAL POTENTIAL OF SELECTED CULINARY HERBS AGAINST SOME FOODBORNE PATHOGENIC BACTERIA

K.P.V.R. Karunanayake[1], D.W.M.M.M. Kumari[1] and P.N. Yapa[2*]

[1]Department of Animal and Food Sciences, Faculty of Agriculture, Rajarata University of Sri Lanka, Anuradhapura, Sri Lanka.
[2]Department of Biological Sciences, Faculty of Applied Sciences, Rajarata University of Sri Lanka, Mihintale, Sri Lanka.
pnyapa40@yahoo.co.uk; neelamanie@as.rjt.ac.lk

https://doi.org/10.34302/crpjfst/2022.14.3.3

Article history:
Received:
10 January 2021
Accepted:
15 August 2022
Published
September 2022

Keywords:
Antibacterial activity;
Culinary herbs;
Foodborne pathogens;
Minimum inhibitory concentration.

ABSTRACT

Culinary herbs consist of bioactive compounds which play an important role as natural antimicrobial agents. The present study was carried out with the objective of evaluating the antibacterial activity of extracts from selected culinary herbs*; Trachyspermum involucratum*, *Laurus nobilis*, *Coriandrum sativum*, *Allium tuberosum*, *Allium schoenoprasum*, *Melissa officinalis*, *Origanum majorana*, *Origanum vulgare*, *Rosmarinus officinalis*, *Santolina chamaecyparissus*, and *Satureja hortensis*. Different extraction solvents (sterilized distilled water, hot distilled water (80°C), absolute methanol, and acetone) were used against three foodborne pathogens (*E. coli* NCTC 10418, *E. coli* ATCC 25922, and *Enterococcus faecalis*) using the agar-well diffusion method. Statistical analysis using two-factor factorial completely randomized design in SAS software revealed that all solvent extracts of *Trachyspermum involucratum* has the highest antibacterial activity ($p<0.05$) followed by *Rosmarinus officinalis*, *Santolina chamaecyparissus*, *Satureja hortensis*, *Origanum vulgare*, and *Coriandrum sativum* against all tested bacteria with variable potential. Further, hot distilled water (80°C) extract of *Trachyspermum involucratum* had significant antibacterial activity against *E. coli* NCTC 10418 (14.67 ± 1.53 mm). In particular, organic extracts of *Rosmarinus officinalis*, *Santolina chamaecyparissus* and *Satureja hortensis* had strong antibacterial activity against *E. coli* NCTC 10418 and *Enterococcus faecalis*. Overall, *Enterococcus faecalis* has highly inhibited the growth followed by *E. coli* NCTC 10418 and *E. coli* ATCC 25922 in extracts of the best anti-bacterially active herbs. The minimum inhibitory concentration of above the herb extracts was 0.2 g mL^{-1} against most of the tested pathogens. It can be concluded that culinary herbs are potentially effective as natural antimicrobials against tested foodborne pathogens.

1. Introduction

Foodborne diseases are an acute illness, a condition that occurs after ingestion of contaminated food and water. Major foodborne illnesses can be caused by foodborne pathogens like bacteria, fungi, viruses, parasites, and/or toxins through contaminated food or water (Sudershan *et al.*, 2014). Amongst the various infectious pathogenic microbes *Corynebacterium diphtheria*, *Escherichia coli*, *Salmonella typhimurium*, *Staphylococcus aureus*, *Enterococcus faecalis*, and *Pseudomonas aeruginosa* are of prime importance as common foodborne pathogens (Panpatil *et al.*, 2013).

Today, food safety has become an important public health issue and researchers and regulatory bodies in food industries are constantly bothered with an increase in the number of food poisoning and spoilage caused by pathogenic foodborne microorganisms (Pesavento *et al*., 2015). It is important to reduce the activity of foodborne pathogens in order to prevent the occurrence of foodborne diseases.

In the food industry, the use of food antimicrobials has become one of the promising solutions for foodborne diseases (Sankar *et al*., 2013). However, the indiscriminate use of chemical preservatives and the misuse of commercial antibiotics over the years have been led to the emergence of antibiotic-resistant pathogens that can amplify foodborne infections has become another major health concern (Witkowska *et al*., 2013). In this regard, the use of natural agents as herbs especially, the culinary herbs provide a better alternative for the development of novel drugs for human being and play a vital role in the alterations of worse conditions produced by infectious foodborne microorganisms (Weerakkody *et al*., 2010).

Culinary herbs are herbaceous plants which primarily used for, and associated with, adding to or enhancing the flavor, aroma, pungency, and appearance of foods (Opara and Chohan, 2014). Culinary herbs have always been an important component of the human diet, which add characteristic flavor to the staple foods, as well as being used for food preservation. They are secondarily used as a natural antimicrobial agent, which contains bioactive compounds. Therefore, today culinary herbs are considered as the most important source for the development of natural antimicrobial agents for different selective foodborne pathogens (Bozin *et al*., 2007).

Therefore, this research is one of the attempts to focus on the potential of culinary herbs as natural antimicrobial agents to control the foodborne diseases caused by selective foodborne pathogenic bacteria. The main objective of this study was to evaluate the antibacterial potential of selected culinary herb extracts and determine their Minimum Inhibitory Concentration (MIC) against selected foodborne bacterial pathogens.

2. Materials and methods

2.1. Materials

2.1.1. Collection of Culinary Herbs

Asamodagam (*Trachyspermum involucratum* L.), bay leaves (*Laurus nobilis* L.), coriander (*Coriandrum sativum* L.), garlic chives (*Allium tuberosum*), onion chives (*Allium schoenoprasum*), lemon mint (*Melissa officinalis*), marjoram (*Origanum majorana* L.), oregano (*Origanum vulgare* L.), rosemary (bush & tree type) (*Rosmarinus officinalis* L.), santolina/lavender cotton (*Santolina chamaecyparissus* L.) and savory/summer savory (*Satureja hortensis*) were collected from Agriculture Research Station – Seetha Eliya, Department of Agriculture, Sri Lanka (Table 1).

