Antibacterial effects and microbial quality of commonly consumed herbs in Dubai, United Arab Emirates

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Abstract

Herbal plants are traditionally known to exhibit antimicrobial properties and used in several countries as an alternative to modern pharmaceutical drugs. This study investigated the antibacterial properties and microbial quality of common herbs used in the United Arab Emirates (UAE). In total, 20 herb samples of parsley *(Petroselinum crispum)*, basil *(Ocimum basilicum)*, sage *(Salvia officinalis)*, mint *(Mentha spicata)*, and thyme *(Thymus vulgaris)* were randomly collected and analysed for the total aerobic bacteria count, yeasts and molds, *Escherichia coli, Staphylococcus aureus, Salmonella* and *Pseudomonas aeruginosa* by standard plate counting method using selective and differential culture media. Antibacterial effects of herbs on *E.coli, S. aureus, Salmonella* and *P. aeruginosa* were tested by disk diffusion method. The microbial analysis of herbs revealed that 50% of herb samples exceeded the world health organization (WHO) limit for the total aerobic bacteria count, and 75% exceeded the permissible limit for total molds and yeast count. 75% of herb samples were found contaminated with *Escherichia coli* and *Salmonella* spp, 65% with *Shigella*, and 10% exceeded the WHO permissible limit for *Pseudomonas aeruginosa*. However, all herb samples were found to be within the WHO acceptable limit for *Staphylococcus aureus*. All herbal extracts exhibited some form of antibacterial activity against *E. coli, S. aureus, Salmonella* and *P. aeruginosa* except for parsley, which had no inhibitory effect on *S. aureus*. However, the results of microbial quality suggest that most of the analysed herbs had unsafe microbial contamination that exceeded the World Health Organization permissible limits. Therefore, strict measures to reduce the risk of microbial contamination by applying Hazard Analysis and Critical Control Point (HACCP) need to be implemented on local and imported herbs prior to consumption.

Introduction

The use of herbal plants has been growing rapidly worldwide. Several herbs have shown antimicrobial activities towards different types of microorganisms. As a result, researchers have explored the antibacterial activity of various types of herbs as alternatives to antimicrobial agents present in the market (Škrinjar and Nemet, 2009). In the United Arab Emirates (UAE), herbal plants are commonly used for their flavoring and curative properties (HAAD, 2005). According to a study on the diversity and conservation status of plants in the UAE, 18% of the plant species were found to possess medicinal properties (Sakkir *et al.*, 2012). In Abu Dhabi, 65 different herbs were used by the local population to treat 48 conditions (AlBraik *et al.*, 2008). While there is a widespread perception that herbs are inherently safe, incidences of intoxications following the use of these herbs have been reported in different parts of the world (Ernst, 2002). Herbs could be contaminated with microorganisms, heavy metals, and pesticides. A recent study that examined the level of heavy metals contamination in several herbs commonly sold in the Dubai local market has shown that most of the analysed herbs contained unsafe levels of heavy metals that exceeded the internationally acceptable permissible limits for these metals in herbs and medicinal plants (Dghaim *et al.*, 2015). The chemical and microbial quality of herbal plants and their formulations depend on various factors including geography, climatic conditions, water, soil and air pollution, growth, transport and storage conditions, and many other environmental factors (Saad *et al.*, 2006). As a result, herbs could act as a vehicle for microbiological hazards as they are ingested with minimal processing prior to consumption (Sospedra *et al.*, 2010).

Among the microorganisms that have been identified in herbs are *Escherichia coli, Salmonella* spp., Pseudomonas aeruginosa and Staphylococcus aureus (Cosano *et al.*, 2009). Many outbreaks of salmonellosis have been associated with the ingestion of contaminated herbs (Vij *et al.* 2006).

