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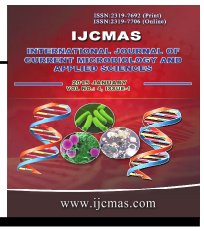

Original Research Article

Antioxidant and antimicrobial activity of celery (*Apium graveolens*) and coriander (*Coriandrum sativum*) herb and seed essential oils

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Keywords

Essential oil, Celery, Coriander, GC-MS, Antioxidant, Antimicrobial

A B S T R A C T

The aim of the present study was to investigate the essential oils constituents, antioxidant and antimicrobial activity of celery *(Apium graveolens)* and coriander (*Coriandrum sativum)* herb and their seeds. The chemical composition of the essential oils obtained by hydrodistillation was analyzed by GC/MS. The major component of celery herb and seed essential oils was *limonene* and for coriander herb and seed essential oils was *linalool*. The antioxidant activities of volatile oils extracted from the celery and coriander herbs and seeds powders were assessed by the Rancimat apparatus and DPPH. The results from this test illustrate that all essential oils under study at various concentrations exhibited antioxidant activity; this means that the entire added essential oils whether added individually or mixed were possess antioxidant effect. The antimicrobial effects of celery, coriander herb and seeds essential oils at concentrations of 0.3, 0.6, 0.9, 10, 50 and 100% were determined in comparison with phenol, at concentration of 1.0 and 10%, against five bacterial strains, two yeast strains and five mold strains, the inhibitory effect of the four essential oils could be ranked as follows: coriander seed > coriander herb > celery seed > celery herb essential oils. Therefore we can use these essential oils as natural antimicrobial and antioxidant in industrial food and drugs.

Introduction

Natural aromatics and spices have been widely used in many food products such as meat and meat products, dairy products and bakery products for preserving and for their medicinal value (Reddy *et al.,* 2005; Shahsavari *et al.,* 2008). Fat and oils are of the most important ingredients used in manufacture of bakery products, and they usually applied in wide range of concentrations (from few parts of less to 50 percent or more).Thus, Consumers all over the world are becoming increasingly conscious of the nutritional value and safety of their food and its ingredients. At the same time, there is an increase preference for natural food and food ingredients which are generally believed to be safer, more healthy and less subject to hazards than food

containing artificial food additives. Lipid substances are easily deteriorated by oxidative rancidity from the reaction with atmospheric oxygen and hydrolytic reactions catalyzed by lipases from food or food micro-organisms (Allen and Hamilton, 1983). Consequently, there is an urgent need for other types of compounds to act as antioxidants. In most reviews of natural antioxidants, various spices, herbs and their volatile oils are included and often identified as being among the most effective natural antioxidants (Sahar *et al.,* 2007, Naglaa and Hany, 2009; Bhat, 2014).

Apium graveolens Linn. (Apiaceae) has a long history of use in Ayurveda and Unani system of medicine. *Apium graveolens* L (Apiaceae) grows wild at the base of the North Western Himalyas and outlying hills in Punjab and in Western India. *A. graveolens* has been used as a food, and at various times both the whole plant and the seeds have been consumed as a medicine. Celery seeds or celery seed extracts are used as flavoring agents and also in anti rheumatic formulations as the seeds have significance as arthritic pain relief, for treating rheumatic conditions and gout. Apart from the role in rheumatism, celery seeds proved its use in asthma, bronchitis and inflammatory conditions (Fazal and Singla, 2012).

Coriander (*Coriandrum sativum* L.) – an annual of the Apiaceae family, is one of valuable medicinal, seasoning and oliferous plants. This species comes from the Mediterranean region and it is grown all over the world. The coriander fruit (*Coriandri fructus*) and the essential oil isolated from it are used for medicinal purposes (Duarte *et al.,* 2012 and Renata, 2013).

The aim of the work was to study the effect of celery and coriander herb and seed essential oils as antioxidant and antimicrobial.

Materials and methods

Celery (*Apium graveolens*) and coriander (*coriandrum sativum* L.) were obtained from Agriculture Research Centre, Giza, Egypt during September, 2011.

Diphenyl-2-Picrylhydrazyl (DPPH) was obtained from Sigma, St. Louis, MO, USA.