Table 1. Types of Culinary Herb

Common Name	**Family Name**	**Scientific Name**	**Parts used**
Asamodagam/ Ajamoda	Apiaceae	*Trachyspermum involucratum* L.	Leaves
Bay leaves	Lauraceae	*Laurus nobilis* L.	Leaves
Coriander/Cilantro	Apiaceae	*Coriandrum sativum* L.	Leaves
Garlic chives	Liliaceae	*Allium tuberosum*	Leaves
Onion chives	Liliaceae	*Allium schoenoprasum*	Leaves
Lemon mint	Lamiaceae	*Melissa officinalis*	Leaves
Marjoram	Lamiaceae	*Origanum majorana* L.	Leaves
Oregano	Lamiaceae	*Origanum vulgare* L.	Leaves

Rosemary (Bush)	Lamiaceae	*Rosmarinus officinalis* L.	Leaves
Rosemary (Tree)	Lamiaceae	*Rosmarinus officinalis* L.	Leaves
Santolina/Lavender cotton	Asteraceae	*Santolina chamaecyparissus* L.	Leaves
Savory/Summer savory	Lamiaceae	*Satureja hortensis*	Leaves

2.1.2. Pathogen Collection

Pure cultures of foodborne bacterial pathogens; *Escherichia coli* NCTC 10418, *Escherichia coli* ATCC 25922, and *Enterococcus faecalis* were obtained from the Faculty of Medicine and Allied Sciences, Rajarata University of Sri Lanka. The bacterial strains were grown in Nutrient agar medium at 37 ^{0}C temperature and the stock cultures were maintained in Nutrient agar medium at 4 ^{0}C and sub-cultured at regular intervals (Allard *et al.*, 2018).

2.2. Methods

2.2.1. Preparation of Culinary Herb Extracts

Culinary herb samples were washed with tap water, dried under shade, and ground separately using a motor and pestle. The ground sample was sieved through a 10 mm sieve. Then 10 g of sieved sample was dissolved in 100 mL of sterilized distilled water, hot distilled water (80 ^{0}C), absolute methanol, and absolute acetone to prepare the extracts (Hinneburg *et al.*, 2006). The mixture was swirled continuously at 120 rpm in an orbital shaker for one hour. Extracts were filtered through Whatman filter paper No: 01 (150 mm). The filtrate was concentrated by rotary evaporator under reduced pressure at 40 ^{0}C temperature and stored at 4 ^{0}C for further analysis (Wong and Kitts, 2006).

2.2.2. Preparation of Bacterial Inoculum

Bacterial inoculum was prepared by matching with 0.5 McFarland turbidity standards (10^8 CFU/mL) and UV visible spectrophotometer was used to measure the absorbance (Mostafa *et al*., 2018).

(0.5 McFarland turbidity = 0.08 to 0.10 absorbance specification at 625 nm)

2.2.3. Antibiotic Susceptibility Testing (ABST)

Antibacterial activity of herb extracts against test pathogens was assessed by the Agar Well Diffusion method (Sharififar *et al*., 2007). 100 µL of bacterial inoculum prepared by matching with 0.5 McFarland turbidity standards (10^8 CFU/mL) was spread on the Mueller Hinton (MH) agar in Petri plates using a sterile cotton swab. Wells of 8 mm diameter was bored in the inoculated media with the help of a sterile cork-borer (8 mm). Then, each well was filled with 50 μL of test herb extract (Reller *et al*., 2009). 50 μL aliquots of positive control and negative control were dispensed into wells of the same plate. The plates were incubated at 37 ^{0}C for 24 - 48 h aerobically. After incubation, the diameter of the inhibition zone was measured in millimeters using a vernier caliper (Ruangpan and Tendencia, 2004).

Sterilized distilled water, hot distilled water (80 ^{0}C), absolute methanol, and absolute acetone were used as negative controls and Amoxicillin was used as a positive control for bacterial pathogens (Jeyaseelan and Jashothan, 2012).

2.2.4. Determination of Minimum Inhibitory Concentrations (MIC)

The crude extraction was done with solvents and prepared 0.2 g mL^{-1}, 0.15 g mL^{-1}, 0.1 g mL^{-1}, and 0.05 g mL^{-1} different concentrations separately and stored in -20 ^{0}C in order to determine the Minimum Inhibitory concentration (MIC) of different herb extracts using the Agar Well Diffusion method as previously described in the ABST testing (Shan *et al.,* 2007).

2.2.5. Statistical Analysis

All experiments were done in triplicate (n = 3) and the inhibition zone diameter was expressed as means ± standard deviation (SD). The results were statistically analyzed in two-factor factorial Completely Randomized Design (CRD) using the SAS program (Version 9.0, SAS Institute Inc. USA). Means were compared using Tukey's simultaneous test set at p <0.05.

3. Results and discussions

3.1. Antibacterial Activity of Herb Extracts

Twelve herb species were investigated to evaluate their antibacterial activity against some foodborne pathogenic bacteria, including two strains of *E. coli* (*E. coli* NCTC 10418 and *E. coli* ATCC 25922) and one strain of *Enterococcus faecalis* using the Agar-well diffusion method. Evaluation of the antibacterial activity of these herb extracts was recorded by the mean diameters of the inhibition zone of all herb extracts against three foodborne pathogens in Table 2. The results revealed that most of the herb extracts were potentially effective in suppressing microbial growth of foodborne pathogenic bacteria with variable potency.

According to Tukey's simultaneous test set at *p<0.05* in the SAS program, *Trachyspermum involucratum* L. has the highest antibacterial activity against three foodborne pathogenic bacteria followed by *Rosmarinus officinalis* L. (Bush), *Santolina chamaecyparissus* L., *Satureja hortensis*, *Origanum vulgare* L. and *Coriandrum sativum* L. respectively. Other herbs have a minimum or may not have the antibacterial activity against the tested foodborne bacterial pathogens.

