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Research Article

Antioxidant and antibacterial investigations on essential oils and acetone extracts of some spices[Ü]

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Abstract

The studies on antioxidant and antibacterial potential of essential/volatile oils and acetone extracts of various spices are presented in this paper. The antibacterial activity of the volatile oils and acetone extracts of anise, ajwain, tejpat, Chinese Cassia bark, fennel, coriander, dill, turmeric and star anise have been studied against *Escherichia coli*, *Salmonella typhi*, *Pseudomonas aeruginosa*, *Bacillus cereus*, *B. subtilis* and *Staphylococcus aureus* by disc diffusion and plate count methods. The results showed that volatile oils and extracts varied in their bioactivity. The volatile oils of ajwain, tejpat, Chinese Cassia bark and coriander were found to possess excellent activity against all the Gram positive and Gram negative bacterial strains tested. These volatile oils and extracts are equally or more effective when compared with standard antibiotics even at very low concentration. However, the acetone extract was found to be less effective as compared to volatile oils. Antioxidant activity of the oils and extracts were studied by DPPH, reducing power, conjugated diene and chelating effect assays. They exerted concentration dependent antioxidant activity in all the tested assays.

Keywords: Spices, Volatile oils, Antimicrobial activity, Acetone extract, Antioxidant activity.

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Introduction

Natural products and naturally derived components from plants have applications in controlling pathogens[1, 2] in foods. The antioxidant and antibacterial property of added material is very important to improve the shelf life of food material and at the same time provide safety to consumers. The challenge is to isolate, purify, stabilize and incorporate natural antioxidants and antimicrobials into foods without adversely affecting sensory, nutritional and safety characteristics. With the passage of time, various active fractions or constituents isolated from higher plants especially from spices in the form of essential oils have been extensively investigated[3]. Essential oils and extracts are heterogeneous group of complex mixtures of organic substances whose quality and quantity vary with growth stages, ecological conditions and other factors of the plant from which it is extracted[4]. The volatility and poor solubility of essential oils and extracts are problematic, particularly with methods that rely on diffusion and dilution of the test substance in a microbiological medium. Both microbiostatic[5] and microbiocidal[6] effects are reported in the literature, although, there are discrepancies about the spectrum of activity and potency of individual plant extracts and essential oils. The antioxidant and antibacterial activity of essential oil and acetone extract of some spices like black cumin, black pepper, mace, etc. have been earlier reported by us[7]. In this paper also, we report the antimicrobial and antioxidant potential of essential oils and extracts isolated from some more spices, viz. anise, ajwain, tejpat, Chinese Cassia bark, fennel, star anise, turmeric, dill and coriander.

Tejpat

Ajwain

Materials and Methods

Plant material

The spices listed in Table 1 were procured from local wholesale market of

Gorakhpur, during June to November, 2004 and voucher specimens were deposited at the Herbarium of Science faculty of DDU Gorakhpur University, Gorakhpur.

Isolation of volatile oil

The spices were powdered (800 mesh size) using domestic model grinder and were subjected to hydrodistillation in a Clevenger type apparatus for 3 hours. The volatile oils thus obtained were dried over anhydrous sodium sulphate to remove traces of moisture and stored in refrigerator in dark at 4°C until use.

Isolation of acetone extract

After the isolation of volatile oil, the powdered spice materials were dried at 45°C. The extract was obtained by extracting 20g of dried powder of spice with 900 ml acetone for 3 hours in a Soxhlet apparatus. The extract was concentrated up to 10 ml. The remaining acetone was evaporated by placing the samples in a vacuum drier under reduced pressure. The viscous extracts were stored in a refrigerator at 4ºC until use.

Coriander Star anise

Antioxidant assays

DPPH and Reducing power assays

The DPPH (2, 2'-diphenyl-1-picrylhydrazyl radical) assay was carried out as described by Cuendet and his co-workers[8]. The reducing power was determined according to methods reported earlier by Oyaizu[9].

Chelating effect of ferrous ions and Conjugated diene assays

Chelating effect was determined according to the method of Shimada *et al*[10]. The antioxidant activity was also determined by the conjugated diene method as reported by Lingnert *et al*[11].

Antibacterial investigations

Tested microorganisms

Six pathogenic bacteria, three Gram positive, *Bacillus cereus*, *B. subtilis* and *Staphylococcus aureus*, and three Gram negative, *Escherichia coli*, *Salmonella typhi* and *Pseudomonas aeruginosa* were selected for the present study. The pure cultures of these bacteria were obtained from Microbiology Department of Defence Food Research Laboratory, Mysore, India. They were subcultured on nutrient agar broth.