Microorganisms: some bacterial strains representing gram positive; *Bacillus cerues and Staphylococcus aureus,* besides gram negative; *Escherichia coli, Pseudomonas aeruginosa* and *Salmonell*a, in addition to 2 strains of yeast; *Saccharomyces cerevisiae* and *Candida lipolytica* and 5 strains of mold; *Aspergillus niger, Aspergillus flavus, Aspergillus Fumigatus, Aspergillus Parasiticus* and *Penicillium digitatum* were obtained from MERCN of the Faculty of Agriculture, Ain Shams University. These microorganisms were checked for their purity and identify and were reactivated by recultivated at interval of 15 day.

Extraction of essential oils: The essential oil of *Apium graveolens herb and seed* and *coriandrum sativum* L. herb and seed were extracted by water distillation using a (Clevenger-type apparatus) for 4 hours. The obtained volatile oil was dried over anhydrous sodium sulphate and then holds in completely filled a glass bottle at -20°C until use (Guenther, 1961).

Separation and identification of essential oils constituents: The GC/MS technique (HP. 5890A) was used to identify the *Apium graveolens* and *Coriandrum sativum* L. essential oils constituents, under the following conditions: packed capillary column (50m×0.2mm×0.3 thickness film of carbowax 20M), Helium was used as a

carrier gas at flow rate 20 cm/sec, HP 7673A automatic injector was used to inject 2.0 µL of diluted samples in ethyl alcohol (1:10, v/v) with split ratio 100:1, at 150°C, the oven temperature (programmed) was set at 60°C for l0min and increasing gradually by the rate of 2.8°C/min to the final temperature (200°C) during 60 min. Mass spectrum was used to identify the constituents by comparing the samples spectrum with the data stored in Chemstation library which containing over 43,000 compounds.

Oxidation systems: Different concentrations of celery and coriander essential oils (50, 100 and 150 ppm) and BHT (200 ppm) were individually prepared by using / 100 g of sunflower oil to study their antioxidant behavior on the stability of this oil through Rancimat test. The test was performed on a Rancimat apparatus 679 (metrohm Ltd. CH-9100 Herisau, Switzerland) by measuring the induction period at 100°C $\pm$ 0.2 and an air flow rate of 20L/hr. Determination of the induction period was based on the conduct metric detection of the volatile degradation products of oil oxidation and used as a mean for comparing the antioxidant activity of the various essential oils added individually to sunflower oil according to the methods described by Mendez *et al.* (1997).

Determination of total antioxidant activities (DPPH assay): The total antioxidant activity contents in water extracts were determined according to the method described by Tepe *et al.* (2005).

Antimicrobial activity of celery and coriander essential oil: The effect of *Apium graveolens* and *coriandrum sativum* L.essential oils on bacterial and yeast growth was studied by the Paper-Disk plate method according to Loo *et al.* (1945) by measuring the inhibition zone.

Result and Discussion

Chemical composition of essential oil

Essential oil percentage of fresh celery herbs was 0.72%. The obtained data are in harmony with the findings of Fazal and Singla (2012). The chemical constituents of *Apium graveolens* volatile oil are tabulated in table 1. From these results, it could be indicated that, 11 components were isolated from *Apium graveolens* herbs essential oil. Eleven component were identified and classified into 5 chemical categories namely, monocyclic terpenes (77.10%), bicyclic terpenes (14.69%), aliphatic hydrocarbons (1.70%), ketones (0.20) and sesquiterpene (2.97%). These identified compounds accounted for 96.66 % of the composition of *Apium graveolens* essential oil. The remainder portion, 3.34 % representing 7 unknown constituents. The first chemical group in table 1 *Apium graveolens* essential oil was monocyclic terpenes which consisted of 2 compounds namely; d-Limonene (76.55%) and γ-terpinine (0.55%). Limonene was reported as the major constituent of *Apium graveolens* essential oil by Van Wassenhove *et al.* (1990), Misic *et al.,* (2008) and Fazal and Singla (2012). The second recorded chemical group was bicyclic terpenes which consisted of 4 compounds namely; α-pinene (1.30%), camphene (0.29%), Sabinen (1.70%) and β-pinene (11.40 %). The third identified chemical group was aliphatic hydrocarbons which consisted of one compound namely; β– myercene (1.70 %). This compound was reported as constituent of *Apium graveolens* essential oil by Misic *et al.,* (2008). The fourth identified chemical group was ketones which consisted of one compound namely; L-carvone (0.20%). The five chemical group was sesquiterpene which consisted of three compounds

namely; β-caryophyllene (1.14 %), β-selinene (0.95 %) and α- selinene (0.88 %).