Table 2. Antibacterial Activity (Diameter of Inhibition Zone) of Herb Extracts

Herb	**Type of Extract**	**Antibacterial Activity (DIZ) (mm)**		
		E. coli NCTC 10418	*E. coli* ATCC 25922	*Enterococcus faecalis*
***Origanum vulgare* L.**	Distilled water	$8.33^{b} \pm 0.58$	$10.00^{ab} \pm 1.00$	$11.00^{b} \pm 1.00$
	Hot Distilled water	$8.33^{b} \pm 0.58$	$8.68^{ab} \pm 0.58$	$10.00^{b} \pm 0.00$
	Acetone	$8.33^{b} \pm 0.58$	$8.00^{b} \pm 0.00$	$15.33^{a} \pm 0.58$
	Methanol	$10.67^{a} \pm 0.58$	$10.67^{a} \pm 1.15$	$11.33^{b} \pm 0.58$
***Rosmarinus officinalis* L. (Tree)**	Distilled water	$8.00^{b} \pm 0.00$	$8.00^{c} \pm 0.00$	$8.00^{b} \pm 0.00$
	Hot Distilled water	$8.00^{b} \pm 0.00$	$8.33^{bc} \pm 0.58$	$9.67^{b} \pm 0.58$
	Acetone	$10.67^{a} \pm 0.58$	$9.67^{a} \pm 0.58$	$17.67^{a} \pm 1.53$
	Methanol	$8.33^{b} \pm 0.58$	$9.33^{ab} \pm 0.58$	$8.67^{b} \pm 0.58$
***Rosmarinus officinalis* L. (Bush)**	Distilled water	$9.33^{b} \pm 0.47$	$9.33^{b} \pm 0.58$	$8.00^{c} \pm 0.00$
	Hot Distilled water	$8.67^{b} \pm 0.58$	$9.00^{b} \pm 0.00$	$8.33^{c} \pm 0.58$
	Acetone	$14.00^{a} \pm 1.00$	$11.67^{a} \pm 0.58$	$16.67^{a} \pm 0.58$
	Methanol	$12.33^{a} \pm 0.58$	$11.33^{a} \pm 0.58$	$12.67^{b} \pm 0.58$
Melissa officinalis	Distilled water	$8.00^{b} \pm 0.00$	$9.67^{a} \pm 0.58$	$9.00^{b} \pm 1.00$
	Hot Distilled water	$8.00^{b} \pm 0.00$	$8.00^{c} \pm 0.00$	$8.00^{b} \pm 0.00$
	Acetone	$8.00^{b} \pm 0.00$	$9.33^{ab} \pm 0.58$	$14.33^{a} \pm 1.15$
	Methanol	$9.33^{a} \pm 0.58$	$8.33^{bc} \pm 0.58$	$8.67^{b} \pm 0.58$

Allium schoenoprasum	Distilled water	$8.00^{a} \pm 0.00$	$8.00^{b} \pm 0.00$	$8.00^{b} \pm 0.00$
	Hot Distilled water	$8.00^{a} \pm 0.00$	$8.00^{b} \pm 0.00$	$8.00^{b} \pm 0.00$
	Acetone	$8.00^{a} \pm 0.00$	$8.00^{b} \pm 0.00$	$14.67^{a} \pm 1.53$
	Methanol	$8.33^{a} \pm 0.58$	$9.00^{a} \pm 0.00$	$8.33^{b} \pm 0.58$
Allium tuberosum	Distilled water	$8.00^{a} \pm 0.00$	$8.00^{a} \pm 0.00$	$8.00^{c} \pm 0.00$
	Hot Distilled water	$8.00^{a} \pm 0.00$	$8.33^{a} \pm 0.58$	$10.00^{b} \pm 0.00$
	Acetone	$8.33^{a} \pm 0.58$	$8.33^{a} \pm 0.58$	$12.67^{a} \pm 0.58$
	Methanol	$8.33^{a} \pm 0.58$	$8.33^{a} \pm 0.58$	$9.33^{c} \pm 0.58$
***Laurus nobilis* L.**	Distilled water	$12.67^{b} \pm 0.58$	$9.33^{a} \pm 0.58$	$8.67^{a} \pm 0.58$
	Hot Distilled water	$8.33^{c} \pm 0.58$	$8.00^{b} \pm 0.00$	$8.00^{a} \pm 0.00$
	Acetone	$17.33^{a} \pm 0.58$	$8.00^{b} \pm 0.00$	$8.00^{a} \pm 0.00$
	Methanol	$8.33^{c} \pm 0.58$	$8.33^{ab} \pm 0.58$	$8.33^{a} \pm 0.58$
Satureja hortensis	Distilled water	$9.33^{c} \pm 0.58$	$9.67^{a} \pm 0.58$	$8.33^{b} \pm 0.58$
	Hot Distilled water	$9.33^{c} \pm 0.58$	$9.67^{a} \pm 0.58$	$8.00^{b} \pm 0.00$
	Acetone	$14.33^{a} \pm 1.15$	$10.33^{a} \pm 0.58$	$10.00^{a} \pm 0.00$
	Methanol	$11.67^{b} \pm 0.58$	$11.33^{a} \pm 1.15$	$10.67^{a} \pm 0.58$
***Origanum majorana* L.**	Distilled water	$9.00^{a} \pm 0.00$	$8.00^{a} \pm 0.00$	$8.00^{b} \pm 0.00$
	Hot Distilled water	$8.00^{b} \pm 0.00$	$8.33^{a} \pm 0.58$	$8.00^{b} \pm 0.00$
	Acetone	$8.00^{b} \pm 0.00$	$8.00^{a} \pm 0.00$	$9.33^{a} \pm 0.58$
	Methanol	$9.33^{a} \pm 0.58$	$8.67^{a} \pm 0.58$	$9.33^{a} \pm 0.58$
***Santolina chamaecyparissus* L.**	Distilled water	$9.67^{c} \pm 0.58$	$8.33^{c} \pm 0.58$	$8.33^{b} \pm 0.58$
	Hot Distilled water	$9.00^{c} \pm 0.00$	$9.33^{bc} \pm 0.58$	$9.33^{b} \pm 0.58$
	Acetone	$14.67^{a} \pm 0.58$	$10.33^{ab} \pm 0.58$	$9.67^{b} \pm 0.58$
	Methanol	$11.33^{b} \pm 0.58$	$11.33^{a} \pm 0.58$	$11.67^{a} \pm 0.58$
***Coriandrum sativum* L.**	Distilled water	$8.67^{b} \pm 0.58$	$11.33^{a} \pm 1.15$	$10.67^{a} \pm 1.15$
	Hot Distilled water	$9.67^{ab} \pm 0.58$	$10.00^{ab} \pm 0.00$	$9.67^{ab} \pm 0.58$
	Acetone	$10.67^{a} \pm 0.58$	$8.33^{b} \pm 0.58$	$8.33^{b} \pm 0.58$
	Methanol	$11.00^{a} \pm 1.00$	$11.00^{a} \pm 1.00$	$10.67^{a} \pm 0.58$
***Trachyspermum involucratum* L.**	Distilled water	$14.00^{a} \pm 1.00$	$12.00^{ab} \pm 1.00$	$10.00^{b} \pm 1.00$
	Hot Distilled water	$14.67^{a} \pm 1.53$	$14.00^{a} \pm 1.00$	$13.67^{a} \pm 0.58$

	Acetone	$10.33^{b} \pm 0.58$	$8.33^{c} \pm 0.58$	$11.00^{b} \pm 1.00$
	Methanol	$11.33^{b} \pm 0.58$	$11.67^{b} \pm 0.58$	$10.33^{b} \pm 0.58$

Notes: Data are means of three replicates (n = 3) ± standard deviation. The well diameter is 8.00 mm, if the DIZ is 8.00 mm means the extract had no activity against bacterium. Means with rows and column different letters are significantly ($p< 0.05$) different.

