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ORIGINAL ARTICLE

Antimicrobial activity of turmeric extract and its potential use in food industry

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Abstract The present study investigates the antimicrobial and preservative potentials of turmeric extracts for food industry. Turmeric extracts prepared in n-hexane, water, chloroform and ethanol were applied to meals as preservatives and antibacterial agent. The samples were assessed microbiologically (total bacterial, total fungal and total coliform counts) and organoleptically (color, odor, taste) at day zero and after 15 days intervals. Meals autoclaved for shorter time (5 min) and treated with combination of 1 % or 2 % turmeric extract preserved for longer period. These results were comparable with samples autoclaved for longer period (15 min) with out turmeric extract. The antibacterial activities of different turmeric extracts were also tested against *Escherichia coli, Staphylococcus aureus, Salmonella typhi* and *Candida albicans* by disc diffusion method. Water extracted samples of turmeric stored at room temperature inhibited the growth of *Escherichia coli* and *Salmonella typhi* while aqueous extract autoclaved at 121 °C for 30 min reduced the growth of *Escherichia coli* and *Staphylococcus aureus*. Methanol extracted samples stored at room temperature or autoclaved at 121 °C was effective to control the growth of all microbes under study. Chloroform and n-hexane extracts (stored at room temperature) showed weak activity against all tested microbes.

Keywords Antibacterial activity · Antifungal activity · Turmeric extracts · Food preservative · Disc diffusion method

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Introduction

Meals ready-to-eat (MRE) is getting popularity in our daily life. These packed foods are designed to have a long shelf life, require very little preparation work and are perfect for emergency survival preparation. Meals are often vulnerable to contamination and subsequent growth by food borne pathogens (*Salmonella Enteritidis, Staphylococcus aureus, Campylobacter jejuni, Listeria monocytogenes*) during their preparation. There is a great concern of increasing antibiotic resistance of these pathogens (Meng et al. 1998; Perreten et al. 1998; Stermitz et al. 2000). Use of natural antibacterial compound such as extracts of spices and herbs etc., for food preservation is getting immense interest among researchers (Smid and Gorris 1999; Estevez et al. 2007; Pezeshk et al. 2011) For food preservation certain systems e.g. heating, refrigeration and addition of antimicrobial compounds are employed, however, these techniques are frequently associated with adverse changes in organoleptic characteristics and loss of nutrients. Within the disposable arsenal of preservation techniques, the food industry is keen to investigate the replacement of traditional food preservation methods by new ones due to increased consumer demands for tasty, nutritious, natural and easy-to-handle food products. Cold distribution chain have made international trade of perishable foods possible, however, refrigeration is not only very expensive but also cannot assure the quality and safety of all perishable foods. Similarly, canning preservation process is also costly, and has adverse effects on the nutritional as well as organoleptic quality of foods.

Investigations of medicinal plants are getting importance among the scientists both for human health and food industry (Dorman and Deans 2000; Novak et al. 2000; Aligiannis et al. 2001; Bakht et al. 2011a, b, c, d; 2012 and 2013a, b). Foods preserved with natural additives have become popular due to greater consumer awareness and concern regarding synthetic

chemical additives. Food industries are looking for natural preservative with no or little adverse effects and to keep their food preserved for long period of time (Beuchat 1994; Nakatani 1994). Spices and herbs not only add flavor to food but also preserve it from different factors effecting quality of food (Tsigarida et al. 2000; Skandamis and Nychas 2001; Mejlholm and Dalgaard 2002; Gill et al. 2002; Tajkarmi et al. 2010; Abdollahzadeh et al. 2014).

Turmeric (*Curcuma longa*) is extensively used as spice, food preservative and coloring material in India, China and South East Asia. Various sesquiterpenes and curcuminoids have been isolated from the rhizome of *C longa*, attributing a wide array of biological activities (Tilak et al. 2004; Kumar et al. 2006) anti-inflammatory (Sandur et al. 2007; Aggarwal and Harikumar 2009) wound healing (Maheshwari et al. 2006), anticancer (Kim et al. 2012) and antibacterial activity (Gupta and Sadhana 2005; Naz et al. 2010). The present study was undertaken to investigate the effect of turmeric extract on shelf life extension of chicken and potato based cooked meal and antimicrobial activity on pure cultures of food borne pathogens in comparison to commercially available antibacterial drugs.

