RESEARCH ARTICLE Asian Journal of Dairy and Food Research, Volume 45 Issue 1: 119-126 (February 2026)

Antimicrobial and Antioxidant Efficacy of Spice Extracts and Their Application against Common Foodborne Pathogens

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10.18805/ajdfr.DRF-387

ABSTRACT

Background: The study aimed to investigate the potential antioxidant and antimicrobial properties of four spice extracts against five common foodborne pathogens.

Methods: The antimicrobial and antioxidant efficacy of four spice extracts from *Zingiber officinales*, *Syzygium aromaticum*, *Cuminum cyminum* and *Origanum vulgare* were examined against five foodborne pathogens. *Listeria monocytogenes, Bacillus cereus, Staphylococcus aureus*, *Escherichia coli* and *Pseudomonas aeruginosa* using disc diffusion technique. The respective five pathogenic strains were tested against the antibiotic Gentamycin (5 mg) as a control.

Result: From the study, it was found that *Z. officinales*, *S. aromaticum, C. cyminum* and *O. vulgare* extracts were found potentially active with diverse efficiency against the five respective bacterial strains at a standard concentration of 10 mg/mL while the extract of *C. cyminum* was only most effective against *L. monocytogenes.* Whereas *E. coli and B. cereus* were found resistant to *Z. officinales* and *C. cyminum.* The *Z. officinales* inhibited the bacterial growth with the MIC at 2.50 mg/mL but other extracts showed an alike response at 5.0 mg/mL. However, the spice extracts showed highly durable bacteriostatic activities against the strains of foodborne pathogens with MIC ranging from 2.5 to 15.0 mg/mL.

Key words: Antimicrobial, Food spoilage, Foodborne pathogens, Spice-extract.

INTRODUCTION

Food spoilage poses a significant public health concern in developing countries, leading to instances of foodborne illness and food poisoning (Sapkota *et al*., 2012; Pirbalouti *et al*., 2009). The main cause of food poisoning is bacteria, mainly Gram-negative, such as *Salmonella typhi*, *Escherichia coli* and *Pseudomonas aeruginosa* (Pandey *et al*., 2011). Additionally, Gram-positive bacteria including *Staphylococcus aureus* and *Bacillus cereus*, have been recognized as causative agents of foodborne illnesses (Braga *et al*., 2005). Moreover, foodborne outbreaks can be caused by a variety of pathogens including *Salmonella enterica*, *Staphylococcus aureus*, *Bacillus cereus*, *Clostridium perfringens*, *C. botulinum*, *Campylobacter jejuni*, *Escherichia coli* O157: H7 and *Listeria monocytogenes* (Seow *et al*., 2013; de Aguirer *et al*., 2018). Avoidance of food spoilage and its etiological agents are conventionally brought off using preservatives of a chemical nature (Shan *et al*., 2007). Although chemical preservatives effectively prevent and control foodborne diseases, their extensive use results in chemical residues building up in the food and feed supply chain, bacterial resistance to these substances and negative impacts on human health (Bialonska *et al*., 2010; Akinyemi *et al*., 2006). Moreover, merely several pathogenic bacteria are responsive against chemical preservatives in food products like *Listeria monocytogenes*; in other words, chemical preservatives are ineffective in reducing the growth of spoilage microorganisms (Silva and Domingues, 2017). Because of such apprehensions, efforts have been concentrated on emerging potentially effective food preservatives.

A good number of research have documented the utilization of herbal extracts as antimicrobial agents for food preservation (Nasar-Abbas and Kadir Halkman, 2004; Mathabe *et al*., 2006; Herman *et al*., 2016; de Aguiar *et al*., 2018). Phenolic compounds like sterols, carotenoids, terpenes, glucosinolates, alkaloids and various sulfur-containing compounds are bioactive phytochemicals richly found in herbs and spices, the most of which have strong antioxidant capacity (Herrera *et al*., 2020; Maji *et al*., 2018). These herbal extracts are regarded as natural reservoirs of antimicrobial agents, recognized for their nutritional safety

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How to cite this article: Islam, M.Z., Arefin, S., Hasan, M.S., Sarker, M.A.H., Khandakar, M.M.H., Rahman, A., Siddiki, M.S.R. and Rashid, M.H. (2026). Antimicrobial and Antioxidant Efficacy of Spice Extracts and Their Application against Common Foodborne Pathogens. *Asian Journal of Dairy and Food Research*. **45(1):** 119-126. doi: 10.18805/ajdfr.DRF-387.