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Salmonellosis was reported among 131,468 cases in the European Union (EU) in 2008. *Salmonella* spp. were found to be responsible for 35.4% of all reported outbreaks and for 55.1% of the verified outbreaks (EFSA, 2012). *Escherichia coli (E. coli)* is another gram-negative bacterium that is naturally found in the human intestinal tract. However, *E. coli* could be an indicator of faecal contamination of soil or water (Vitullo *et al*., 2011). Studies have shown that contaminated irrigation water could transfer *E. coli* and other pathogenic bacteria into growing herbs (Song *et al*., 2006). *Staphylococcus aureus* is a gram-positive bacterium that can cause nosocomial infections in humans. *S. aureus* could contaminate the exterior of the herb through handling processes. The presence of *S. aureus* could indicate improper hygiene practices during harvesting, processing and storage (Vitullo *et al*., 2011).

A widespread presence of herbs contaminated with pathogenic microorganisms has been found in different parts of the world. These herbs are usually imported from places with poor hygienic conditions and practices (Vitullo *et al.*, 2011). In the UAE, herbs are imported from different areas of the world, which may contribute to the risk of selling herbs that are highly contaminated with microorganisms. To our knowledge, there are no studies that have investigated the antimicrobial effects and microbial quality of herbs sold in the UAE market. This study investigated the occurrence of selected opportunistic pathogenic bacteria, molds, and yeast in a number of the commonly consumed herbs in the UAE. More specifically, this study detects the total aerobic bacteria and the total yeast and mold count in five herbs (Parsley, Basil, Sage, Mint, and Thyme), determines the concentration of possible bacterial contaminants such as *Escherichia coli, Salmonella, Pseudomonas aeruginosa* and *Staphylococcus aureus*, and compares it with the WHO permissible limits. Furthermore, an antibacterial effect of five herbs used in this study was evaluated on selected opportunistic bacterial pathogens.

Materials and Methods

Sample collection and preparation

A total of 20 herb samples of Parsley *(Petroselinum crispum)*, Basil *(Ocimum basilicum)*, Sage *(Salvia officinalis)*, Mint *(Mentha spicata)*, and Thyme *(Thymus vulgaris)* were collected during the months of April and May 2014 from four local markets in the Emirate of Dubai. The samples were transported and stored at room temperatures and analyzed within 24 hours after collection.

All utensils were sterilised by either autoclaving at 121ºC for 15 minutes or kept in the oven at 71ºC for 1 hour. For the microbial quality of herbs, Wong and Kitts (2006) method was used with slight modification. All herb samples were ground, then diluted with sterile water in a 1:10 (w/v) ratio. The mixture was left in a shaker for 4 hours (h), followed by filtration. All extracts were used immediately for analysis. For the antimicrobial activity of herbs, the herb samples were grinded and diluted in absolute ethanol in a 1:10 (w/v) ratio i.e. 1 g of herb to 10 ml of absolute ethanol. Then the mixture was shaken manually for 5 minutes and left to stand for 30 minutes to allow the grounded herb to settle at the bottom and the extract to float at the top.

Total viable aerobic count (TVAC)

Serial dilutions and plate counts were used to determine the concentration of total aerobic bacteria and the total molds and yeasts. In the first step, a serial dilution was made by taking 1 ml of sample mixture and placing it into 9ml of distilled water to produce a 10-fold dilution. This step was repeated six more times, in which 1ml of the diluted solution was added to 9 ml of distilled water. For bacteria count, 0.1 ml of each dilution was added to culture plates with solidified casein-soybean digest agar (CSA). The culture plates were inverted and incubated at 35°C for 24-48 hours. The number of colonies formed was counted, and the CFU/g was calculated using the following equation: CFU/g = (number of colonies x dilution factor) / volume of diluted culture added. Colony-forming unit (CFU) is a measure of possible bacterial or fungal cell contamination. The higher dilutions were prepared to obtain a colony count within countable range. For molds and yeast count, solidified potato dextrose agar (PDA) was used. The culture plates were incubated at 25°C for 5 days and then the number of colonies formed were counted and calculated as CFU/g for samples with less than 100 colonies (WHO, 2007). The averages of duplicate plates were reported. The microbial quality of herb samples was assessed according to the WHO recommended limits (WHO, 2007).