Materials and methods

Plant materials

Turmeric rhizomes were obtained from local market of Peshawar KPK Pakistan. The collected rhizomes were shade dried. The dried plant materials were finely powdered by tissue homogenizer (Infinigen™ Tissue Mixer Mill).

Preparation of turmeric oil/extract

Turmeric oil extract was isolated as described in Funk et al. (2010) with some modification. About 1,000 g of dried powdered was mixed five litters each of distilled water, n-hexane, methanol, and chloroform in flasks separately and kept at room temperature for 7 days. During this period, shaking of the flasks was performed daily. The solvent soluble compounds were filtered using double filter paper (Whatman™). Fresh solvents were added into the used plant material and the process was repeated three times. The filtered solutions containing plant compounds were dried by rotary evaporator (Rotavapor ®-R 210/R215; BUCHIL Labortechnik AG).

Meal preparation

For this purpose, food containing potato, boneless chicken cooking oil, masala, tomato and salt was prepared. The prepared meal samples were divided into 8 lots (control, 1 % turmeric oil, 2 % turmeric oil, 0.1 % sodium benzoate, 0.1 % sodium benzoate +1 % turmeric oil, 1 % turmeric oil + autoclaved at 121 °C for 5 min, 2 % turmeric oil + autoclaved at 121 °C for 5 min and autoclaved only at 121 °C for 15 min). The treated samples were packed in Tetra pack pouches using HEKELMAN Vacuum System Boxer 42 and stored at room temperature for a period of 90 days. They were analyzed for total bacterial, fungal, coliform, salmonella and sensory quality initially and after 15 days interval for a total period of 3 months.

Microbiological assessment

The prepared meals were tested for microbiological parameters i.e. total bacterial counts (TBC), coliform group of bacteria, fecal coliform, Salmonella, and total fungal counts.

Total bacterial counts (TBC)

TBC were determined by dilution plate method using nutrient agar media (Feng et al. 2002). The colonies were counted by colony counter and TBC were calculated by multiplying average number of colonies by dilution factor and reported as number of colonies g^{-1} of sample.

Total coliform count

The samples were transferred to Lauryl tryptose broth (LSB) (1:3 ratio) and incubated at 35 °C for 24 h. The tubes were examined and a reaction for gas production was recorded. The gas negative tubes were re-incubated for next 24 h and checked for any positive gas production. Coliform counts were calculated with the help of most probable number (MPN) (Feng et al. 2002).

Total fungal count

Total fungal count in the samples was determined by the dilution plate method (US FDA 1998). Fifty gram samples were mixed with appropriate amount of 0.1 % peptone water to the weighed sample to achieve 10^{-1} dilution, homogenized in a stomacher for 2 min. Dilutions upto 10^{-6} was prepared in 0.1 % peptone water. Hundred micro-liters of each dilution were pipetted aseptically on pre-poured, solidified Dichloran rose bengal chloramphenicol (DRBC) agar plates and spreaded with a sterile, bent glass rod. The petri plates were incubated in inverted position at 25 ±1 °C for 5 days. Data on total fungal counts were calculated as TFC g^{-1} of meal sample.

Sensory evaluation

The prepared meals samples were tested for their sensory quality (color, taste, flavor, and overall acceptance) by a panel

of 10 judges during the 3 months storage, using a 0–9-point hedonic scale by the method of Larmond (1977).

Micro-organisms used for antibacterial activities

Different micro-organisms tested for antimicrobial activities were *Staphylococcus aureus* (Gram-positive, clinical isolates and ATCC #6538), *Salmonella typhi* (Gram-negative, clinical isolates), *Escherichia coli* (ATCC # 25922) and *Candida albicans* (Fungus).