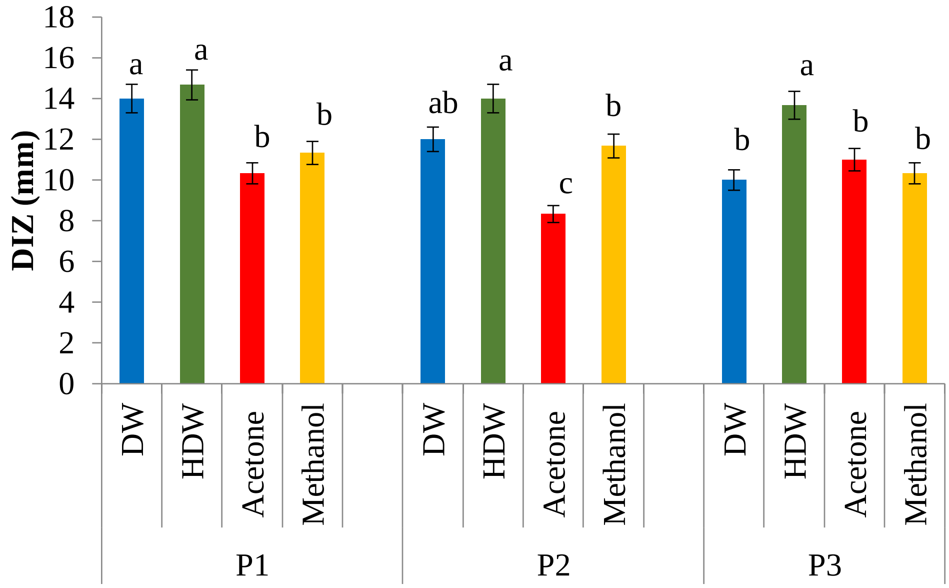

Figure 1. The diameter of the growth inhibition zone around the wells in *Trachyspermum involucratum* L. Columns with different letters are significantly ($p<0.05$) different. (P1- *E. coli* NCTC 10418, P2- *E. coli* ATCC 25922, P3- *Enterococcus faecalis*)

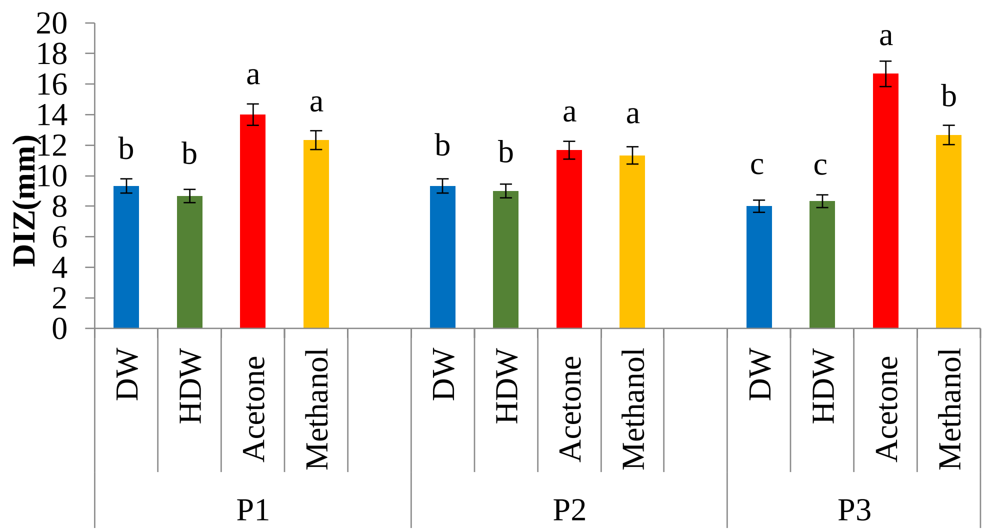

Figure 2. The diameter of the growth inhibition zone around the wells in *Rosmarinus officinalis* L. (Bush). Columns with different letters are significantly ($p<0.05$) different. (P1- *E. coli* NCTC 10418, P2- *E. coli* ATCC 25922, P3- *Enterococcus faecalis*)