Antibacterial screening

Two different methods disc diffusion and plate count were employed for the determination of antimicrobial activities. The screening of spices showing activity was done using method reported earlier by us[7].

Statistical analysis

For the essential oil or acetone extarct, three samples were prepared for assays of every antioxidant and antibacterial attribute. The data were presented as mean ± standard deviation of three determinations (data were not shown). Statistical analyses were performed using a one-way analysis of variance[12]. A probability value of $P < 0.05$ was considered significant.

Table 1 : Spices, parts and their major components used in the present study

Common name	Botanical name	Family	Parts used	Major components
Anise	***Pimpinella anisum* Linn.**	Apiaceae	Seed	Anethole
Ajwain	***Trachyspermum ammi* (Linn.) Sprague**	Apiaceae	Seed	Thymol
Tejpat	***Cinnamomum tamala* Nees & Eberm.**	Lauraceae	Leaf	Eugenol
Chinese Cassia bark	***Cinnamomum aromaticum* Nees** syn. *C. cassia* Blume	Lauraceae	Bark	Cinnamaldehyde
Fennel	***Foeniculum vulgare* Mill.**	Apiaceae	Seed	Anethole
Star anise	***Illicium verum* Hook. f.**	Magnoliaceae	Fruit	Anethole
Turmeric	***Curcuma longa* Linn.**	Zingiberaceae	Rhizome	Ar-turmerone
Dill	***Anethum graveolens* Linn.**	Apiaceae	Seed	Carvone
Coriander	***Coriandrum sativum* Linn.**	Apiaceae	Seed	Linalool

Results and Discussion

Antimicrobial studies

The data reported in Tables 2 and 3 showed excellent activities against the test bacteria. Using the disc diffusion method (Table 2), the volatile oil of ajwain showed a broad spectrum of inhibition against all tested organisms. It is interesting to note that it causes complete inhibition of *B. subtilis* only at 10µl dose of the oil and more than 80% mycelial zone inhibition was obtained at 6µl. Moreover, a complete zone of inhibition was obtained using dill volatile oil against *B. subtilis* at 10 µl dose and more than 40% at 6 µl. The volatile oil of cinnamon was found to be highly effective against *E. coli*, *P. aeruginosa*, *B. subtilis* and *Staphylococcus aureus* as more than 40% zone inhibition was obtained at 10 µl. Chinese Cassia bark volatile oil was found to be highly active against *B. cereus* and *S. aureus* at 10µl. The turmeric oil was found to be inactive against *Salmonella typhi* and *P. aeruginosa*. For all other organisms, it was found to show considerable zone inhibition. The acetone extracts of turmeric and coriander were also found to be ineffective against all the test organisms.

The above results were further confirmed using plate count method (Table 3). Using this method, the volatile oils of ajwain and cinnamon were found to be highly effective as complete reduction of 10^6 cfu/ml of all the tested organisms was obtained at only 2µl. The extract of cinnamon also showed complete reduction against all tested Gram positive bacteria. However, acetone extract of fennel showed less activity. Moreover, the volatile oils of star anise, dill, coriander and turmeric were also found to be highly active against all tested microorganisms except *Salmonella typhi,* whereas their extracts exhibited some activity though lesser than volatile oils. The data was found to be highly significant ($P>0.05$).

The oils and extracts though less effective at lower concentration, gave rise to complete inhibition of bacterial growth when their concentration increased. The volatile oils and extracts are equally or more effective when compared with standard antibiotics, at very low concentrations. Individual compounds derived from volatile oils such as anethole from anise, fennel and star anise, thymol from ajwain, eugenol from tejpat, cinnamaldehyde from Chinese Cassia bark, ar-turmerone from turmeric, carvone from dill and linalool from coriander are already reported to have antimicrobial activities[13-18]. This indicates the antimicrobial activities of the oils are mainly due to major components. The innovative activities of fennel, star anise and anise, in spite of having same major constituent i.e. anethole, may be due to synergistic or antagonistic effects[19, 20] of minor components present in volatile oil. In comparison with two methods plate count method is the suitable method for determining antibacterial activity of essential oils. In plate count method almost all the essential oils and extracts gave activity. Raybaudi-Massilia *et al*[21] recently reported antibacterial activity of Chinese Cassia bark, lemongrass at 1µl/ml against *Salmonella enteritidis*, *E. coli* and *Listeria innocua*. The results were comparable with our present studies at 6 and 10 µl dose. The essential oil of fennel has been reported to possess bacteriostatic effect by Smith-Palmer *et al*[22]. Essential oils from dill (***Anethum graveolens* Linn.**), coriander (seeds of ***Coriandrum sativum* Linn.**), cilantro (leaves of immature ***C. sativum***) and eucalyptus (***Eucalyptus dives***) were also tested against Gram positive and Gram negative bacteria[3]. Recently, Gupta *et al*[23] reported antimicrobial activity of garlic, ginger, carrot and turmeric pastes against *E. coli*.