Essential oils of food products affect their nutritional availability due to their direct responsibility for consumer acceptance or rejection. Essential oil percentage of celery herbs after dryer at 50°C was 0.08%. Thus, the changes occurred in the chemical composition of the essential oil of each celery dryer at 50°C, at oven temperature were followed up. The obtained results are shown in table 1; it could be observed that of celery dryer at 50°C caused detectable decreases in the total contents of the 5 chemical group of celery. The decrements included: monocyclic terpenes, bicyclic terpenes, aliphatic hydrocarbons, ketones and sesquiterpene contents in comparison with celery. The decrement percentages were 5.84 % of monocyclic terpenes, 27.84 % of bi cyclic terpenes, 17.65 % of aliphatic hydrocarbons, 35 % of ketones and 18.18 % of sesquiterpene for celery dryer at 50°C. The obtained data were in harmony with finding of Okoh *et al.,* (2008).

On the other hand, Essential oil percentage of celery seed was 1.9, the first chemical group in *Apium graveolens* seed essential oil was monocyclic terpenes which consisted of 2 compounds namely; d-Limonene (58.38 %) and γ-terpinine (0.03 %). Limonene was reported as the major constituent of *Apium graveolens* seed essential oil by Sowbhagya *et al.,* (2010) and Al-Snafi (2014).

The second recorded chemical group was bicyclic terpenes which consisted of 4 compounds namely; α-pinene (0.15 %), camphene (0.04 %), Sabinen (0.98 %) and β-pinene (0.52 %). The third identified chemical group was aliphatic hydrocarbons which consisted of one compound namely; β– myercene (2.33 %). This compound was reported as constituent of *Apium graveolens* seed essential oil by Rana *et al.* (2010). The fourth identified chemical group was ketones which consisted of one compound namely; L-carvone (0.59 %). The five chemical group was sesquiterpene which consisted of three compounds namely; β-caryophyllene (0.87 %), β-selinene (27.03 %) and α- selinene (2.67 %).

Meanwhile, Essential oil percentage of fresh coriander herbs was 0.18%. The obtained data are in harmony with the findings of Shahwar *et al.,* 2012. The chemical constituents of *coriandrum sativum* L. volatile oil are tabulated in table 1. From these results, it could be indicated that, 13 components were isolated from *coriandrum sativum* L. herbs essential oil. Thirteen component were identified and classified into 7 chemical categories namely, monocyclic terpenes (3.49%), bicyclic terpenes (9.40%), aromatic hydrocarbons (0.82%), ketones (1.76), sesquiterpene (0.37%), alcohols (81.07%) and terpene esters (1.88%). These identified compounds accounted for 98.79 % of the composition of *coriandrum sativum* L. essential oil and the remaining portion (1.21%) representing 5 unknown constituents. The first chemical group in table 1 is of *Coriandrum sativum* L. essential oil that is a monocyclic terpene which consisted of 2 compounds namely; d-Limonene (1.86%) and γ-terpinine (1.63%). The second recorded chemical group was bicyclic terpenes which consisted of 4 compounds namely; α-pinene (5.64%), camphene (1.26%), Sabinen (0.58%) and β-pinene (1.92%). The third identified chemical group was aromatic hydrocarbons which consisted of one compound namely; P– cymene (0.82%). This compound was reported as constituent of *coriandrum sativum* L. essential oil by Renata (2013). The fourth identified chemical group was ketones which consisted of one compound namely; camphor (1.76%). The five

chemical group was sesquiterpene which consisted of one compound namely; β-caryophyllene (0.37%). The six recorded chemical group was alcohols which consisted of three compounds namely; linalool (33.66 %), β-citronellol (1.83 %) and geraniol (45.58 %). The seven chemical groups were terpene esters which consisted of two compounds namely; neryl acetate (0.08%) and geranyl acetate (1.80%).

Essential oils of food products affect their nutritional availability due to their direct responsibility for consumer acceptance or rejection. Essential oil percentage of coriander herbs after dryer at 50°C was 0.10%. Thus, the changes occurred in the chemical composition of the essential oil of each coriander dryer at 50°C, at oven temperature were followed up. The obtained results are shown in table 1; it could be observed that of coriander dryer at 50°C caused detectable decreases in the total contents of the 7 chemical group of coriander. The decrements included: monocyclic terpenes, bicyclic terpenes, aromatic hydrocarbons, ketones, sesquiterpene, alcohols and terpene esters contents in comparison with coriander. The decrement percentages were 35.82 % of monocyclic terpenes, 27.66 % of bi cyclic terpenes, 62.20 % of aromatic hydrocarbons, 32.95 % of ketones, 70.27 % of sesquiterpene, 6.28 % of alcohols and 29.79 % of terpene esters for coriander dryer at 50°C.