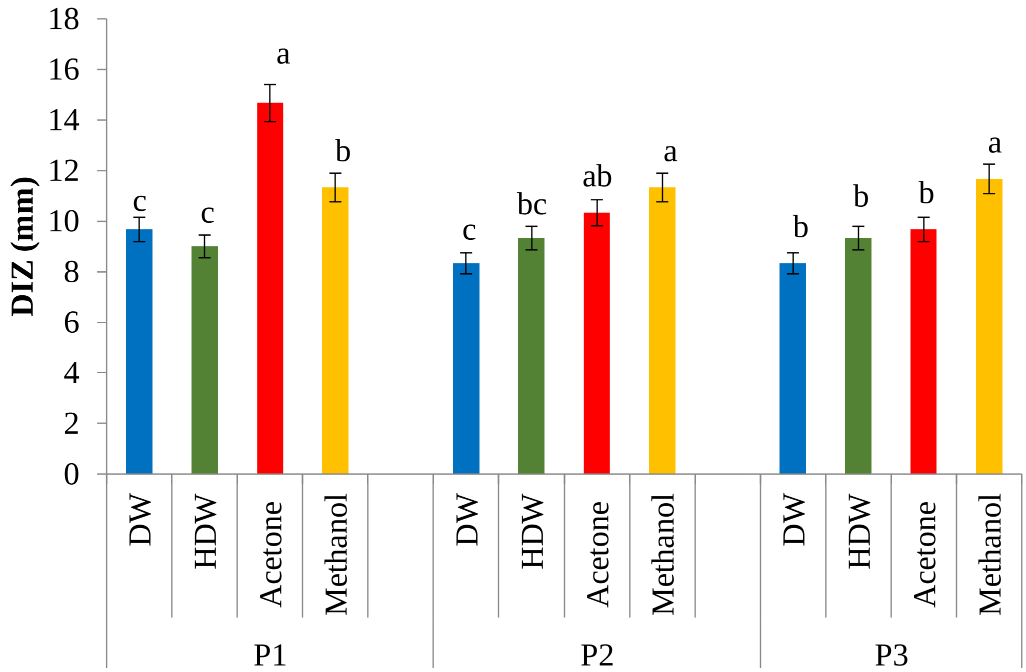

Figure 3. The diameter of the growth inhibition zone around the wells in *Santolina chamaecyparissus* L. Columns with different letters are significantly ($p<0.05$) different. (P1- *E. coli* NCTC 10418, P2- *E. coli* ATCC 25922, P3- *Enterococcus faecalis*)

Trachyspermum involucratum L. was the most effective herb that retards the growth of the three bacterial pathogens in a considerable amount for all tested extracts. The hot distilled water (80 ^{0}C) extract of *Trachyspermum involucratum* L. has significant antibacterial activity against *E. coli* NCTC 10418 (DIZ=14.67 mm) followed by *E. coli* ATCC 25922 (DIZ=14.00 mm) and *Enterococcus faecalis* (DIZ=13.67 mm) compared to other extracts of the herb (Figure 1**)**. The bioactive compounds present in the water extract of *Trachyspermum involucratum* L. as thymol, dipentene like compounds may cause the growth reduction of the tested foodborne pathogens (Gunathilake and Ranaweera, 2016). *Trachyspermum involucratum* L. is commonly known as asamodagam which is one of the famous medicines for abdominal pain caused by different foodborne pathogenic bacteria. Normally, the seeds of asamodagam herb are used as a medicine, but the leaves of the herb also have the potential to inhibit the growth of foodborne pathogenic bacteria as shown in the results.

The acetonic extract of *Rosmarinus officinalis* L. (Bush) showed more activity against *Enterococcus faecalis* (DIZ=16.67 mm) in comparison to other extracts (methanol and water extracts). However, the methanol extract of *Rosmarinus officinalis* L. (Bush) exhibited a substantial zone of inhibition against all tested microorganisms in the present study (Figure 2**)**. The inhibitory effect of *Rosmarinus officinalis* L. is the result of the action of rosmarinic acid, rosmaridiphenol, carnosol, epirosmanol, and rosmanol present in the herb (Nieto *et al*., 2018).

As shown in Figure 3, the methanol and acetone extractions of *Santolina chamaecyparissus* L. showed antibacterial activity (11.33-14.67 mm) against all tested foodborne pathogenic microorganisms. The water extracts (distilled and hot distilled water) of *Santolina chamaecyparissus* L. also contributed to the inhibition of bacterial growth with a notable inhibition zone ranging from 8.33 mm to 9.67 mm. The literature search revealed as the herb contains artemisia ketone, di-hydro aromadendrene, β-phellandrene, camphor, and cubenol active compounds that proved to be effective against various foodborne pathogens (Niu *et al.*, 2019).

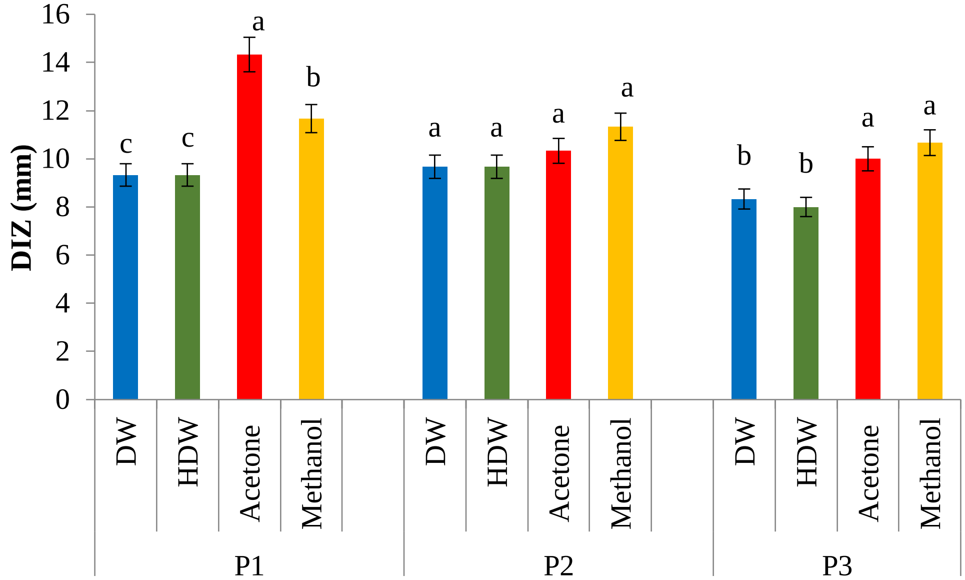

Figure 4. The diameter of the growth inhibition zone around the wells in *Satureja hortensis*. Columns with different letters are significantly ($p<0.05$) different. (P1- *E. coli* NCTC 10418, P2- *E. coli* ATCC 25922, P3- *Enterococcus faecalis*)