Detection of specific bacterial species

To determine the level of possible bacterial contaminant species (*Escherichia coli, Salmonella, Pseudomonas aeruginosa* and *Staphylococcus aureus)*, specific microbial tests were conducted for each type of bacterium. The colonies were counted and reported as CFU/g and compared to the WHO permissible levels (WHO, 2007). For analysis of *E. coli*, 0.1 ml of the prepared herbal and sterile water

mixture up to 10-2 dilutions were added to solidify MacConkey agar culture plates and incubated at 45°C for 18–24 hours. The growth of red colonies indicated the possible presence of *E. coli.* To check the presence of *Salmonella*, 0.1 ml of the prepared herb/water solution without and with dilutions up to 10-2 were added to solidified Hektoen Enteric (HE) agar plates, and subsequently, plates were incubated at 37°C for 18–24 hours. The growth of blue-green with black center colonies indicated the possible presence of Salmonella. The growth of light green and orange colonies indicated the presence of *Shigella*, and other coliform bacteria, respectively. *Pseudomonas aeruginosa* colonies were counted by adding 0.1ml of the prepared herb/water mixture (without dilution) to Cetrimide agar (CA) plates followed by incubation of plates at 35°C for 18-72 hours. The growth of yellow-green to blue-green colonies indicated the possible presence of *Pseudomonas aeruginosa*. For *Staphylococcus aureus*, 0.1 ml of the prepared herb solution was added to Mannitol salt agar (MSA) followed by incubation of plates at 37°C for 18-24 hours. The growth of yellow colonies indicated the presence of *Staphylococcus aureus* species.

Evaluation of antibacterial effects

To investigate the antibacterial activity of herbs on *Escherichia coli, Salmonella, Pseudomonas aeruginosa* and *Staphylococcus aureus*, disk diffusion test method described by EUCAST (2013) was used. *Escherichia coli, Salmonella, Pseudomonas aeruginosa* and *Staphylococcus aureus* colonies were isolated and grown in Mueller-Hinton broth and incubated at 37°C for 24 hr. 0.5 McFarland turbidity standard was prepared by mixing 0.5 ml of 0.048 M $BaCl_2$ to 99.5 mL of 0.18 M $H2S04$. The density of standard was checked using spectrophotometer with absorbance at 625 nm in the range 0.08 to 0.13. The density of the growth culture suspension was compared visually to a 0.5 McFarland turbidity standard. If the density of the culture is more than the standard, more Mueller-Hinton broth was added. If the density of the culture is less than the standard, more of the culture was added. After that, 0.1ml of each broth sample was spread uniformly on a separate solidified Mueller-Hinton agar in a Petri dish. 100ºL of the prepared herb sample solution was pipetted onto sterile paper disks (6 mm in diameter) and placed on the surface of each agar plate. Plates were incubated for 24-48 hours at 37°C. Replicates for each herb solution were performed. The diameters of the zones of inhibition were measured (in mm) using a transparent meter ruler as described in EUCAST (2013).

Results

Total viable aerobic count

The concentrations of total aerobic bacteria and total molds and yeasts in herb samples (20 samples) using CSA and PDA culture media respectively are presented in Table 1. The occurrence of aerobic bacteria was observed in all 20 herb samples. All herb samples showed microbial growth with varied amounts. Out of the 20 herb samples, 10 samples (50%) exceeded the WHO limit for the total aerobic bacteria.

Parsley was found to be the most contaminated herb among all five herbs, and all parsley samples exceeded the WHO limit for total aerobic bacteria (Table 1). The average CFU/g for the total aerobic bacteria in Mint and Sage also exceeded the acceptable WHO limits. On the other hand, all Thyme and Basil samples were found within acceptable limits of WHO (Figure 1) shows the average CFU/g for total aerobic bacteria of each herb compared to WHO limit.

As for the total concentration of molds and yeasts, of the 20 samples, 15 (75%) exceeded the WHO limit for the total molds and yeasts (Table 1). Parsley and Mint were found to be most contaminated with all samples exceeding WHO limit for total molds and yeasts (Table 1). Thyme and Basil were the least contaminated herbs with mold and yeast; 2 out of 4 samples exceeded the acceptable limits of WHO.