Antioxidant studies

DPPH and Reducing power

The scavenging effect of the essential oils and acetone extracts on DPPH radical linearly increased with increasing concentration (Table 4). All the acetone extracts exhibited strong radical scavenging activity in comparison with commercial antioxidants, BHA (81.2-94.9%). Reducing power of essential oils and acetone extracts were moderate and increased with increasing concentration (Table 5). However, essential oils and acetone extracts exhibited low scavenging and reducing power at lower concentration in comparison with BHT. The reducing power of essential oils and acetone extracts might be due to their hydrogen-donating ability[9, 20] and is generally associated with the presence of reductants[24]. The components present in the essential oil and acetone extracts could act as good reductants, which could react with free radicals to stabilize and terminate radical chain reactions.

Chelating effect on ferrous ions and Conjugated diene assays

The chelating effect on various essential oils and acetone extracts on

Table 2 : Antibacterial activity of volatile oils and acetone extracts by disc diffusion method

Tests	Zone inhibition(mm)											
	Gram negative						Gram positive					
	Escherichia coli		*Salmonella typhi*		*Pseudomonas aeruginosa*		*Bacillus cereus*		*Bacillus subtilis*		*Staphylococcus aureus*	
Volatile oils	6 µl	10 µl	6 µl	10 µl	6 µl	10 µl	6 µl	10 µl	6 µl	10 µl	6 µl	10 µl
Anise	(-)b	(-)a	(-)a	13.3±0.8b	14.7±1.2b	16.7±1.2b	17.6±0.8a	24.6±1.4a	(-)a	17.6±1.2b	13.3±1.4a	18.6±0.8a
Ajwain	19.0±1.1a	53.7±2.4a	21.3±1.2a	52.0±1.7c	23.7±2.0a	61.7±1.4c	36.6±1.3c	71.3±1.8b	81.6±2.4a	+	44.6±1.7a	60.0±0.6b
Tejpat	24.0±1.1c	50.7±2.3b	20.6±1.8a	32.7±2.0a	24.3±1.4c	47.0±1.6a	23.3±1.7c	38.0±0.6d	36.3±1.7a	61.3±2.0b	27.0±1.1a	48.0±0.6c
Chinese Cassia bark	33.0±1.1a	36.6±1.8c	(-)b	(-)d	23.0±1.5d	43.3±2.0d	41.3±1.7d	52.6±1.2c	(-)a	22.6±1.8a	27.0±0.9a	44.6±0.8d
Fennel	12.0±1.1e	19.0±1.7d	13.3±3.6c	21.6±0.8f	13.3±0.8a	15.3±0.8f	15.6±1.2b	28.3±0.8f	19.0±0.6b	27.6±1.4a	15.0±1.1b	18.0±0.6c
Star anise	(-)d	(-)a	(-)a	13.0±0.6g	(-)f	(-)c	18.3±0.8b	25.3±0.8a	15.3±0.8d	20.6±0.8a	(-)c	(-)a
Dill	18.0±1.1f	23.3±1.7f	(-)a	(-)a	15.3±0.8a	23.0±1.1a	22.0±1.1b	31.3±1.8b	44.0±2.6b	+	16.3±0.8a	25.3±1.4a
Coriander	15.0±1.1g	24.6±1.2a	(-)a	(-)a	14.7±1.2b	24.0±1.7b	15.3±0.8a	31.0±1.5d	(-)a	35.0±1.7c	15.6±1.2a	4.6±1.2a
Turmeric	(-)b	15.0±1.1b	(-)a	(-)a	(-)b	(-)c	36.0±1.1a	47.3±1.2f	23.3±0.8a	31.6±1.5b	15.4±1.2a	17.6±0.8a
Acetone Extracts												
Anise	(-)b	(-)b	(-)a	(-)a	(-)b	(-)a	(-)a	(-)a	(-)a	(-)a	(-)a	(-)a
Ajwain	(-)a	(-)b	(-)a	(-)a	(-)a	(-)c	19.0±1.2b	28.3±0.9b	(-)a	(-)a	(-)a	15.7±1.2a
Tejpat	(-)a	(-)a	(-)a	(-)a	(-)a	(-)b	(-)a	21.7±2.4c	(-)a	(-)a	(-)a	16.7±1.4a
Chinese Cassia bark	(-)a	(-)a	(-)a	(-)a	(-)a	(-)a	14.0±1.2b	17.0±1.2a	(-)a	(-)a	(-)a	(-)a
Fennel	(-)a	14.7±1.2c	(-)a	(-)a	(-)a	(-)a	(-)a	(-)b	(-)a	(-)a	(-)a	(-)a
Star anise	14.0±0.6c	18.7±2.0b	(-)a	(-)a	17.7±0.9d	25.0±1.2a	15.7±0.8b	19.0±1.2c	(-)a	(-)a	(-)a	(-)a
Dill	(-)b	(-)a	(-)a	(-)a	(-)f	(-)c	(-)a	(-)b	(-)a	(-)a	(-)a	(-)a
Coriander	(-)b	(-)a	(-)a	(-)a	(-)a	(-)c	(-)a	15.3±0.9a	(-)a	(-)a	(-)a	(-)a
Turmeric	(-)b	(-)a	(-)a	(-)a	(-)a	(-)c	(-)a	(-)a	(-)a	(-)a	(-)a	(-)a
Antibiotics*												
Penicillin-G	22.0±0.6a	24±1.1b	(-)a	18.7±1.6b	(-)a	(-)a	18.6±1.1b	20.6±2.4b	15.8±2.0b	19.7±2.3b	13.8±1.7b	15.7±1.7d
Amikacin	19.7±1.7a	20.0±0.8c	13.3±1.5a	19.3±0.8c	15.7±0.5a	18.6±2.0b	22.8±1.7c	25.9±0.7d	17.8±1.7c	19.3±1.3c	24.6±2.0c	28.9±0.6e
Gentamycin	18.7±1.2a	19.6±0.7f	15.6±1.8d	24.0±0.2b	25.3±0.8a	29.6±2.2c	13.3±1.8a	17.9±0.6c	18.5±0.3a	21.5±0.7a	19.7±1.2a	25.6±0.9f