Submitted: 15-02-2024 **Accepted:** 16-08-2024 **Online:** 04-10-2024

and well-tolerance in the human body (Liu *et al*., 2017) and certainly degradable (Ogbulie *et al*., 2007). Moreover, Chan *et al*. (2018) reported that spice oils are natural, safe and non-toxic, have antimicrobial activity and are beneficial for health. The antimicrobial activity of spices can be exerted in two ways: firstly, by reducing the spoilage microorganism growth and, secondly, by inhibiting the pathogenic growth (Gottardi *et al*., 2016; Naik *et al.,* 2021). Many studies have confirmed that plant extracts can kill bacteria that cause food poisoning (Verma *et al*., 2012; Akinpelu *et al*., 2014; Zhu *et al*., 2020). The bactericidal activity of ethanolic and aqueous herbal extracts against food spoiling was found by Gupta *et al*. (2010). For antimicrobial activity, spices have a wide-ranging spectrum of active constituents that are mainly secondary metabolites associated with their volatile essential oil fraction. Allicin, allyl isothiocyanate, eugenol, carvacrol, thymol, gingerols and shogaols are some of the major active ingredients of spices. Allicin in garlic oil has the potential to prevent both Gram-negative and Gram-positive bacteria (Amrita *et al*., 2009). Numerous studies have demonstrated spice extracts' antimicrobial and antioxidant properties, highlighting their potential as natural food preservatives (Chan *et al*., 2018; Gottardi *et al*., 2016; Verma *et al*., 2012; Akinpelu *et al*., 2014; Das *et al.,* 2022). Spice extracts, serving as food additives, have demonstrated implicit effectiveness against certain foodborne pathogens, with their antibacterial properties extensively examined by numerous scholars (Parekh and Chanda, 2007; Rahman *et al*., 2010; Hernández-Ochoa *et al*., 2014). However, there is still a need to explore the efficacy of specific spice extracts against common foodborne pathogens, especially in the context of developing countries where foodborne illnesses are prevalent. Furthermore, most earlier studies have concentrated on the antimicrobial properties of specific spices, including clove (Hoque *et al*., 2007; Kammon *et al*., 2019; Pandey and Singh, 2011), cumin seeds (Shan *et al*., 2007), garlic (Amrita *et al*., 2009) and *Punica granatum* (Al-zoreky, 2009; Mahboubi *et al*., 2015).

A comprehensive investigation that compares the antimicrobial and antioxidant potential of multiple spice extracts, including *Zingiber officinales*, *Syzygium aromaticum*, *Cuminum cyminum* and *Origanum vulgare*, against a range of foodborne pathogens is lacking. Hence, this study aims to assess the antimicrobial and antioxidant efficacy of the four spice extracts against five prevalent foodborne pathogens. By systematically examining the efficacy of these extracts and their potential as natural food preservatives, this research aims to contribute to the development of safer and more sustainable strategies for preventing food spoilage and controlling foodborne diseases. The findings of this study will fill the existing research gap and provide valuable insights into the application of spice extracts as alternative preservatives in the food industry.

MATERIALS AND METHODS

This study was carried out at the Department of Dairy Science and the Department of Microbiology and Hygiene at Bangladesh Agricultural University, Mymensingh-2202, during the years 2019.

Spice extracts preparation

Four spice extracts, namely, Cumin (*Cuminum cyminum*), Clove (*Syzygium aromaticum*), Ginger (*Zingiber officinales*) and Oregano (*Origanum vulgare*), were purchased from the nearest local supermarket (KR market) of the Bangladesh Agricultural University Campus, Mymensingh-2202, Bangladesh. The information related to the spices is presented in Table 1. The collected spice samples were wet-washed and cleaned using distilled water and air-dried. Then, the dried spices were ground into a fine powder by a laboratory mill, passing through a 1 mm sieve in the process. 50 g of the powder from each spice was saturated in 200 mL of ethanol and stirred, then left for 48 h. After centrifugation, the mixture, for 10 min at 9000 rpm, was filtered with Whatman filter paper No. 1 and then filtered again with Whatman filter paper No. 4. The moisture was evaporated and the filtrates of four spices were dried at 40°C by hot air oven. The extracts were kept at 4°C in a tiny, airtight container.