Antimicrobial activity of turmeric oil/extract by well diffusion susceptibility method

The antibacterial activity of different solvent extracted samples of turmeric was carried by disc diffusion assay as described in Bauer et al. (1966) and antifungal activity by Ramdas et al. (1998). Briefly, for disc diffusion assay, filter paper discs (Whatman no. 1) of 8 mm diameter were prepared and sterilized. Using sterile forceps, these discs were aseptically placed over nutrient agar plates seeded with the respective test microorganisms. Two different concentrations of turmeric extracts/oil (6 and 12 μg in DMSO) were aseptically transferred to these discs. The plates were incubated in an upright position at 37 °C for 24 h. The diameters of inhibition zones (in mm) were measured. For antifungal activity, the selected fungi were grown on Czapeck dox agar (CDA) medium and plates were incubated at 37 °C. The mycelial discs of 5 mm diameter were cut along with adhering agar from the 7 days old cultures and were used as inoculums throughout the present study. Radial growths of fungi in terms of average diameter (mm) were recorded on the 5th day. The data was used for calculating percent inhibition of mycelial growth according to the following formula

$$\%\text{Mycelial zone of inhibition} = \frac{dc-dt}{dc} \times 100$$

where dc and dt are average diameters of mycelia colony of control and treated sets, respectively.

For antibiotic sensitivity testing, the cultures were prepared in sterile nutrient broth for 16–18 h at 37 °C. The cultures were aseptically swabbed on the surface of sterile Nutrient Agar plates. Different antibiotics (Arithromycine, Ciprofloxacin at 50 μg concentration for Gram-positive and Gram-negative bacteria; 50 μg Clotrimazol for fungus in DMSO) were aseptically placed over the seeded agar plates. The plates were incubated at 37 °C for 24 h and the diameter of the inhibition zones (in mm) were measured.

Results

The total bacterial count of control was more compared with samples with 1 % or 2 % turmeric extracts (Table 1). The sealed pouches of control sample were found swollen within 24 h and considered spoiled. After 15 days storage period, gas was produced in some of the samples treated with 1 or 2 % turmeric extract. Both treatments were discarded from the trial and not tested for further storage period. The initial bacterial count in the sample treated with 0.1 % sodium benzoate was 2.5×10^1 and slightly increased to 6.1×10^1 TBC g^{-1} of meal sample after 15 days storage period. After 30 days, this lot was also discarded due to the swelling of the pouches. Samples treated with both 1 % turmeric extract and 0.1 % sodium benzoate were found safe for consumption and kept for further 45 days storage period. Negligible bacterial counts were noted till 45 days storage period, however, later on, some pouches were filled with gas and discarded. No bacterial growth was noted in samples treated with combination of 1 % turmeric extract + autoclaved and 2 % turmeric extract + autoclaved during the 90 days storage period and was found safe for human consumption. Similar results were also recorded for the meal samples autoclaved for 15 min at 121 °C without the addition of turmeric extract.

The initial fungal counts of the control sample were 1.5×10^2. This lot was spoiled within 24 h as mentioned earlier (Table 2). The initial fungal counts of samples treated with 1 % turmeric extracts was less compared with 2 % turmeric extract (Table 2). Later on, both the samples did not retain their quality and were discarded. No fungal counts were noted in the samples treated with 0.1 % sodium benzoate, however, these samples were also discarded after 15 days of storage

Table 1 Effect of turmeric extract and autoclaving on total bacterial counts of meals packed in Tetra pack pouches during storage

Treatments	Storage days						
	0	15	30	45	60	75	90
1	3.2×10^2	Discarded	–	–	–	–	–
2	2.6×10^2	Discarded	–	–	–	–	–
3	1.5×10^2	Discarded		–	–	–	–
4	2.5×10^1	6.1×10^1	Discarded	–	–	–	–
5	2.0×10^1	ND	ND	ND	–	–	–
6	ND	ND	ND	ND	ND	ND	ND
7	ND	ND	ND	–	–	–	–
8	ND	ND	ND	–	–	–	–

Key: 1. Control; 2. One percent turmeric oil (n-hexane); 3. Two percent turmeric oil