On the other hand, essential oil percentage of coriander seed was 1.1%, the first chemical group in *Coriandrum sativum* L. seed essential oil was monocyclic terpenes which consisted of 2 compounds namely; d-Limonene (4.94%) and γ-terpinine (5.55%). The second recorded chemical group was bicyclic terpenes which consisted of 4 compounds namely; α-pinene (18.10%), camphene (3.07%), Sabinen (1.26%) and β-pinene (1.10%). The third identified chemical group was aromatic hydrocarbons which consisted of one compound namely; P– cymene (0.04%). This compound was reported as constituent of *Coriandrum sativum* L. essential oil by Bhuiyan *et al.* (2009). The fourth identified chemical group was ketones which consisted of one compound namely; camphor (3.73%). The five chemical group was sesquiterpene which consisted of one compound namely; β-caryophyllene (0.16%). The six recorded chemical group was alcohols which consisted of three compounds namely; linalool (54.08 %), β-citronellol (0.33 %) and geraniol (1.09 %). Linalool was reported as the major constituent of *Coriandrum sativum* L. seed essential oil by Shahwar *et al.* (2012). The seven chemical groups were terpene esters which consisted of two compounds namely; neryl acetate (0.13%) and geranyl acetate (2.04%).

Antioxidant activity of volatile oils:

The antioxidant activities of volatile oils extracted from the celery and coriander herbs and seeds powders were assessed by the Rancimat apparatus. This method assigned the induction period for the onset of oxidative rancidity in sunflower oil at 100°C ± 0.2 °C and the longer induction period indicates the stronger antioxidant activity. The activities of the four used essential oils were individually tested in triplicates at concentration (900 ppm). Moreover, a mixture of both essential oils, (celery and coriander herbs and seeds; 1:1) was also in concentration (900 ppm) to assess their synergistic behavior. The data are presented in table 2. The experiment was performed where sunflower oil was treated by 200 ppm BHT in order to compare the antioxidant efficiency of the essential oils under study with the most commonly used

synthetic antioxidant material. It has been reported that synthetic antioxidants (BHT, BHA and PG) are added at concentrations ranging from 100-400 ppm to fats and oils to suppress the development of peroxides during food storage (Allen and Hamilton, 1983). Table 2 shows the effect of essential oils extracted from celery and coriander herbs and seeds on the oxidative rancidity of sunflower oil. Sunflower oil without any essential oil and sunflower oil mixed with BHT (200 ppm) systems were used as a guide to indicate the antioxidant or prooxidant phenomenon and also to compare the antioxidant power possessed by different natural antioxidants. Hence, a negative value indicates a prooxidant effect while the positive values demonstrated an antioxidant activity.

Accordingly, the percentage of antioxidant activity values for BHT (200 ppm) was 64.02%, celery and coriander herbs essential oils at (900 ppm) were 19.75 and 21.71 %, celery and coriander seeds essential oils at (900 ppm) were 32.32 and 37.20 %, respectively, the mixture, 1:1 (celery and coriander herbs essential oils) at (900 ppm) was 48.17% and the mixture, 1:1 (celery and coriander seeds essential oils) at (900 ppm) was 55.24 %. Consequently, the results illustrate that all essential oil under study at various concentrations exhibited antioxidant activity.

The induction periods for all systems were approximately twice that of the induction period of sunflower oil alone. This means that the entire added essential oils whether added individually or mixed were possessed antioxidant effect. These structural requirements are supported by the powerful antioxidant activities of the well-known synthetic BHT and the natural antioxidant (Sahar *et al.,* 2007, Naglaa and Hany, 2009 and Bhat, 2014).

$$(AA)\% = \frac{\text{Induction period of sample} - \text{Induction period of control}}{\text{Induction period of control}} \times 100$$

One would relate the antioxidant activity to BHT was inhibited of hydroperoxide formation. The first step in lipid oxidation is the abstraction of hydrogen atom from a fatty acid and oxygen involvement gives a peroxy radical. Generally, the antioxidants suppress the hydrogen atom abstraction from the fatty acid which leads to the decrease of hydroperoxide formation. It is well known that the phenolic compounds act as hydrogen donors to that reaction mixture and therefore, the formation of hydroperoxides is decreased. The results of the present work are in line with this statement. One would except that the increase in the number of phenolic OH groups leads to increase the antioxidant phenomenon. In general, the phenolic OH has to be in the free form and if these groups are attached to other groups would prevent their antioxidant power due to the lack of hydrogen atom donates to a fatty acid radical (Asakura *et al.,* 1989).