Antioxidant activity

DPPH (1,1-Diphenyl-2-Picrylhydrazyl) radical scavenging activity

We used the DPPH radical assay to measure free radical scavenging activity, following Brand-Williams *et al*. (1995) method. After making a 100 µM DPPH in an ethanol solution, 1 mL of this solution was added to each of the 4 mL test samples. The reaction mixture was then shaken and left to stand at room temperature for half an hour. Using a blank as a reference, a UV-Vis spectrophotometer (Carry 100 UV-VIS, Santa Clara, California, USA) was used to measure the absorbance of the solution at 517 nm. Using a standard curve made with trolox, the DPPH free radical scavenging activity was calculated as µmol of trolox equivalents (TE) per gramme of material.

ABTS (2, 20-Azino-Bis-3-Ethylbenzthiazoline-6-Sulphonic acid) cation decolourization assay

For evaluating the capability to scavenge free ABTS radicals, an ABTS radical assay was employed, following the methodology outlined by Re *et al*. (1999) with slight

Table 1: The extract and pH of five spice species.

Common name	Scientific name	Family	Extract pH
Ginger	*Zingiber officinale*	Zingiberaceae	7.1
Clove	Syzygium aromaticum	Myrtaceae	5.3
Cumin	*Cuminum cyminum*	Apiaceae	6.2
Oregano	*Origanum vulgare*	Lamiaceae	5.8

adjustments. By combining 2.45 mM potassium persulfate (1:1, v/v) with a 7.4 mM ABTS stock solution, ABTS radical cations (ABTS+) were produced. The combination was then left to remain at room temperature in the dark for 12 to 16 h. Distilled water was added to the ABTS radical solution until the absorbance range of 1.0-1.2 was reached. 50 mL of each created radical solution was mixed with 1 mL of the diluted spice sample and the mixture was kept out of the light for 60 min. At 734 nm, absorbance was measured with a spectrophotometer. Trolox equivalents (TE) in µmol per g of material were used to calculate the results and display them, along with a standard curve created using Trolox.

Total phenolic content

To assess the total phenolic compounds (TPC), the extracts from the spice samples were prepared following the method described by Chandra *et al*. (2014). Briefly, the samples were dried, freeze-dried and grounded properly. Afterward, 10 g samples were extracted with 75 mL of 95% ethanol (v/v) at 40°C for 10 min. 5 mL of methanol was added to 50 mg of extract, which was then dissolved for 45 min at 40°C. Next, we centrifuged the mixture at 1,000 rpm for 10 min at room temperature to separate the supernatant. The sample extracts (500 µL) were placed into test tubes, then 2.5 mL of Folin-Ciocalteu reagent (Merck, India), diluted 10 times with water and 2 mL of sodium carbonate (7.5% w/v) were added. The tubes were incubated at 50°C for 10 min with intermittent agitation in the dark. The absorption at 760 nm was measured using a UV-VIS spectrop hotometer (UH 5300, Hitachi, Japan). On a fresh basis, the results were represented as mg of gallic acid equivalents (GAE)/100 g.

Total flavonoid content

The total flavonoid contents of the spice extracts were evaluated using a modified colourimetric method adapted from Sakanaka *et al*. (2005), with quercetin as the reference standard. Extracts/standard solutions (250 µL) were mixed well with distilled water of 1.25 mL and 75 µL of 5% sodium nitrite solution. Approximately 5 min later, 150 µL of 10% aluminium chloride solution was added to the mixture. Again, after 6 min, 0.5 mL of 1 M sodium hydroxide and 0.6 mL distilled water were added. The solutions were gently mixed and the absorbance was measured at 510 nm. The results were reported as mg of quercetin per g of sample.