Values are means±S.D. of three independent determinations.
Means within a column followed by the same letter are not significantly different ($P>0.05$)
(-) ineffective; + 100% activity; *10mg/disc

Table 3 : Antibacterial investigations of spice volatile oils and acetone extracts by plate count method

Tests	Colony formation (10^7/Units/ml)											
	Gram negative						Gram positive					
	Escherichia coli		*Salmonella typhi*		*Pseudomonas aeruginosa*		*Bacillus cereus*		*Bacillus subtilis*		*Staphylococcus aureus*	
Volatile oils	2 µl	6 µl	2 µl	6 µl	2 µl	6 µl	2 µl	6 µl	2 µl	6 µl	2 µl	6 µl
Anise	0.4a	+	1.9a	+	+	+	0.3b	0.2a	+	+	0.6a	+
Ajwain	+	+	+	+	+	+	+	+	+	+	+	+
Tejpat	+	+	+	+	+	+	+	+	+	+	+	+
Chinese Cassia bark	+	+	29.1b	+	36.0c	10.0a	+	+	+	+	+	+
Fennel	+	+	30.2c	+	+	+	+	+	+	+	1.2b	1.0c
Star anise	+	+	19.6d	11.0a	0.3b	+	1.5b	+	0.3c	0.2a	+	+
Dill	+	+	43.1f	+	+	+	+	+	+	+	20.0c	+
Coriander	+	+	3.4a	+	5.0d	+	5.3c	4.3b	2.1b	1.7a	2.0c	+
Turmeric	1.2c	1.0b	42.0b	40.0c	+	+	+	+	+	+	+	+
Acetone extracts												
Anise	(-)a	(-)a	(-)a	(-)a	(-)a	(-)a	(-)a	(-)a	(-)a	(-)a	(-)	(-)a
Ajwain	+	+	20.7b	13.2b	5.1c	2.4b	+	+	2.8b	+	15.1c	9.2b
Tejpat	5.9b	4.0a	62.2c	26.4c	6.5b	3.2c	2.2d	0.3a	2.4c	2.3b	25.2c	1.8c
Chinese Cassia bark	3.9c	3.5a	44.1d	31.3c	9.7b	7.3d	+	+	+	+	+	+
Fennel	4.7a	4.4c	41.1a	40.5c	11.9b	9.7a	+	+	1.7b	+	19.1a	15.2c
Star anise	9.5a	8.9b	47.3a	36.6c	(-)a	(-)a	8.3a	7.2b	+	+	15.5a	9.3a
Dill	4.5a	5.9d	32.7a	28.3a	(-)a	(-)a	1.5a	3.5c	7.7b	5.5b	22.7a	16.7a
Coriander	20.2b	10.6f	37.3a	30.2a	16.4d	2.3b	8.2a	2.6d	4.3b	3.7b	26.9a	23.3b
Turmeric	40.3c	50.3a	42.5a	35.3a	(-)a	(-)a	5.1a	3.9a	2.2b	2.5b	23.5a	15.2x
Antibiotics*												
Penicillin-G	21.0d	18.7c	17.4c	13.3a	14.3a	12.0b	+	+	+	+	5.6c	7.7d
Amikacin	5.6f	4.3b	9.4b	7.6b	45.0b	38.9c	12.2b	11.5a	12.7a	11.0a	8.6b	5.5a
Gentamycin	23.7c	20.0a	11.1a	8.9c	32.3c	26.5c	41.1c	10.6b	15.3a	12.1a	5.9d	3.7c