DPPH radical scavenging activity (%)

The DPPH radical scavenging activity (%) of volatile oils extracted from the celery and coriander herbs and seeds powders were, 56.68, 69.30, 74.35 and 87.50, respectively. These data were shown in table 3. Generally, the DPPH free radical scavenging activities for the studied essential oils are sorted in the following descending order: coriander seed > celery seed > coriander herb > celery herb. DPPH free radical is a stable free radical, which has been widely accepted as a tool for estimating free radical-scavenging activity of antioxidants (Fenglin *et al.,* 2004).

The 2, 2-diphenyl-2-pcrylhydrazyl was used as generating substance of free radicals in order to determine the radical scavenging activity of celery and coriander herbs and seeds essential oils (Stoilova *et al.,* 2007).

Shahwar *et al.* (2012) founded that the essential oil from coriander seeds showed significant radical scavenging activity (66.48 ± 0.80%) at a concentration of 500 µg in comparison with essential oil of coriander leaves (56.73 ± 1.82%). Dima *et al.* (2014) agree with these findings which the inhibition percentages of the DPPH radicals, in the case of the crude and encapsulated coriander EO, have values close to the BHT values (87.89%±2.54 for coriander EO; 79.77%±1.74 for the coriander EO/ β-CD complex and 97.15%±3.41 for BHT), in comparison with the ascorbic acid (57.54%±2.78).

Antimicrobial activity of celery, coriander herb and seeds essential oils

The antimicrobial effects of celery, coriander herb and seeds essential oils at concentrations of 0.3, 0.6, 0.9, 10, 50 and 100% were determined in comparison with phenol, at concentration of 1.0 and 10%, against five bacterial strains, two yeast strains and five mold strains. The diameters of the inhibition zones (mm) was taken as a criterion for measuring the antimicrobial activity, in vitro of these essential oils and the obtained results are given in tables 4 and 5.

The results showed that coriander seed and herb essential oil had the highest animicrobial activities their antimicrobial spectra were 1374 and 1171, respectively followed with celery seed essential oil (1105) while the lower one was celery herb essential oil (967). coriander seed and herb essential oil showed antimicrobial activity over that of phenol, in respect of this the antimicrobial spectrum of the gram positive bacterial of 10% coriander seed and herb essential oil were 1.77 and 1.52 times that of 10% phenol, respectively while, the antimicrobial spectrum of the gram negative bacterial were 1.27 and 1.10 times that of 10% phenol, respectively. Also, anti-yeast spectrum was 1.46 and 1.31 times that of 10% phenol, respectively. Moreover, the anti-mold were 1.04 and 0.78 times that of 10% phenol, respectively and the antimicrobial spectra of 10% coriander seed and herb essential oil were 1.24 and 1.02 times that of 10% phenol, respectively (Table 5).

Same data table 4 showed that celery herb and seed essential oil had the lowest antimicrobial properties against test microorganisms, concerning this the antimicrobial spectrum of the gram positive bacterial, the antimicrobial spectrum of the gram negative bacterial, the anti-yeast spectrum, the anti-mold and the antimicrobial spectra of 10% celery seed and herb essential oil were 1.33, 1.15; 1.2, 0.9; 1.23, 1.12; 0.75, 0.67 and 0.995, 0.843 times those of 10% phenol, respectively.

In general, it is interested to note that there were a liner relationship between the antimicrobial activity and the applied concentration of each essential oil. Also, it could be noticed that the above studied four essential oils had higher antimicrobial activity against gram-negative bacteria than gram-positive bacteria. Moreover, same data indicated that coriander seed was the only essential oil which had a strong inhibitory effect against the tested pathogenic microbe namely, *Staphylococcus aureus*, since the antibacterial activity was 2.5 times that of 10% phenol, compared with 1.9, 1.7 and 1.5 times for coriander herb, celery seed and celery herb essential oils, respectively.