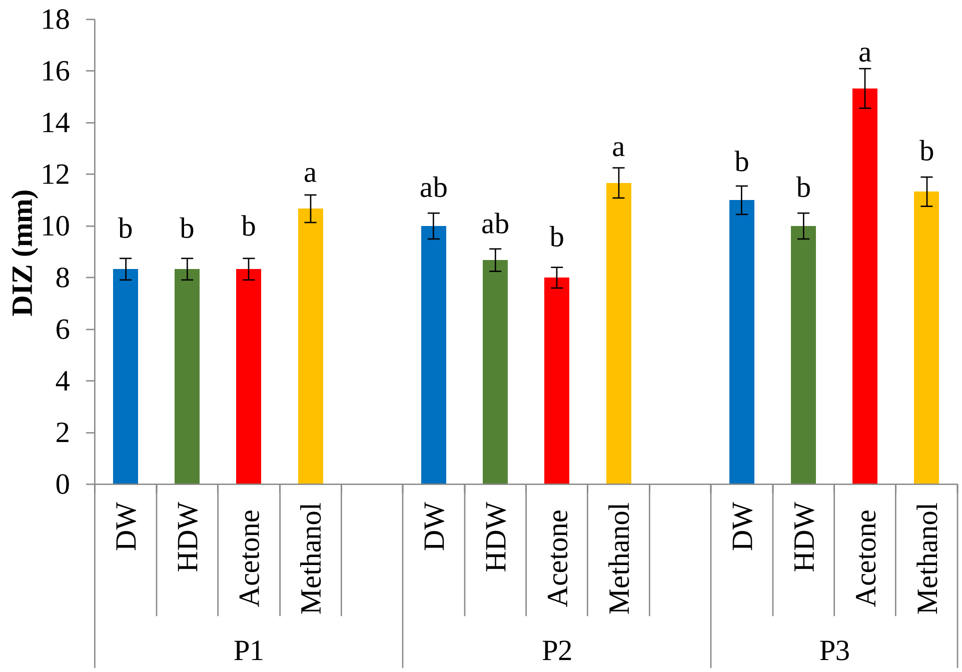

Figure 5. The diameter of the growth inhibition zone around the wells in *Origanum vulgare* L. Columns with different letters are significantly ($p<0.05$) different. (P1- *E. coli* NCTC 10418, P2- *E. coli* ATCC 25922, P3- *Enterococcus faecalis*)

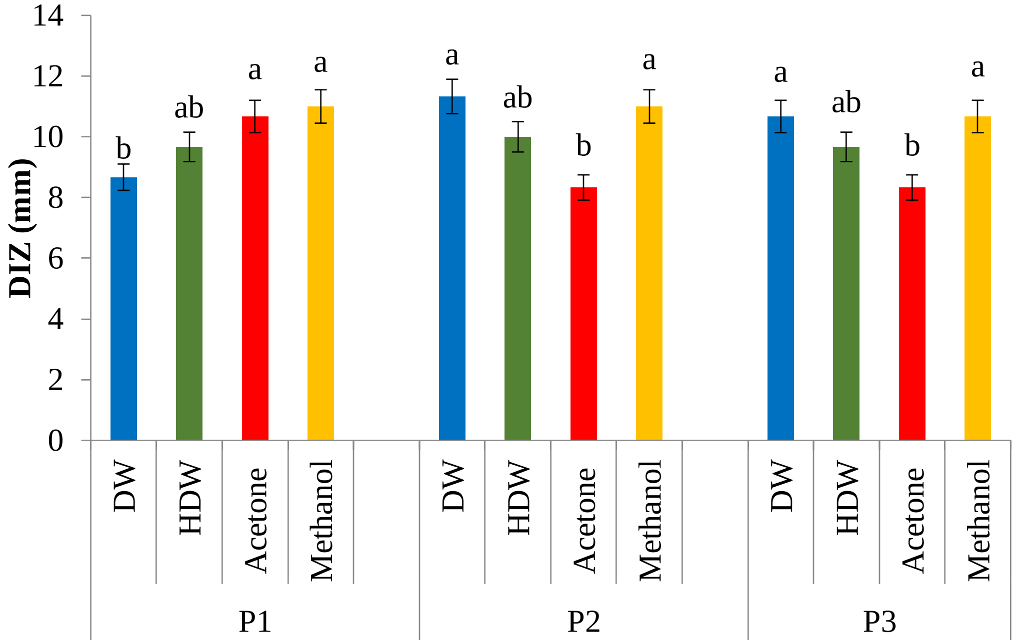

Figure 6. The diameter of the growth inhibition zone around the wells in *Coriandrum sativum* L. Columns with different letters are significantly (*p<0.05*) different. (P1- *E. coli* NCTC 10418, P2- *E. coli* ATCC 25922, P3- *Enterococcus faecalis*)

Satureja hortensis is another herb that showed antibacterial activity against tested pathogens. The acetonic extract of *Satureja hortensis* showed a higher inhibitory effect (DIZ=14.33 mm) against *E. coli* NCTC 10418 over other tested pathogens. The presence of high phenolic compounds such as thymol, carvacrol, or p-cymene caused the antimicrobial activity of *Satureja hortensis* (Mahboubi and Kazempour, 2011). In the present study, methanolic extract of *Satureja hortensis* also has antibacterial activity against all tested microbes (Figure 4).

As shown in Figure 5, all the extracts of *Origanum vulgare* L. herb displayed considerable inhibitory effect against all three pathogens. However, the methanolic extract of *Origanum vulgare* L. showed more antibacterial activity compared to the other extracts. *Origanum vulgare* L. has a wide variety of secondary metabolites, most of the phenolic compounds such as flavonoids, terpenoids, phenolic acids, and alkaloids, which are the main components responsible for its action (Teles *et al.*, 2019).

Coriandrum sativum L. is one of the famous herbs commonly used for culinary and medicinal purposes. The present study showed all the extracts of *Coriandrum sativum* L. has the potential to inhibit the growth of all three pathogens (Figure 6). The presence of a wide range of phytochemical constituents as alkaloids, flavonoids, saponins, and terpenoids can be beneficial to inhibit the growth of pathogenic microbes (Patel and Vakilwala, 2016).

As the results are shown in Table 2; *Rosmarinus officinalis* L. (Tree), *Melissa officinalis*, *Allium schoenoprasum*, *Allium tuberosum*, *Laurus nobilis* L., and *Origanum majorana* L. of all extractions (water, methanol, and acetone) showed less inhibitory effect against all tested foodborne bacterial pathogens. Among these less antibacterial active herbs, acetonic and methanolic extracts of some herbs have the notable antibacterial potential against particular microbe comparison to the water extract of that herb. As an example, the acetone extract of *Rosmarinus officinalis* L. (Tree) (DIZ=17.67 mm), *Melissa officinalis* (DIZ=14.33 mm) and *Allium schoenoprasum*

(DIZ=14.67 mm) showed antibacterial potential against *Enterococcus faecalis*. In particular, the aqueous extracts of *Allium schoenoprasum* and *Allium tuberosum* had no antibacterial activity against all of the three tested foodborne bacterial pathogens.