4. One tenth percent sodium benzoate; 5. One tenth percent sodium benzoate + 1 % turmeric oil; 6. One percent turmeric oil + Autoclave at 121 °C for 5 min at 121 °C for 05 min; 7. Two percent turmeric oil + Autoclave at 121 °C for 5 min (*ND* Not Detected)

Table 2 Effect of autoclave with out turmeric extract on fungal and bacterial count

Treatments	Storage days						
	0	15	30	45	60	75	90
1	1.5×10^2	Spoiled	Spoiled	Spoiled	Spoiled	Spoiled	Spoiled
2	1.2×10^2	Spoiled	Spoiled	Spoiled	Spoiled	Spoiled	Spoiled
3	1.0×10^2	Spoiled	Spoiled	Spoiled	Spoiled	Spoiled	Spoiled
4	ND	ND	Spoiled	–	–	–	–
5	ND	ND	ND	ND	–	–	–
6	ND	ND	ND	ND	ND	ND	ND
7	ND	ND	ND	ND	ND	ND	ND
8	ND	ND	ND	ND	ND	ND	ND

Key: 1. Control; 2. One percent turmeric oil (n-hexane); 3. Two percent turmeric oil; 4. One tenth percent sodium benzoate; 5. One tenth percent sodium benzoate + 1 % turmeric oil; 6. One percent turmeric oil + Autoclaved at 121 °C for 05 min at 121 °C for 05 min; 7. Two percent turmeric oil + Autoclaved at 121 °C for 05 min (*ND* Not Detected)

period due to swelling of the pouches. The other two lots of meals treated with turmeric extract + autoclaved were found free from fungal contamination during the entire storage time of 90 days. The prepared and packed meal samples were tested organoleptically for color, flavor and taste by a panel of 10 expert judges using a 9 points hedonic scale where 9 expressed extremely likeness while zero shows extremely dislike. The initial average scores for color given by the judges were 8.5, 8.4, 8.5, 8.5, 8.4, and 8.5 for all samples at day zero (Table 3). The first 3 samples (1, 2, and 3) were discarded and not further tested for color due to their bacterial spoilage. Sample No 4 and 5 were also discarded after 15 and 30 days storage period respectively. With the prolonging storage time, the scores for color decreased to 6.7 to 5.7. High marks were given to sample No.6 (combination of 1 % turmeric extract + autoclaved) and the lowest were observed in case of autoclaved sample.

At day zero, the average score for odor was 8.0, 8.7, 8.5, 8.2, 8.2, 8.0, 7.8 and 7.4 for the meal samples no 1, 2, 3, 4, 5, 6, 7 and 8 respectively (Table 4). The first three samples were discarded from the experimental lots at the start of the experiment and the other 2 samples (4 and 5) were also considered spoiled and discarded after 15 and 45 days storage period. The remaining 3 samples (6, 7 and 8) were assessed for odor for a total period of 90 days. At 90 days storage period, the score for odor in case of samples 6, 7 and 8 decreased in the order of 6.3 (sample 4), 6.1 (sample 5) and 5.5 (sample 6). The highest average score was noted in case of sample 6 (treated with combination of 1 % turmeric extract + autoclaved for 5 min) followed by sample 7 (2 % turmeric extract + autoclaved for 5 min) while the lowest score was observed in case of sample No, 8 (autoclaved meal sample for 15 min). Data regarding taste of the prepared packed meals are given in Table 5. The scores of the prepared packed meal samples at day zero storage were 8.6 (sample 1), 7.8 (sample 2) and 7.4 (sample 3), 8.2 (sample 4), 8.2 (sample 5), 7.8 (sample 6), 7.8 (sample 7) and 7.2 (sample 8). After completion of 90 days storage period, the score was decreased to 6.2, 5.8 and 5.4 for samples No. 6, 7 and 8 respectively.