Table.1 Chemical components of celery (*Apium graveolens*) and coriander (*Corundum sativum* L.) essential oils fractionated and identified by GC/Mass technique

Chemical compounds	Area celery %			Area coriander %		
	Herbs		*Seed*	*Herbs*		*Seed*
	Fresh	*50°C*		*fresh*	*50°C*	
1-Monocyclic terpenes:						
d-Limonene	76.55	72.25	58.38	1.86	1.30	4.94
γ-terpinene	0.55	0.35	0.03	1.63	0.94	5.55
Total:	**77.10**	**72.60**	**58.38**	**3.49**	**2.24**	**10.49**
2-Bi cyclic terpenes:						
α-pinene	1.30	0.95	0.15	5.64	4.82	18.10
Camphene	0.29	0.15	0.04	1.26	0.22	3.07
Sabinen	1.70	1.40	0.98	0.58	0.31	1.26
β-pinene	11.40	8.10	0.52	1.92	1.45	1.10
Total:	**14.69**	**10.60**	**1.69**	**9.40**	**6.80**	**23.53**
3-Aliphati hydrocarbons:						
β-Myercene	1.70	1.40	2.33	-	-	-
Total:	**1.70**	**1.40**	**2.33**	-	-	-
4-Aromatic hydrocarbons:						
P-cymene	-	-	-	0.82	0.31	0.04
Total:	-	-	-	**0.82**	**0.31**	**0.04**
5- Ketones:						
L-Carvone	0.20	0.13	0.59	-	-	-
Camphor	-	-	-	1.76	1.18	3.73
Total:	**0.20**	**0.13**	**0.59**	**1.76**	**1.18**	**3.73**
6-Sesquiterpene:						
β-Caryophyllen	1.14	0.93	0.87	0.37	0.11	0.16
β-selinene	0.95	0.80	27.03	-	-	-
α- selinene	0.88	0.70	2.67	-	-	-
Total:	**2.97**	**2.43**	**30.57**	**0.37**	**0.11**	**0.16**
7- Alcohols						
Linalool	-	-	-	33.66	31.91	54.08
β-Citronellol	-	-	-	1.83	0.90	0.33
Geraniol	-	-	-	45.58	43.17	1.09
Total:	-	-	-	**81.07**	**75.98**	**55.50**
8-Terpene esters						
Neryl acetate	-	-	-	0.08	0.02	0.13
Geranyl acetate	-	-	-	1.80	1.30	2.04
Total:	-	-	-	**1.88**	**1.32**	**2.17**
9-Unknown:	3.34	12.84	6.44	1.21	12.06	4.38

Table.2 Effect of celery and coriander essential oils on sunflower oil oxidative rancidity

System	Induction Period (hr)[a]	Percentage antioxidant activity[b]
Sunflower oil (Control, C)	7.75	0
C +BHT (200 ppm)	13.40	72.90
C + celery herb essential oil (900ppm)	9.82	19.75
C + coriander herb essential oil (900ppm)	9.98	21.71
C + celery seed essential oil (900ppm)	10.85	32.32
C + coriander seed essential oil (900ppm)	11.25	37.20
C+(celery+coriander,1:1) herb essential oil (900ppm)	12.15	48.17
C +(celery+coriander,1:1) seed essential oil (900ppm)	12.73	55.24

Table.3 DPPH radical scavenging activity (%) of celery and coriander herbs and seeds essential oils

Treatments	DPPH Radical-scavenging activity (%)
Celery herb essential oil (900ppm)	56.68
Coriander herb essential oil (900ppm)	69.30
Celery seed essential oil (900ppm)	74.35
Coriander seed essential oil (900ppm)	87.50

In general, the data in tables 4 and 5 indicated that, the inhibitory effect of coriander seed, herb and celery seed, herb essential oils increased with increasing their concentrations. Moreover, the inhibitory effect of the four essential oils could be ranked as follows: coriander seed > coriander herb > celery seed > celery herb essential oils.

The differences in sensitivity between the gram- negative and gram-positive bacteria to the effect of plant essential oils are supported by other researches including Shelef (1983) and Farbood *et al.*, (1976). It is not known exactly why gram-negative bacteria should be less susceptible, but it may be related to outer membrane of gram-negative bacteria which endows the bacterial surface with strong hydrophilicity and acts as a strong permeability barrier (Nikaido and Vaara, 1985).