However, the results of the present study showed *Enterococcus faecalis* has highly inhibited the growth followed by *E. coli* NCTC 10418 and *E. coli* ATCC 25922 in the six herbs selected as the best antibacterial herbs out of the twelve herbs. But in general, those six herbs have the potential to inhibit the growth of all tested pathogens in comparison with the other herbs.

The extraction of biologically active compounds from plant material mostly depends on the sort of solvent employed in the extraction procedure. Extraction of *Rosmarinus officinalis* L. (bush) and *Origanum vulgare* L. with acetone has resulted in an exceedingly product with larger overall antibacterial activity than extraction with methanol and water. This might be the result of dissolving agent could be a sensible solvent because of its ability to dissolve in each polar and nonpolar substance, whereas other solvents can only dissolve one or the opposite. Further, methanolic extracts of *Santolina chamaecyparissus* L. and *Satureja hortensis* showed higher inhibition against *E. coli* ATCC 25922 and *Enterococcus faecalis*. The present study disclosed that organic extracts provided additional powerful antibacterial activity compared to aqueous extracts. However, a number of the herbs as *Trachyspermum involucratum* L. and *Coriandrum sativum* L. have higher antibacterial activity in the aqueous extract.

Researchers investigated the potential of herb extracts and their effective compounds as antimicrobial agents to manage the accretion of foodborne infective bacterium. Some researchers have shown the restrictive result of those herb extracts to property characters of herb extracts that modify them to react with the super-molecule (protein) of the microbial cell membrane and mitochondria distressful their structures and dynamical their porousness might disrupt of microorganism (Burt, 2004). Different researchers have urged that antimicrobial compounds of the herbal extracts move with enzymes and proteins of the microbial cell membrane, inflicting its disruption to disperse a flux of protons towards the cell exterior, that induces death or may inhibit enzymes necessary for organic compound biogenesis (Gill and Holley, 2006).

3.2. Determination of Minimum Inhibitory Concentration (MIC)

The minimum inhibitory concentration was determined for six herbs that were selected as the best antibacterial herbs out of the twelve culinary herbs against three tested foodborne bacterial pathogens. The results of the MIC values of herb extracts were presented in Table 3.

The MIC results of best antibacterial active herbs demonstrated that overall organic extracts and the aqueous extracts have 0.15 g mL^{-1} and 0.2 g mL^{-1} MIC values to inhibit the growth of *E. coli* NCTC 10418, *E. coli* ATCC 25922, and *Enterococcus faecalis*. When comparing the MIC values of the tested herbs, all four extracts of *Origanum vulgare* L. and *Rosmarinus officinalis* L. (Bush) were inhibited the growth of *E. coli* NCTC 10418 and *E. coli* ATCC 25922 at the concentration of 0.2 g mL^{-1}, whereas the organic extracts of these two herbs inhibited the growth of *Enterococcus faecalis* at the concentration of 0.15 g mL^{-1}.

In particular, the organic extracts (acetone, methanol) of *Satureja hortensis*, *Santolina chamaecyparissus* L., and *Coriandrum sativum* L. inhibited the growth of the most tested pathogens at the concentration of 0.15 g mL^{-1}. However, the hot distilled water extract of *Trachyspermum involucratum* L. inhibited the growth of *E. coli* NCTC 10418, *E. coli* ATCC 25922, and *Enterococcus faecalis* at the concentration of 0.15 g mL^{-1}. It has been established that MIC results do not always correlate well with the DIZ values but, in the present investigation, the observation of MIC related with the DIZ value might be due to the adoption of well diffusion assay for both antimicrobial activity and MIC determination of herb extracts (Dhiman *et al.*, 2016).

Table 3. MIC ($g\ mL^{-1}$) of Herb Extracts in Different Solvents

Herb	**Type of Extract**	**MIC value for herb extracts ($g\ mL^{-1}$)**		
		E. coli NCTC 10418	*E. coli* ATCC 25922	*Enterococcus faecalis*
***Origanum vulgare* L.**	Distilled water	0.2	0.2	0.2
	Hot distilled water	0.2	0.2	0.2
	Acetone	0.2	0.2	0.15
	Methanol	0.2	0.15	0.15
***Rosmarinus officinalis* L. (Bush)**	Distilled water	0.2	0.2	0.2
	Hot distilled water	0.2	0.2	0.2
	Acetone	0.2	0.2	0.15
	Methanol	0.2	0.2	0.15
Satureja hortensis	Distilled water	0.2	0.2	0.15
	Hot distilled water	0.2	0.2	0.2
	Acetone	0.2	0.15	0.15
	Methanol	0.15	0.2	0.15
***Santolina chamaecyparissus* L.**	Distilled water	0.2	0.2	0.2
	Hot distilled water	0.2	0.2	0.2
	Acetone	0.15	0.15	0.15
	Methanol	0.15	0.15	0.15
***Coriandrum sativum* L.**	Distilled water	0.2	0.2	0.15
	Hot distilled water	0.2	0.15	0.15
	Acetone	0.2	0.2	0.2
	Methanol	0.15	0.15	0.15
***Trachyspermum involucratum* L.**	Distilled water	0.2	0.2	0.2
	Hot distilled water	0.15	0.15	0.15
	Acetone	0.2	0.2	0.15
	Methanol	0.2	0.15	0.2

4. Conclusions

The results of the present study established that *Trachyspermum involucratum* L., *Rosmarinus officinalis* L. (Bush), *Santolina chamaecyparissus* L., *Satureja hortensis*, *Origanum vulgare* L. and *Coriandrum sativum* L. have the higher antibacterial activity out of twelve culinary herbs against all tested foodborne pathogenic bacteria. *Enterococcus faecalis* has highly inhibited the growth followed by *E. coli* NCTC 10418 and *E. coli* ATCC 25922 in the six herbs selected as the best antibacterial herbs out of the twelve herbs. Organic extracts as methanolic and acetonic extracts are the most effective extraction solvents which can use for making plant extracts. Therefore, culinary herbs proved to be potentially effective as natural antimicrobials with effective, nontoxic, and natural compounds.

5. References

Allard, M. W., Bell, R., Ferreira, C. M., Gonzalez-Escalona, N., Hoffmann, M., Muruvanda, T., Ottesen, A., Ramachandran, P., Reed, E., Sharma, S. and Stevens, E., 2018. Genomics of foodborne pathogens for microbial food safety. *Current Opinion in Biotechnology*, 49, 224–229.