Detection of specific bacterial species in herbs

Results for the determination of specific bacterial species concentration (CFU/g) in each herb sample of different origin are summarised in Table 2. A total of 15 out of 20 herb samples (75%) were found to be contaminated with *E.coli*. Similarly, 15 out of 20 herb samples (75%) were contaminated with *Salmonella* and 13 of 20 samples (65%) were contaminated with Shigella. In total, 8 out of 20 samples (40%) were contaminated with *P. aeruginosa*, and only 2 samples (10%) exceeded the WHO limit for *P. aeruginosa*. Thirteen out of 20 samples (65%) were contaminated with *S. aureus*. The concentration of *S. aureus* was found to be below the WHO limit in all samples.

Antibacterial activity of herbs

The antimicrobial activity of herbs was evaluated by measuring the zone of inhibition (mm). All control disk with absolute ethanol showed no growth inhibition with any of the microorganism including *E.coli, Salmonella, P. aeruginosa* and *S. aureus*. Extracts of different herbs, evaluated by disc diffusion assay, had the following relative inhibitory effects on E.coli: sage > thyme > basil > mint > parsley,

Table 1. Total viable aerobic bacteria, total mold and yeast count
(CFU/g) in each herb sample of different origin

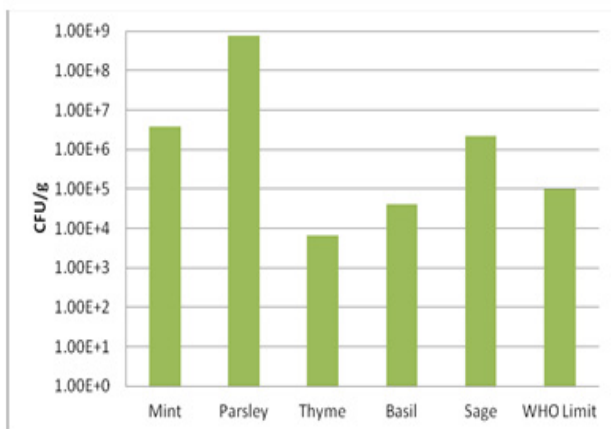| Herbs Name	Herb's Origin	Shop Number	TVAC(CFU/g)	Total mold and yeast (CFU/g)
Mint	Tunis	1	5.11×10^6	1.50×10^6
Mint	UAE	2	8.05×10^4	1.75×10^4
Mint	South Africa	3	1.4×10^4	1.40×10^4
Mint	Iran	4	9.87×10^6	3.70×10^6
Parsley	Tunis	1	1.89×10^9	1.38×10^7
Parsley	UAE	2	2.80×10^4	5.20×10^6
Parsley	Spain	3	2.04×10^6	1.50×10^4
Parsley	Bangladesh	4	2.19×10^7	3.70×10^6
Thyme	Spain	1	1.38×10^4	4.70×10^4
Thyme	France	2	8.63×10^4	7.73×10^4
Thyme	Turkey	3	7.00×10^4	0
Thyme	Iran	4	3.15×10^4	0
Basil	USA	1	1.53×10^5	3.33×10^5
Basil	UAE	2	4.00×10^4	0
Basil	Spain	3	4.47×10^4	1.75×10^4
Basil	Iran	4	4.65×10^4	0
Sage	Spain	1	1.70×10^6	4.90×10^4
Sage	Kenya	2	3.50×10^4	2.40×10^4
Sage	France	3	3.06×10^6	6.50×10^4
Sage	Syria	4	3.77×10^6	1.25×10^4

Figure 1. Average CFU/g for total aerobic bacteria in each herb compared to WHO limit

Salmonella: sage > mint > thyme > parsley > basil, *P. aeruginosa*: basil > sage > thyme > mint > parsley, *S. aureus*: thyme > sage > basil and mint where parsley showed no activity against *S. aureus*. There were no significant differences between the same herbs with different origin on the bacterial growth. Table 3 shows the mean value of the zone of inhibition in mm for each herb on *E.coli, Salmonella, P. aeruginosa* and *S. aureus*.