Table 3 Effect of turmeric and autoclave on color of meal storage days

Treatments	Storage days						
	0	15	30	45	60	75	90
1	8.0	Spoiled	–	–	–	–	–
2	8.2	Spoiled	–	–	–	–	–
3	8.5	NT	–	–	–	–	–
4	8.0	8.4	Spoiled	Spoiled	–	–	–
5	8.2	8.2	8.0	7.6	–	–	–
6	7.8	7.8	7.6	7.1	7.1	6.7	6.7
7	7.6	7.5	7.5	7.2	6.9	6.6	6.3
8	7.3	6.6	6.6	6.2	6.0	57	5.7

Key: 1. Control; 2. One percent turmeric oil (n-hexane); 3. Two percent turmeric oil; 4. One tenth percent sodium benzoate; 5. One tenth percent sodium benzoate + 1 % turmeric oil; 6. One percent turmeric oil + Autoclaved at 121 °C for 05 min at 121 °C for 05 min; 7. Two percent turmeric oil + Autoclaved at 121 °C for 05 min

Table 4 Effect of turmeric extracts on odor of meal

Treatments	Storage days						
	0	15	30	45	60	75	90
1	8.0	Spoiled	–	–	–	–	–
2	8.7	–	–	–	–	–	–
3	8.5	–	–	–	–	–	–
4	8,2	8.0	–	–	–	–	–
5	8.2	7.8	7.5	NT	–	–	–
6	8.0	7.5	7.2	7.0	6.6	6.6	6.3
7	7.8	7.5	7.2	6.9	6.6	6.5	6.1
8	7.4	7.0	6.8	65	6.5	6.2	5.5

Key: 1. Control; 2. One percent turmeric oil (n-hexane); 3. Two percent turmeric oil; 4. One tenth percent sodium benzoate; 5. One tenth percent sodium benzoate + 1 % turmeric oil; 6. One percent turmeric oil + Autoclaved at 121 °C for 05 min at 121 °C for 05 min; 7. Two percent turmeric oil + Autoclaved at 121 °C for 05 min

Table 5 Effect of turmeric extract on taste of meal

Treatments	Storage days						
	o	15	30	45	60	75	90
1	8.6	Spoiled	–	–	–	–	–
2	7.8	–	–	–	–	–	–
3	7.4	NT	–	–	–	–	–
4	8.2	7.7	–	–	–	–	–
5	8.2	7.8	7.5	–	–	–	–
6	7.8	7.6	7.3	7.3	7.0	6.5	6.2
7	7.8	7.4	7.1	6.9	6.5	6.0	5.8
8	7.2	7.0	6.7	6.4	6.1	5.7	5.4

Key: 1. Control; 2. One percent turmeric oil (n-hexane); 3. Two percent turmeric oil; 4. One tenth percent sodium benzoate; 5. One tenth percent sodium benzoate +1 % turmeric oil 6. One percent turmeric oil + Autoclaved at 121 °C for 5 min at 121 °C for 5 min;7. Two percent turmeric oil + Autoclaved at 121 °C for 5 min

The antibacterial and antifungal activity of methanol (at room temperature and 121 °C), chloroform, n-hexane and water (at room temperature and 121 °C) extracted turmeric samples was also investigated (Tables 6 and 7). *Escherichia coli* were susceptible to all the extracts recording different zones of inhibition in these solvents extracted samples. The data further suggested that maximum zone of inhibition (13.5 mm) was noted for *Staphylococcus aureus* by methanol (room temperature) extracted samples when applied at 12 μg concentration followed by methanol (121 °C) recording 11.5 mm zone of inhibition at the same concentration. Zero zone of inhibition was noted for *Candida albicans* and *Staphylococcus aureus* in water extracted samples applied at 6 and 12 μg concentrations. Similarly, water (121 °C) extracted samples recorded 0 mm against *Candida albicans* applied at both concentrations.