Antibacterial activity of the spice-extracts

Bacterial strains and inoculums preparation

The antibacterial efficacy of spice extracts was assessed against five pathogenic bacterial strains known to cause food spoilage: *Listeria monocytogenes* ATCC 19115, *Bacillus cereus* ATCC 11778, *Escherichia coli* ATCC 25922, *Staphylococcus aureus* ATCC 25923 and *Pseudomonas aeruginosa* ATCC 27853. All strains were uniformly cultured on Tryptic Soy Agar (TSA) to ensure optimal growth conditions and facilitate comparative analysis. Each bacterial strain was incubated overnight at 37°C. Following incubation, the bacterial cultures were harvested using 5 mL of sterile saline water. The optical density of these cultures was measured at 580 nm and the cultures were subsequently diluted to achieve a target concentration of 10^7 CFU/mL using a spectrophotometer (Malvern Panalytical, UK).

Determination of antimicrobial activity

The antimicrobial activity of each extract was assessed using the agar disc diffusion method. Fifty mg of the extract were mixed with 2.5 mL of ethanol, filtered with a 0.22 mm microfilter and then placed onto sterile paper discs, each 8 mm in diameter, resulting in a concentration of 10 mg per disc. After pouring 10 mL of agar medium into Petri dishes, a bacterial suspension containing 1 mL of 10^7 CFU was added to each dish, resulting in a concentration of 10^5 CFU/mL of medium. The discs were then placed on the surface of TSA agar plates containing a spice extract concentration of 10 mg/mL. The plates were refrigerated at 4°C for 2 h to solidify the dispersion of spice extracts, followed by an incubation period at 37°C for 24 h. The presence of inhibition zones was measured with a slide calliper, serving as an indication of antimicrobial activity.

Determination of minimum inhibitory concentrations (MIC)

The most potent extracts demonstrating long-lasting antibacterial effects at a concentration of 10 mg/mL were further assessed for their antibacterial efficacy using the disc diffusion method. This was to evaluate their potential to control bacteria that cause food poisoning. The spice extract was prepared at various concentrations (2.5, 5.0, 10.0, 12.5 and 15.0 mg/mL) by dissolving 50 mg of the extract in 2.5 mL of ethanol, followed by sterilization through a microfilter. The solutions were then applied to 8 mm diameter paper discs. These discs, each saturated with different concentrations of the spice extract, were placed on Tryptic Soy Agar (TSA) plates. The plates were initially stored at 4°C for 2 h to allow for diffusion and then incubated at 37°C for 24 h. The inhibition zones around each disc were measured using a Vernier caliper to assess the relative antibacterial activity of the various concentrations of the spice extracts.

Statistical analysis

The descriptive statistical analysis (per cent, mean and standard deviation) of the variables was carried out using SPSS version 18.0 (SPSS Inc., Chicago, IL, USA).

RESULTS AND DISCUSSION

Antioxidant activity

DPPH and ABTS radical cation assays were performed to assess the free radical-scavenging activities of spice extracts and the results are presented in Table 2. DPPH in methanol solution produced a violet colour due to its stability as a nitrogen-cantered free radical. When DPPH

interacts with antioxidants, it acts as a suitable reducing agent, causing the solution to undergo a colour change which is based on the number of electrons absorbed (Umamaheswari and Chatterjee, 2008). Our research found that spice extracts exhibited different levels of scavenging abilities. In the DPPH assay, the most antioxidant property (µmol TE/g) was observed in *S. aromaticum* (7.15), followed by *C. cyminum* (5.56), *Z. officinales* (4.45) and *O. vulgare* (3.24). The antioxidant activity in the ABTS assay showed a comparable association to the DPPH technique in a similar trend, but the values were observed lower than in the DPPH assay. The quantified reduced antioxidant activity in ABTS radicals ranged between 3.90 to 1.59 µmol TE/g where the highest antioxidant capacity was observed in *S. aromaticum* (3.90) followed by *Z. officinales* (2.55), *C. cyminum* (2.45) and *O. vulgare* (1.59). In general, it was noted that free radicals' neutralizing capability represents the high antioxidant activity of the extract. Previous studies have reported that *S. aromaticum* extract exhibited one of the strongest antioxidants, slightly surpassing the antioxidant activity of some synthetic antioxidants such as butylated hydroxytoluene or butylated hydroxylanisole (Radha krishnan *et al*., 2013). Eugenol is the main constituent of *S. aromaticum* and this abundant eugenol is attributed to the strongest activity of *S. aromaticum*. The main component of *C. cyminum* is cumin aldehyde, which is responsible for its antioxidant activities. Abbdellaoui *et al*. (2019) found that *C. cyminum* possesses excellent antioxidant activity and could be used for food preservation. *Z. officinale* contains phenolics such as polyphenol compounds which are responsible for antioxidant properties and showed moderate levels of radical scavenging activity. *O. vulgare* showed antioxidant activity owing to the presence of carvacrol. In our study, *O. vulgare* showed lower radical scavenging activities among four extracts but in a study, Bounatirou *et al*. (2007) found the most antioxidant activity.