Discussion

Herbs could easily be contaminated with multiple pathogenic bacteria during their growth, harvest, processing or distribution phase (Tortora *et al.*, 2011). The results of this study showed that the total aerobic bacteria count and the total yeast and mold count, *E.coli, Salmonella*, and *Shigella* of most herb samples exceeded the WHO maximum limit. Several studies in the region have shown that herbal plants are contaminated with a broad variety of pathogenic microorganisms. An overall of 15.6% of herbal medicines collected randomly from the local market of the city of Riyadh, Saudi Arabia in 2008 showed enumeration limits that exceeded the US Pharmacopoeia limits set for the total fungal count. Additionally, 60% of the sampled herbs showed a presence of fungi, *Aspergillus flavus* and *Aspergillus fumigates* and other common microbial isolates (Alwakeel, 2008). Another study that examined the microbial quality of 79 medicinal herbs collected from the Egyptian market detected *Salmonella* spp. in 22.78% of the samples (Abou-Arab *et al.*, 1999). This indicates a potential health risk to the population in the region. One major factor that may contribute to herbal contamination with pathogenic microorganisms is the

Table 2. Concentration of specific bacterial species (CFU/g) in each herb
sample of different origin

Herb Name (Origin)	E.coli CFU/g	Salmonella CFU/g	Shigella CFU/g	P.aeruginosa CFU/g	S.aureus CFU/g
Mint (Tunis)	4.85×10^2	65.0	40.0	0	30.0
Mint (UAE)	1.00×10^4	1.15×10^3	1.80×10^3	1.49×10^3	20.0
Mint (South Africa)	0	20.0	0	0	50.0
Mint (Iran)	1.75×10^2	8.17×10^2	60.0	9.70×10^2	30.0
Parsley (Tunis)	1.85×10^5	1.00×10^4	3.00×10^4	9.80×10^2	70.0
Parsley (UAE)	9.60×10^4	4.00×10^3	2.00×10^4	8.70×10^2	1.60×10^2
Parsley (Spain)	30.0	1.20×10^2	60.0	20.0	1.00×10^2
Parsley (Bangladesh)	1.30×10^2	8.20×10^2	4.47×10^2	1.60×10^3	1.90×10^2
Thyme (Spain)	1.01×10^3	5.07×10^2	60.0	1.00×10^2	0
Thyme (France)	2.00×10^3	4.17×10^2	3.00×10^2	30.0	80.0
Thyme (Turkey) + (Iran)	0	0	0	0	0
Basil (USA)	2.28×10^3	4.97×10^2	8.17×10^2	0	20.0
Basil (UAE)	0	0	0	0	0
Basil (Spain)	40.0	0	0	0	0
Basil (Iran)	40.0	0	40.0	0	6.00×10^2
Sage (Spain)	4.83×10^2	20.0	0	0	0
Sage (Kenya)	0	10.0	0	0	0
Sage (France)	1.39×10^3	40.0	1.20×10^2	0	0
Sage (Syria)	3.00×10^2	20.0	1.50×10^2	0	80.0

use of wastewater for irrigation. Wastewater used for irrigation of herbs and plants may act as a fertilizer; however, wastewater also includes salts, some toxic chemicals and pathogen microorganisms, which can be transferred into the herb and eventually into the human body (Halablab *et al.*, 2011).

The total aerobic bacterial count and total yeast and mold count reflect the general contamination of the herb samples and the presence of a favourable environment for the growth of microorganisms (Tortora *et al.*, 2011). The total aerobic bacterial count and total yeast and mold count should not exceed 10^5 CFU/g and 10^3 CFU/g, respectively, to consider these herbs safe for human consumption (WHO, 2007). The highest mean count of bacteria was detected in parsley while the lowest contamination was in found in thyme and basil. The total aerobic bacterial count and the total yeasts and molds count in herbs of the same type varied according to their countries of origin. Microbial contamination of imported fresh herbs has been observed in several other studies. In the UK during 2005 and 2006, Salmonella contamination was identified in 13.1% of imported fresh herbs from non-EU countries examined at the point of entry, including a variety of basil grown in Thailand (Sagoo *et al.*, 2009). Similarly, in 2005 and 2007 in Norway, 28% and