Bozin, B., I. B., Mimica-Dukic, N., Samojlik, I. and Jovin, E., 2007. Antimicrobial and antioxidant properties of rosemary and sage (Rosmarinus officinalis L. and Salvia officinalis L., Lamiaceae) essential oils. *Journal of Agricultural and Food Chemistry, 55(19)*, pp. 7879–7885.

Burt, S., 2004. Essential oils : their antibacterial properties and potential applications in foods - a review. *International Journal of Food Microbiology*, 94(3), 223–253.

Dhiman, R., Aggarwal, N., Aneja, K.R. and Kaur, M., 2016. In vitro antimicrobial activity of spices and medicinal herbs against selected microbes associated with juices. *International Journal of Microbiology*, 2016, 1-10.

Gill, A.O. and Holley, R. A., 2006. Disruption of *Escherichia coli* , *Listeria monocytogenes* and *Lactobacillus sakei* cellular membranes by plant oil aromatics. *International Journal of Food Microbiology*, 108(1), 1–9.

Gunathilake, K. P. P. and Ranaweera, K. K. D. S., 2016. Antioxidative properties of 34 green leafy vegetables. *Journal of Functional Foods*, 26, 176–186.

Hinneburg, I., Dorman, H.D. and Hiltunen, R., 2006. Antioxidant activities of extracts from selected culinary herbs and spices. *Food chemistry*, 97(1), 122-129.

Jeyaseelan, E.C, and Jashothan, P.J., 2012. In vitro control of Staphylococcus aureus (NCTC 6571) and *Escherichia coli* (ATCC 25922) by *Ricinus commu*nis L. *Asian Pacific Journal of Tropical Biomedicine,*2(9), 717–721.

Mahboubi, M. and Kazempour, N., 2011. Chemical composition and antimicrobial activity of Satureja hortensis and Trachyspermum copticum essential oil. *Iraanian Journal of Microbiology*, 3(4), 194–200.

Mostafa, A.A., Al-askar, A.A., Almaary, K.S., Dawoud, T.M., Sholkamy, E.N. and Bakri, M.M., 2018. Antimicrobial activity of some plant extracts against bacterial strains causing food poisoning diseases. *Saudi Journal of Biological Sciences* 25 (2): 361–366.

Nieto, G., Ros, G. and Castillo, J., 2018. Antioxident and antimicrobial properties of rosemary (*Rosmarinus officinalis*, L.): Reveiew. *Medicines*, 5(3), 98.

Niu, L.L., Qin, Q.P., Wang, L.T., Gai, Q.Y., Jiao, J., Zhao, C.J. and Fu, Y.J., 2019. Chemical pro filing of volatile components of micropropagated *Santolina chamaecyparissus* L. *Industrial Crops & Products*, 137, 162–170.

Opara, E.I. and Chohan, M., 2014. Culinary herbs and spices: their bioactive properties, the contribution of polyphenols and the challenges in deducing their true health benefits. *International Journal of Molecular Sciences*, 15(10), 19183-19202.

Panpatil, V.V., Tattari, S., Kota, N., Nimgulkar, C. and Polasa, K., 2013. In vitro evaluation on antioxidant and antimicrobial activity of spice extracts of ginger, turmeric and garlic. *Journal of Pharmacognosy and phytochemistry*, *2*(3), 143-148.

Patel, K. and Vakilwala, M. 2016. phytochemical study and bioactivity of solvent extracts on *Coriandrum sativum*, *International Journal of Advanced Research in Biological Sciences* 3(5), 193–199.

Pesavento, G., Calonico, C., Bilia, A.R., Barnabei, M., Calesini, F., Addona, R., Mencarelli, L., Carmagnini, L., Di Martino, M.C. and Nostro, A.L., 2015. Antibacterial activity of Oregano, Rosmarinus and Thymus essential oils against *Staphylococcus aureus* and *Listeria monocytogenes* in beef meatballs. *Food Control*, 54, 188-199.

Ruangpan, L. and Tendencia, E.A., 2004. *Laboratory manual of standardized methods for antimicrobial sensitivity tests for bacteria isolated from aquatic animals and environment.* Aquaculture Department, Southeast Asian Fisheries Development Center.

Sankar, R., Karthik, A., Prabu, A., Karthik, S., Shivashangari, K.S. and Ravikumar, V., 2013. *Origanum vulgare* mediated biosynthesis of silver nanoparticles for its antibacterial and anticancer activity. *Colloids and Surfaces B: Biointerfaces*, 108, 80-84.

Sharififar, F., Moshafi, M.H., Mansouri, S.H., Khodashenas, M. and Khoshnoodi, M., 2007. In vitro evaluation of antibacterial and antioxidant activities of the essential oil and methanol extract of endemic *Zataria multiflora* Boiss. *Food Control*, 18(7), 800–805.

Shan, B., Cai, Y.Z., Brooks, J.D. and Corke, H., 2007. The in vitro antibacterial activity of dietary spice and medicinal herb extracts. *International Journal of Food Microbiology*, 117(1), 112–119.

Sudershan, R.V., Naveen Kumar, R., Kashinath, L., Bhaskar, V. and Polasa, K., 2014. Foodborne infections and intoxications in Hyderabad India. *Epidemiology Research International*, 2014.

Teles, A. M., Rosa, T.D.D.S., Mouchrek, A. N., Abreu-silva, A. L., Calabrese, K.D.S. and Almeida-souza, F., 2019. Cinnamomum zeylanicum, Origanum vulgare, and Curcuma longa essential oils : Chemical composition , antimicrobial and antileishmanial activity. *Evidence-Based Complementary and Altrnative Medicine, 2019*.

Weerakkody, N.S., Caffin, N., Turner, M.S. and Dykes, G.A., 2010. In vitro antimicrobial activity of less-utilized spice and herb extracts against selected food-borne bacteria. *Food Control*, *21*(10), 1408-1414.

Wong, P.Y. and Kitts. D.D., 2006. Studies on the dual antioxidant and antibacterial properties of parsley (*Petroselinum crispum*) and cilantro (*Coriandrum Sativum*) extracts. *Food Chemistry*, 97(3), 505–515.

Witkowska, A.M., Hickey, D.K., Alonso-Gomez, M. and Wilkinson, M., 2013. Evaluation of antimicrobial activities of commercial herb and spice extracts against selected foodborne bacteria. *Journal of Food Research*, 2(4), 37