Values are means±S.D. of three independent determinations.

Means within a column followed by the same letter are not significantly different ($P>0.05$)

(-) ineffective; + 100% activity; * 10mg/petridish

Table 4 : DPPH radical scavenging activity of essential oils and acetone extracts

Essential oil (µl)	DPPH radical scavenging activity (%)									
	BHA	Anise	Ajwain	Star anise	Tejpat	Chinese Cassia bark	Dill	Turmeric	Fennel	Coriander
5	86	47.2	61.2	28.8	50.31	41.8	26.1	29.33	29.3	49.98
10	88.2	49.8	67.21	33.44	57.65	47.99	30.11	36.11	35.55	66.67
15	91.26	53.5	75.21	40.22	61.11	55.2	35.11	39.22	41.21	75.98
20	94	58.22	83	46.44	64.11	61.22	37.99	45.11	43.7	87.2
25	96	65.22	88.2	53.11	70.29	67.22	43.62	49.1	48.1	96.1
Acetone extracts										
5		47.2	63.33	33.1	56.11	57.1	27.11	36.11	29.1	45.11
10		48.66	67.21	37.88	59.1	59.1	30.11	39.1	34.55	51.33
15		54.33	74.11	40.22	66	64.1	36	42.11	37.77	56.11
20		60.1	84.66	45.1	69.11	70.12	42	45.11	42.12	61.22
25		67	87.22	52.11	74.44	76.37	45.88	48.2	46.21	66.14

Table 5 : Reducing power of essential oils and acetone extracts

Essential oil (µl)	Reducing power (%)									
	BHA	Anise	Ajwain	Star anise	Tejpat	Chinese Cassia bark	Dill	Turmeric	Fennel	Coriander
5	69.8	43.6	42.2	43.8	44.1	47.2	44.9	46.3	43.1	43.1
10	75.1	56.4	46.2	49.6	48.5	52.3	53.6	53.6	48.7	48.7
15	79.8	63.5	51.2	55.1	54.7	61.2	59.6	62.8	53.2	53.2
20	83.1	66.1	58.7	61.3	59.5	67.7	63.2	66.2	59.6	59.6
25	87.91	67.2	65.2	67.8	64.7	68.5	67.1	67.4	65.8	65.8
Acetone extracts										
5		67.3	66.5	66.4	64.3	63.21	62.3	67.2	65.9	61.9
10		69.8	68.3	69.9	70.6	72.6	71.1	72.3	70.9	66.9
15		71.5	71.8	73.1	72.3	73.5	76.4	78	75.4	72.1
20		78.6	78.2	77.9	76.3	80.2	81.1	81.3	79.5	77.5
25		84.2	83.2	82.5	81.2	87.2	85.2	85.6	81.2	87

ferrous ions increased with increasing concentration and a similar trend was observed for acetane extracts (Table 6). However, the chelating ability of EDTA was 76.3 % at 20 µL. Apparently, the essential oil and acetane extracts could chelate ferrous ions but were not as effective chelators as EDTA. Since, ferrous ions are the most effective pro-oxidants in food systems[25], the moderate to high chelating effects of essential oils and acetone extracts would be beneficial.