As for, the antimicrobial effect of celery and coriander essential oils, it could be related to the major component d-Limonene and Linalool, respectively according to Olle and Bender (2010), Suganya *et al.*, (2012) and Bagdassarian *et al.*, (2013).

Moreover, the presence of other aromatic components which could inter acts and affects the polarity and consequently the extent of inhibition (Farag *et al.*, 1989). The obtained data are in harmony with the findings of Naglaa and Gehad (2011).

Table.4 Antimicrobial activity of different concentrations of Celery herb and seed essential oils by using disc diffusion method

Microbial Strains	Diameter of inhibition zone (mm)													
	Celery herb essential oil concentration (%)						Celery seed essential oil concentration (%)						Phenol (%)	
	0.3	**0.6**	**0.9**	**10**	**50**	**100**	**0.3**	**0.6**	**0.9**	**10**	**50**	**100**	**1**	**10**
Gram- positive bacteria														
Bacillus cerius	3	5	13	16	22	30	4	7	15	19	25	33	8	17
Total	89						103						25	
Staphylococcus aureus	3	7	10	15	26	35	5	9	12	17	27	35	6	10
Total	96						105						16	
Gram-- negative bacteria														
Escherichia coli	2	5	10	12	21	26	4	7	11	17	23	28	6	12
Total	76						90						18	
Pseudomonas aeruginosa	2	5	13	18	27	35	3	6	16	25	31	40	14	20
Total	100						121						34	
*Salmonill*a	1	6	11	15	25	32	3	8	12	18	29	38	9	18
Total	90						108						27	
Yeasts														
Saccharomyces cerevisiae	2	5	10	15	21	27	3	7	11	15	23	29	12	16
Total	88						88						28	
Candida lipolytica	2	4	8	14	18	24	2	5	12	17	20	26	6	10
Total	70						82						16	
Molds														
Aspergillus niger	1	3	6	8	14	23	2	4	6	9	17	25	8	14
Total	55						63						22	
Aspergillus flavus	1	4	6	9	16	21	1	4	7	11	18	24	6	13
Total	57						65						19	
Aspergillus Fumigatus	1	2	7	12	17	25	1	3	8	13	19	27	12	25
Total	64						71						37	
*Aspergillus Para*siticus	2	2	6	17	26	32	2	3	9	18	27	38	14	28
Total	85						97						42	
Penicillium digitatum	1	5	10	22	27	32	2	7	12	25	30	36	10	22
Total	97						112						32	
Antimicrobial Spectra	967						1105							

Table.5 Antimicrobial activity of different concentrations of Coriander herb and seed essential oils by using disc diffusion method

Microbial Strains	Diameter of inhibition zone (mm)*													
	Coriander herb essential oil concentration (%)						Coriander seed essential oil concentration (%)						Phenol (%)	
	0.3	0.6	0.9	10	50	100	0.3	0.6	0.9	10	50	100	1	10
Gram- positive bacteria														
Bacillus cerius	4	9	14	22	27	34	5	8	15	23	30	38	8	17
Total	110						113						25	
Staphylococcus aureus	6	10	14	19	30	38	7	12	17	25	32	47	6	10
Total	117						140						16	
Gram-- negative bacteria														
Escherichia coli	5	8	13	18	20	26	6	12	18	21	26	30	6	12
Total	90						113						18	
Pseudomonas aeruginosa	4	5	16	20	33	44	4	7	14	23	35	49	14	20
Total	110						132						34	
*Salmonill*a	5	9	14	17	26	43	2	5	11	18	32	50	9	18
Total	114						118						27	
Yeasts														
Saccharomyces cerevisiae	5	8	11	16	21	30	3	7	10	18	25	36	12	16
Total	91						99						28	
Candida lipolytica	3	7	13	18	22	27	5	12	16	20	27	32	6	10
Total	90						112						16	
Molds														
Aspergillus niger	2	5	6	11	19	28	2	5	8	18	30	35	8	14
Total	71						98						22	
Aspergillus flavus	1	4	7	10	15	25	4	7	11	15	20	28	6	13
Total	62						85						19	
Aspergillus Fumigatus	2	5	9	13	18	26	3	6	10	18	22	30	12	25
Total	73						89						37	
*Aspergillus Para*siticus	2	5	9	20	29	36	3	5	12	25	37	42	14	28
Total	108						124						42	
Penicillium digitatum	3	9	14	26	32	37	5	12	18	30	38	42	10	22
Total	97						145						32	
Antimicrobial Spectra	1171						1374							

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