15% respectively, of imported fresh pre-cut herbs of basil, mint, and coriander from Southeast Asia were contaminated with *Salmonella* spp. and 35% of imported fresh herbs in 2005 were contaminated with *E coli*. The difference in the total aerobic bacterial count and total yeast and mold count values between these different origins was attributed to differences in agriculture and irrigation practices (Halablab *et al.*, 2011). The high total aerobic bacterial count in mint, parsley, and sage beyond WHO limits have been observed in several other studies (Johnston *et al.*, 2005; Halablab *et al.*, 2011; Vitullo *et al.*, 2011). Unlike studies that have shown that basil and thyme had the highest mean total aerobic bacterial count among all other herbs tested (Remiszewski *et al.*, 2006; Wójcik-Stopczyñska *et al.*, 2009), the average total aerobic bacterial count in basil and thyme in the analysed samples did not exceed the permissible limits.

The contamination of 75% of herb samples with *E.coli* is an indicator of faecal contamination and the possible presence of enteric pathogens (Abou-Arab *et al.*, 1999). This may result from faecal contamination either by individuals, animals, or contaminated irrigation water (Viswanathan and Kaur, 2001). In this study, the presence of *E.coli* in herb samples ranged from 7.03×10^4 CFU/g in parsley to 5.43×10^2

Table 3. Zone of inhibition (in mm) for each herb on
E.coli, Salmonella, P. aeruginosa and *S. aureus.*

Herbs Name (origin)	Salmonella (mm)	E.coli (mm)	S. aureus (mm)	P. aeruginosa (mm)
Mint	1.75±2.22*	0.5±1	0.5±0.57	1±0
Parsley	0.625±0.75	0.25±0.5	0±0	0.75±0.95
Basil	0.25±0.5	1±1.41	0.25±0.5	1.625±0.85
Sage	3.625±3.03	3.25±3.77	0.5±1	1.25±0.64
Thyme	1.125±1.65	2±1.41	0.625±1.25	1.125±0.25

*Mean±Standard Deviation

CFU/g in sage. Similar findings on contamination of herbs with *E. coli* had been reported in many other studies (Chomnawang *et al.*, 2003; Johnston *et al.*, 2005; Remiszewski *et al.,* 2006; Elviss *et al.*, 2009; Halablab *et al.*, 2011). In this study, high *E.coli* count was observed in parsley samples imported from less developed countries. In general, the globalisation of food supplied in fresh produce brings with it some health risks, including microbial contamination resulting from the use of untreated sewage water for irrigation and other growth and processing factors. *Salmonella* and *Shigella* are gram-negative bacteria that are the leading cause of gastroenteritis worldwide. *Salmonella* should be absent in treated ready-to- eat spices and herbs (CODEX, 1995). The result of this study showed that 75% of herb samples were contaminated with *Salmonella,* and 65% of herb samples were contaminated with *Shigella. Salmonella* has been demonstrated to have a high desiccation tolerance, and thus they can survive for an extended period even in dried herbs (Zweifel and Stephan, 2012). Washing samples with potable water in addition to disinfecting agents can reduce contamination, but cannot ensure complete elimination (European Commission, 2002, Doyle and Erickson, 2008; Elviss *et al.*, 2009). Therefore, effective decontamination and correct food handling practices are critical to eliminating these pathogenic bacteria in herbs.

P. aeruginosa is an opportunistic pathogenic bacterium commonly found in soil and natural environments and can cause severe, life-threatening infections in the urinary tract, burns, and wounds in immunocompromised patients (Owlia *et al.*, 2010). In this investigation, 40% of herb samples were contaminated with P. aeruginosa, whereas only 10% of the samples exceeded the WHO limit for *P. aeruginosa.*

While plate count tests are the quick, useful tool to identify microbial contaminants in fresh herbs, studies have shown discrepancies between quantitative polymerase chain reaction (qPCR)

and plate counts in the analysis of authentic food supplements (Rossi *et al.*, 2010).

According to WHO and FAO, green leafy vegetables including fresh herbs present the greatest concern regarding microbiological hazards based on the number of microbial related outbreaks worldwide (Elviss *et al.*, 2009). Given the microbiological concerns about the quality of herbs sold in the UAE market, the relevant authorities should be vigilant in ensuring food safety control of both domestic and imported fresh herbal produce. Strategies should be developed to ensure safe agriculture, manufacture, and processing practices, and to implement a hazard analysis critical control point (HACCP) system.