Total phenol and flavonoid content

In the recent few years, phenolic compounds have been paying attention to various research areas such as food, therapeutic, health and cosmetic industries. The total phenolic compound levels in the tested spice extract samples ranged from 21.35 to 14.21 mg GAE/g, as shown in Table 2. It was found that *S. aromaticum*, *O. vulgare*, *Z. officinales* and *C. cyminum* extracts contain 21.35, 19.22, 18.11 and 14.21 mg GAE/g of total phenolic content, respectively. However, *S. aromaticum* exhibited the highest total phenolic content, while *C. cyminum* had the lowest. Flavonoids are the most widespread and diverse group of natural antioxidant compounds. The most important natural phenolics comprise flavones, flavonoids, isoflavones, anthocyanins and catechins (Sim and Han, 2007). Total flavonoid content of *Z. officinale*, *C. cyminum*, *S. aromaticum* and *O. vulgare* extracts were found as 11.02, 7.67, 7.45 and 7.31 mg quercetin/g, respectively. Antioxidant activities of polyphenolic compounds from plant origin have been widely observed for their biological function, which is crucial for maintaining oxidative stress levels below a critical threshold in the body (Zhou *et al*., 2006). Studies have confirmed a correlation between total phenolic content and antioxidant activity in different plants and fruits (Radhakrishnan *et al*., 2013). Because of their high redox potentials, which enable them to donate hydrogen, neutralise singlet oxygen and function as reducing agents, phenolic compounds have antioxidant properties (Miguel *et al*., 2010).

Antibacterial properties of spice extract

Our study revealed that extracts were effective at variable degrees against microbial growth of food spoilage bacteria (Table 3). Extracts of *S. aromaticum* and *O. vulgare* were found to be the most potent against microbial growth of all tested dominant food pathogenic strains at a concentration of 10 mg/mL. However, it was observed that *S. aromaticum* extract expressed the most significant potentials against *S. aureus* (18.50 mm) which was followed by *P. aeruginosa* (16.10 mm), *B. cereus* (15.01 mm) and *E. coli* (14.20 mm). The extract of *O. vulgare* exhibited the highest potential against *L. monocytogenes* (16.01 mm). However, *Zingiber officinale* and *C. cyminum* extracts were found resistant only against *E. coli* and *B. cereus,* respectively.

Minimum inhibitory concentrations (MIC)

MICs were performed for the spice extracts of *Z. officinales*, *S. aromaticum*, *C. cyminum* and *O. vulgare* by agar disc diffusion method to determine their bacteriostatic and bactericidal potentiality. The inhibitory concentration of *Z. officinales* was 2.5 mg/mL, leading to inhibition zones of 9.61 mm against *P. aeruginosa* and 8.03 mm against *S. aureus* (Table 4). Conversely, at a dosage of 5 mg/mL, extracts of *S. aromaticum* and *C. cyminum* inhibited the growth of the tested strains of bacteria. The inhibition zones were 11.41 mm and 9.11 mm for *S. aromaticum* and 8.0 mm

Table 2: Extraction yield, DPPH radical scavenging ability, ABTS, total phenolic content and total flavonoid content for water extracts of spices.