Discussion

In the present study food was preserved using natural product from turmeric extracts in comparison to chemical preservation in various combinations. The treated meal prepared from boneless chicken meat was stored at ambient temperature for a total period of 90 days to investigate the effect of turmeric extract/oil on the shelf life extension. From our results, it is clear that samples treated with turmeric extract alone, received comparatively high scores organoleptically from the panel of judges at day zero, however, these samples could not retain their quality due to the undesirable odor and filling of gas inside the pouches. The microbiological assessment of the samples indicated that the above deterioration was not due to growth of aerobic microorganisms, as its count was quite low and also within the permissible limit. It can be assumed that the meal spoilage inside the pouches might be due to the attack of anaerobic spore forming microbes that were resistant to turmeric extract at the tested concentrations. Meal samples treated with 0.1 % sodium benzoate + 1 % turmeric extract were found acceptable for human consumption up to 45 days, however, after that period, this lot was also discarded due to the swelling of some of the pouches. However, meal samples treated with combination of 1 % or 2 % turmeric extract oil + autoclaved at 121 °C for 5 min were found safe and free from microbiological contamination for the entire 90 days storage period. From our findings, it is clear that turmeric extract can be applied successfully in combination with any other preservative techniques for meal ready to eat prepared from boneless

Table 6 Antimicrobial activity of fresh turmeric extracts in different solvent

Turmeric extract	Quantity used (μg)	Tested microbes and zone of inhibition (mm)			
		C. abican[b]	*E. coli*[c]	*S. typhi*[b]	*Staph. aureus*[b]
Methanol RT[a]	6	9	7.5	7	10.5
	12	9	10	8.5	13.5
Methanol 121 °C	6	7	8	7	10
	12	8.5	9	11.5	10
Water RT[a]	6	0	7	7	0
	12	0	7	10	0
Water 121 °C	6	0	6	0	6
	12	0	7.5	0	8.5
N-Hexane RT[a]	6	8	7.2	7	9
	12	10	10.5	7	10
Chloroform RT[a]	6	7	7	8	7
	12	7	8	7	9

Key: 1. Control; 2. One percent turmeric oil (n-hexane); 3. Two percent turmeric oil

4. One tenth percent sodium benzoate; 5. One tenth percent sodium benzoate + 1 % turmeric oil;6. One percent turmeric oil + Autoclaved at 121 C for 5 min at 121 °C for 5 min; 7. Two percent turmeric oil + Autoclaved at 121 C for 05 min

[a] Room temperature

[b] Clinical isolate

[c] ATCC Standard

Table 7 Antimicrobial activity of stored extracts of Turmeric (4 °C for 30 days)

Turmeric extract	Quantity used (μg)	Tested microbes and zone of Inhibition (mm)			
		C. abica[b]	*E. coli*[c]	*S. typhi*[b]	*Staph.aureus*[c]
Methanol RT[a]	6	10	22.5	11	10.5
	12	14	11.5	9	9
Methanol 121 °C	6	10	11	9	11
	12	9.5	11.5	10	9
Water RT[a]	6	0	7	7	0
	12	0	9	8.5	0
Water 121 °C	6	0	0	0	0
	12	0	0	0	0
N-Hexane RT[a]	6	9	11.5	9	9.5
	12	9.5	13	10	12
Chloroform RT[a]	6	8	10	9	6
	12	11.5	12	10.5	7

Key: 1. Control; 2. One percent turmeric oil (n-hexane); 3. Two percent turmeric oil 4. One tenth percent sodium benzoate; 5. One tenth percent sodium benzoate + 1 % turmeric oil; 6. One percent turmeric oil + Autoclaved at 121 C for 5 min at 121 °C for 5 min; 7. Two percent turmeric oil + Autoclaved at 121 C for 5 min

[a] Room temperature

[b] Clinical isolate

[c] ATCC Standard

chicken meat. Similar results were also observed in case of prepared packed samples autoclaved at 121 °C for 15 min without the addition of turmeric extract or any other natural or chemical preservatives. No bacterial and fungal growth was observed during the entire storage period of 90 days, however, organoleptically, the meal samples treated in combination of turmeric extract + autoclaved for short time (5 min) were comparable with those autoclaved for longer time (15 min) only. Prakash et al. (2007) and Lim et al. (2011) reported anti-oxidant and free radical scavenging activities in *Curcuma zeoderia* leaves and *Curcuma longa* extracts. Similar results are also concluded by Pezeshk et al. (2011). An over cooked smell and taste were noted by the judges in autoclaved meal samples. This undesirable smell and taste might have been developed due to over cooking of the meal samples in the autoclave.