Using the conjugated diene method, all the essential oils and acetone extracts showed moderate to good antioxidant activity at 5-25 µL level (Table 7). The antioxidant activity exerted by all the essential oils and extracts was comparable with synthetic antioxidants (BHT) at 5-25 mg level. Using three different methods to measure antioxidant activities, BHT consistently showed strong antioxidant activities at all tested concentrations. In all the three methods, the antioxidant activities exerted by essential oils or extracts were moreover equal and comparable among them.

Table 6 : Chelating effect of essential oils and acetone extracts on ferrous ions

Essential oil (µl)	Chelating effect (%)									
	EDTA	Anise	Ajwain	Star anise	Tejpat	Chinese Cassia bark	Dill	Turmeric	Fennel	Coriander
5	50.61	17.42	23.45	28.67	24.61	21.25	18.47	23.79	27.45	20.01
10	58.5	23.8	26.34	33.1	27.85	26.35	26.42	28.69	29.56	23.43
15	64.9	26.71	29.09	37.2	29.24	27.95	28.32	32	31.76	27.63
20	76.3	30.12	32.34	42.5	33.21	32.78	31.27	39.7	34.9	29.17
25	90.4	34.87	39.72	51.1	45.6	35.98	34.51	49.5	42	32.43
Acetone extracts										
5		20.12	24.45	33.31	24.71	40.44	20.04	23.79	25.71	19.01
10		23.8	30.06	41.14	28.15	44.55	26.78	28.69	30.01	25.40
15		30.01	32.08	46.91	33.20	49.95	36.91	32	35.98	31.63
20		33.12	37.07	55.11	36.21	57.74	41.17	39.7	41.09	38.17
25		38.80	44.72	60.02	44.56	65.90	44.01	49.5	46.71	44.42

Table 7 : Antioxidant activity of essential oils and acetone extracts in terms of conjugated diene method

Essential oil (µl)	Conjugated diene method — Antioxident activity (%)									
	BHA	Anise	Ajwain	Star anise	Tejpat	Chinese Cassia bark	Dill	Turmeric	Fennel	Coriander
5	69.34	57.1	63.5	65.2	53.6	51.6	57.2	55.4	59.8	61.2
10	73.11	63	67.3	68.3	57.2	56.3	61.5	64.2	63.9	67.4
15	79.34	71.2	71.2	71.2	62.5	61.5	64.2	69.8	67.1	70.9
20	83.39	73.5	73.5	73.2	68.7	66.99	68.1	73.2	70.1	72.3
25	87.98	75.5	76.5	74.1	72.3	70.22	73.2	75.2	71.3	75.7
Acetone extracts										
5		60.5	66.7	64.2	65.3	67.6	62.5	68.2	62.3	61.8
10		66.8	69.8	67.2	68.3	68.7	66.7	69.3	67.4	67.5
15		70.6	72.4	71.8	72.5	71.4	69.3	72.6	72.8	70.9
20		72.4	73.5	75.3	73.6	74.7	72.6	74.6	74.3	75.1
25		73.1	78.2	76.4	80.3	83.5	82.3	80.8	74.9	79.4

Antioxidant activity of the volatile oil may be due to a combined effect of the chemical components in the essential oil or acetone extract. An early study of Chilpault *et al.*[26] demonstrated the antioxidant activity of 32 spices and herbs and their solvent extracts both in edible oils and in oil-in-water emulsions. A large number of methods have been developed in order to evaluate antioxidant activity[27-29] which provides particular, but limited information about antioxidant activity. We applied different methods to evaluate antioxidant activity in our present investigation, which would provide additional information in the assessment of the antioxidant potential of essential oil and extract.

Conclusion

Based on above results, it could be said that the volatile oils and extracts of ajwain, tejpat, Chinese Cassia bark and coriander possess excellent antimicrobial properties even at very low concentration against *Escherichia coli*, *Salmonella typhi*, *Pseudomonas aeruginosa, Bacillus cereus*, *B. subtilis* and *Staphylococcus aureus*. They have also shown moderate to strong antioxidant activity by DPPH and other radical scavenging assays. These studies can be useful as starting point for further

applications of essential oils and acetone extracts in food and pharmaceutical preparations.

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