Parameters	*Z. officinales*	*S. aromaticum*	*C. cyminum*	*O. vulgare*
Extraction yield (%)	25.22±0.95	25.15±1.10	24.10±0.85	21.32±1.20
DPPH (µmol TE/g)	4.45±0.25	7.15±0.28	5.56±0.35	3.24±0.16
ABTS (µmol TE/g)	2.55±0.07	3.90±0.10	2.45±0.09	1.59±0.08
Total phenolic content	18.11±0.90	21.35±1.06	14.21±0.71	19.22±0.96
(mg GAE/g)	11.02±0.55	7.45±0.37	7.67±0.38	7.31±0.36

Mean ± SE (standard error).

and 9.12 mm for *C. cyminum*, respectively. These findings align with the results documented by Verma *et al*. (2012); Qader *et al*. (2013) and Mahboubi *et al*. (2015). A significant difference in MIC of different extracts was observed in several studies; this might be due to the difference in extraction technique, components and microbial strains involved. Similarly, alteration in MIC of diverse extracts may arise from distinction in the volatile nature of their components and biochemical elements. In distinction, it was found that extracts of *S. aromaticum* are effective against *L. monocytogenes*, *B. cereus*, *S. aureus*, *E. coli* and *P. aeruginosa* at a concentration of 10 mg/mL, prohibiting bacterial growth with inhibition zones of 14.21, 15.01, 18.50, 16.10 and 14.20 mm, respectively. These findings support the results of Pandey and Singh (2011), who found that *C. cyminum* was ineffective in inhibiting the growth of microbial strains of *B. cereus* and *E. coli*. However, these results differ from those of Mostafa *et al*. (2018), whoreported that the MIC range of potentially effective cumin is between 6.25 and 12.5 mg/mL.

Alternatively, cumin extract of greater concentration of 60 mg/mL, may be necessary to effectively combat food-deteriorating bacteria. This finding of our study was aligned with the previous one by Sheikh *et al*. (2010). The efficacy of spice extracts and their combinations is essential to inhibit and control the proliferation of microorganisms causing food

Table 3: Antimicrobial activity of spice extract (10 mg/mL) against dominant food pathogens.

Spice types	Inhibition zones (mm)				
	Gram (+ve)			Gram (-ve)	
	L. monocytogenes	*B. cereus*	*S. aureus*	*E. coli*	*P. aeruginosa*
Zingiber officinale	12.01±0.16	10.56±0.22	14.80±0.41	NR	13.41±0.11
Syzygium aromaticum	14.01±0.16	15.01±0.16	18.50±0.13	14.20±0.61	16.10±0.46
Cuminum cyminum	15.01±0.16	NR	12.50±0.74	5.53±0.04	8.22±0.35
Origanum vulgare	16.01±0.16	14.02±0.04	14.10±0.21	6.22±0.04	7.33±0.14
*Gentamycin (5 mg)	18.00±0.15	16.80±0.37	20.50±0.24	14.65±0.53	13.11±0.35

Mean±SE (standard error), *Control, NR= No response.

Table 4: Minimum inhibitory concentrations (MIC) of the potential spice extracts to encounter foodborne pathogens.

Spice extract	Extract conc. mg/mL	Inhibition zones (mm)				
		Gram (+ve)			Gram (-ve)	
		L. monocytogenes	*B. cereus*	*S. aureus*	*P. aeruginosa*	*E. coli*
Z. officinales	Control	0.00	0.00	0.00	0.00	0.00
	2.50	-	6.13±0.15	8.03±0.95	9.61±0.65	NR
	5.0	7.13±0.15	11.02±0.10	13.02±0.21	10.82±0.83	NR
	10.0	12.21±0.06	10.56±0.22	14.80±0.41	13.41±0.11	NR
	12.5	15.32±0.16	18.05±0.36	18.05±0.36	21.42±0.46	NR
	15.0	19.41±0.36	22.06±0.74	22.06±0.74	23.71±0.35	NR
S. aromaticum	Control	0.00	0.00	0.00	0.00	0.00
	2.50	6.71±0.10	6.00±0.20	-		- -
	5.0	10.11±0.15	9.11±0.80	9.11±0.80	11.41±0.37	8.17±0.12
	10.0	14.21±0.14	15.01±0.16	18.50±0.13	14.20±0.61	16.10±0.46
	12.5	15.21±0.14	14.17±0.52	14.17±0.52	16.60±0.13	18.60±0.13
	15.0	18.21±0.14	17.51±0.35	17.51±0.35	19.30±0.65	22.52±0.18
C. cyminum	Control	0.00	0.00	0.00	0.00	0.00
	2.50	7.12±1.10	NR	-	-	-
	5.0	12.12±0.37	NR	9.12±1.10	8.00±1.10	7.00±1.10
	10.0	15.51±0.11	NR	12.50±0.74	5.53 ±0.04	8.22 ±0.35
	12.5	15.41±0.37	NR	15.41±0.37	11.41±0.37	12.41±0.22
	15.0	16.18±0.45	NR	16.18±0.45	12.18±0.45	14.48±0.37
O. vulgare	Control	0.00	0.00	0.00	0.00	0.00
	2.50	-	-	-	-	-
	5.0	7.12±0.40	7.12±0.10	9.12±1.10	-	-
	10.0	16.11±0.12	14.02±0.04	14.10±0.21	6.22±0.04	7.33±0.14
	12.5	18.11±0.12	15.41±0.37	15.41±0.37	11.41±0.37	10.1±0.37
	15.0	24.11±0.12	16.18±0.45	16.18±0.45	12.18±0.45	12.18±0.45