The antimicrobial activity of five herb types was evaluated by measuring the zone of inhibition against *E. coli, Salmonella, S. aureus* and *P. aeruginosa.* The results of this study found no significant difference between the similar herbs with different origin on the antimicrobial activity of herbs. This result is similar to another study conducted by Nzeako, Al-Kharousi and Al-Mahrooqui (2006) in which the researchers noticed no difference in antimicrobial activity between Iranian thyme or Omani thyme. Also, all herbs have shown some antibacterial activity against *E.coli, Salmonella, S. aureus,* and *P. aeruginosa* except for parsley, which did not have any activity against *S. aureus.* The zone of inhibition produced by the herb extract in this study was smaller than other studies (Nzeako, Al-Kharousi, and Al-Mahrooqui, 2006; Srivastava *et al.*, 2014; Mosafa *et al.*, 2014). This difference might be because other studies used the oil extracts of herbs rather than the ethanol extract used in our study. The antimicrobial agent concentration in oil extract is more than in ethanol extracts, which will cause the oil extracts to have bigger zones of inhibition (Mosafa *et al.*, 2014). Different herbs have different inhibiting abilities for each tested bacterium as was clearly seen in the results of this study. Sage and thyme had the strongest antibacterial activity against *E.coli, Salmonella, S. aureus*, and *P. aeruginosa.* The findings of this study are similar to other studies (Nzeako, Al-Kharousi and Al-Mahrooqui, 2006; Mosafa *et al.*, 2014). Thyme is known to have some antimicrobial properties. Thyme contains multiple antimicrobial agents such as thymol, terpenes, eugenol, flavones, and aliphatic alcohols which may operate alone or in groups to kill both bacteria and fungi as described by Nzeako, Al-Kharousi and Al-Mahrooqui (2006).

Basil showed some antimicrobial activity against all bacteria tested. High inhibitory activities against all microorganisms imply that basil could be used to control bacterial pathogens. Multiple studies have

reported the antibacterial activity of basil against many pathogenic microorganisms that were correlated to the existence of the high amount of linalool in the basil leaves (Wannissorn *et al.*, 2005; Srivastava *et al.*, 2014). In the current study, basil exhibited strong antibacterial activity against *P. aeruginosa.* A study conducted by Opalchenova and Obreshkova, 2003 found similar results where basil essential oil extract had strong inhibitory activity against *P. aeruginosa* and resistant strains of *P. aeruginosa.*

Parsley had shown some bactericidal properties towards all bacteria tested except *S. aureus*. A study (El Astal *et al.*, 2003) confirms these study findings where the researchers found that parsley extract had antibacterial activities against Gram-negative bacteria including *P. aeruginosa* and *E.coli.* However, parsley extract did not have any inhibitory action against Gram-positive bacteria *(S. aureus)*. Parsley has an antimicrobial activity because of the presence of phenolic compounds containing a polar isopropyl functional group, which act as an antimicrobial agent. Moreover, the presence of multiple bioactive flavonoids in parsley displays antibacterial activities against Gram-negative bacteria as mentioned by Wong and Kitts (2006).

Conclusion

The results of this study have shown that herbs sold in the UAE markets harboured high bacterial count that included total aerobic bacteria, *E. coli, Salmonella, Shigella* and *P. aeruginosa*. This indicates poor handling, storage and a general lack of hygiene, possibly during cultivation and transportation of these herbs. The results of this study emphasize the urgent need for regular sampling and monitoring programs of herbs by the concerned local authority and highlight the importance of proper hygiene practices before consumption. The study also sets the baseline for further research on sanitizing treatment protocols and their impact on the quality of herbs. Furthermore, future research will be directed towards the development and the application of qPCR tests specific for monitoring potential pathogenic contaminants in fresh herbs. Furthermore, all tested herbs were found to have some antibacterial effects against four opportunistic bacterial pathogens. However, more detailed research need to be conducted to fully elucidate the antimicrobial potential of herbs used in this study.

Acknowledgement

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