In the present study, an aqueous, n-hexane, chloroform and methanolic extracts of turmeric exhibited different ranges of activity against *Candida albicans*, *Salmonella typhi*, *Staphylococcus aureus* and *Escherichia coli*. The methanolic and aqueous extracts autoclaved at 121 °C were active against *Staphylococcus aurues* isolates (7.5 mm–12.5 mm ZI respectively). Chandrana et al. (2005) and Kim et al. (2005) reported that turmeric extract was effective against *Escherichia colii, Bacillus subtilis* and *Staphylococcus aureus* which may be due to the presence of curcuminoid, a phenolic compound. Negi et al. (1999a, b) reported that turmerone and curlone components of turmeric possessed better antibacterial activity against a wide range of microbes including *Bacillus cereus, Bacillus coagulans, Bacillus subtilis, Staphylococcus aureus. Escherichia coli and Psuedomonas aeruginosa*. The antimicrobial activity of turmeric is reported to be due to the presence of essential oil, curcumins, curcuminoids, turmeric oil, turmerol and veleric acid (Cikricki et al. 2008; Rai et al. 2008; Basniwal et al. 2011).

The antifungal activity of turmeric extracts was also tested against *Candida albicans*. Our results are comparable with Arora and Kaur (1999) and Roth et al. (1998) who demonstrated the antifungal activity of turmeric extracts. However, antifungal activity against other molds such as *Aspergillus niger, Penicillium digitatum Aspergillus flavus, Penicillium javanium, Curvularia oryzae* and *Trichophyton mentagrophytes* has also been reported (Kapoor 1997; Arora and Kaur 1999). Methanol, chloroform and n-hexane extracts from turmeric showed distinct antimicrobial activities and aqueous extract did not show any activity against *Candida albicans.* These findings are in accordance with Mohammad et al. (2010). Wilson et al. (2005) concluded that petroleum ether, hexane, chloroform, acetone and ethanol extracts of *Curcuma zedoaria* and *Curcuma malabarica* exhibited antibacterial as well as antifungal activity. Similarly, essential oil extracted from *Zingiber officinale* exhibited activity against food-borne pathogenic fungal and bacterial species (Singh et al. 2008). The possible mechanisms of antifungal activity of spices may be due to cytoplasm granulation, cytoplasmic membrane rupture and inactivation and/or inhibition of intracellular and extracellular enzymes alone or in combination (Cowan 1999). It is also reported that plant lytic enzyme act in the fungal cell wall causing breakage of β-1,3 glycan, β-1,6, glycan and chitin polymer (Brull and Coote 1999). The probable reasons for zero antifungal activity of aqueous extracts of turmeric may be due to the lack of antimicrobial activity in the plant part used or the procedure of extraction (Arora and Kaur 1999) or the time of collection of herbal material and climate, which might have affected the amount of active constituents in the plant material (Prakash et al. 2007).

Among different microorganisms, *Staphylococcus aureus* was found to be the most susceptible pathogen to all extracts except aqueous at room temperature. Similarly, Wang et al. (2009) reported that microcapsule curcumin was more effective

against *Staphylococcus aureus*. Zones of inhibition produced by turmeric extracts in the present study were about 10.5–12.5 mm. The antimicrobial activity of methanol and chloroform extracts was similar to those reported by Mohammad et al. (2010).

Our results showed that methanol, chloroform and n-hexane extracted samples had activity against *Salmonella*. Similar results were also reported by Mohammad et al. (2010), however, no activity was recorded by aqueous extract against *Salmonella* (Mohammad et al. 2010). The data obtained in the present study revealed that different extracts of turmeric had antimicrobial activity against *Escherichia coli* produced different zones of inhibition. These results agree with Chandrana et al. (2005) and Mohammad et al. (2010). Nevertheless, in relation to the composition of foods and fruits, further investigations are necessary to identify the conditions that maximize their activity without detrimental effects on the organoleptic properties of the product.

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