Mean± SE (standard error). '-' = No inhibition zoon; NR= No response.

spoilage as recommended by several studies. Moreover, according to various studies (Gill and Holley, 2006; Burt, 2004), antimicrobial compounds found in spice extracts, such as terpenoids, alkaloids and phenolic compounds, along with enzymes, disrupt bacterial cell membranes, leading to cell death or inhibiting enzymes necessary for amino acid synthesis, thus preventing spoilage. The hydrophobic characteristics of herbal extracts allowed them to react with the proteins of the bacterial cell membrane and the interrupting of their mitochondrial structures as well as altering their absorbency, is the inhibitory effect of these herbal plant extracts justified by several other reviewers (Friedman *et al*., 2004; Tiwari *et al*., 2009).

CONCLUSION

The food industry is facing challenges regarded to prevent food spoilage as well as the growth of food-borne pathogens. The extracts of plant herbs and spices are rich in natural antioxidants, which could be valuable resources and substitutes for chemical preservatives for food preservation. In this study, *S. aromaticum* and *Z. officinales* showed better antioxidant potentials in DPPH and ABTS assay along with total phenolic and flavonoid content. At the same time, *Z. officinales* and *S. aromaticum* showed their efficacy at minimum concentrations followed by *C. cyminum* and *O. vulgare.* Therefore, the food industry could utilize these spice extracts for their remarkable antimicrobial and antioxidant properties against common food-borne pathogens in addition to their health benefits.

ACKNOWLEDGEMENT

The authors are thankful to the Ministry of Science and Technology, People's Republic of Bangladesh, for the partial financial support of this project.

Authors' contribution

Conceptualization: Md. Zakirul Islam, Mohammad Shohel Rana Siddiki and Md. Harun-ur-Rashid; methodology: Md. Zakirul Islam, Md. Sayed Hasan and Sumaiya Arefin; validation: Md. Zakirul Islam, Mohammad Shohel Rana Siddiki and Md. Harun-ur-Rashid; investigation: Md. Zakirul Islam, Sumaiya Arefin, Md. Sayed Hasan, Mehedi Hasan Khandakar and Md. Abid Hasan Sarker; resources: Md. Zakirul Islam, Md. Harun-ur-Rashid, Mohammad Shohel Rana Siddiki; writing and original draft preparation: Md. Zakirul Islam, Sumaiya Arefin, Mehedi Hasan Khandakar and Md. Abid Hasan Sarker; writing and review and editing: Mehedi Hasan Khandakar, Md. Abid Hasan Sarker, Arifur Rahman and Mohammad Shohel Rana Siddiki; supervision: Mohammad Shohel Rana Siddiki and Md. Harun-ur-Rashid; funding acquisition: Md. Harun-ur-Rashid; critical revisions and writing: Md. Zakirul Islam, Mehedi Hasan Khandakar and Md. Abid Hasan Sarker and Mohammad Shohel Rana Siddiki.

Conflict of interest

The authors declare that there is no conflict of interest.

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