



Efficacy of various plant hydrosols as natural food sanitizers in reducing *Escherichia coli* O157:H7 and *Salmonella* Typhimurium on fresh cut carrots and apples

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ABSTRACT

In the present study, inhibitory effects of the hydrosols of thyme, black cumin, sage, rosemary and bay leaf were investigated against *Salmonella* Typhimurium and *Escherichia coli* O157:H7 inoculated to apple and carrots (at the ratio of 5.81 and 5.81 log cfu/g for *S. Typhimurium*, and 5.90 and 5.70 log cfu/g for *E. coli* O157:H7 on to apple and carrot, respectively). After the inoculation of *S. Typhimurium* or *E. coli* O157:H7, shredded apple and carrot samples were washed with the hydrosols and sterile tap water (as control) for 0, 20, 40 and 60 min. While the sterile tap water was ineffective in reducing ($P > 0.05$) *S. Typhimurium* and *E. coli* O157:H7, 20 min hydrosol treatment caused a significant ($P < 0.05$) reduction compared to the control group. On the other hand, thyme and rosemary hydrosol treatments for 20 min produced a reduction of 1.42 and 1.33 log cfu/g respectively in the *E. coli* O157:H7 population on apples. Additional reductions were not always observed with increasing treatment time. Moreover, thyme hydrosol showed the highest antibacterial effect on both *S. Typhimurium* and *E. coli* O157:H7 counts. Inhibitory effect of thyme hydrosol on *S. Typhimurium* was higher than that for *E. coli* O157:H7. Bay leaf hydrosol treatments for 60 min reduced significantly ($P < 0.05$) *E. coli* O157:H7 population on apple and carrot samples. In conclusion, it was shown that plant hydrosols, especially thyme hydrosol, could be used as a convenient sanitizing agent during the washing of fresh-cut fruits and vegetables.

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1. Introduction

Fresh cut fruits and vegetables have been very popular for the bioavailability of numerous vitamins, minerals and other phytochemicals (Tournas, 2005). However, they may naturally contain a wide variety of bacteria, fungi and yeast species (Romeo et al., 2010). Although most of the microorganisms are harmless to human health, high level of microbial population, estimated 10^5 – 10^7 cfu/g, may accelerate food spoilage and shorten their shelf life (Francis et al., 1999; Heard, 2002; Beuchat, 2002; Shirron et al., 2009). Moreover, the increasing number of outbreaks has been associated with the consumption of commercial fresh cut fruits and vegetables (Brackett, 1999; Hodge, 1999; Thunberg et al., 2002; Ruiz-Cruz et al., 2007). According to Francis and O'Breine (1998), *Salmonella* Typhimurium and *Escherichia coli* O157:H7 are the most important foodborne pathogens which cause outbreaks through the consumption of the contaminated fresh products. It is estimated that these contaminations to fresh products may occur during the growing or harvesting and postharvest handling or distribution (Abadias et al., 2008).

Commercial or homemade fresh cut fruits and vegetables are prepared by some simple treatments such as washing, cutting, grating, shredding and packaging (Artes and Allende, 2005). Among these steps, washing may be considered as the most critical step since it removes the soil particles and reduces the microbial load from the surface (Ruiz-Cruz et al., 2007). Antimicrobial effects of chlorine based sanitizers on fresh cut produce have been previously reported, because they have been widely used as washing solution for fresh cut products to eliminate the microorganisms. (Zhang and Farber, 1996; Erkmén, 2010). However, there is a common tendency to reduce the use of chlorine due to the environmental and health risks concerning with the formation of carcinogenic by-products (Olmez and Kretzschmar, 2009; Gil et al., 2009). In this context, many researchers investigated alternative sanitizing agents such as essential oils or their components (Singh et al., 2002; Uyttendaele et al., 2004; Obaidat and Frank, 2009; Gutierrez et al., 2009; Gunduz et al., 2010; Romeo et al., 2010), organic acids (Vijayakumar and Wolf-Hall, 2002; Uyttendaele et al., 2004; Sengun and Karapinar, 2005; Chang and Fang, 2007), ozone (Kim et al., 2006; Koseki and Isobe, 2006; Yuk et al., 2006), electrolyzed water (Park et al., 2001; Koseki et al., 2004; Koide et al., 2009) and hydrogen peroxide (Lin et al., 2002; Ukuku, 2004; Gopal et al., 2010).

The spices have been added to several food products for many years. Besides improving the flavor, spices and their derivatives

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extend the shelf life of foods because they act as antimicrobial agents. In recent years, there has been an increasing interest in the discovery of new natural antimicrobials and disinfectants due to an increase in risk in the rate of infections with antibiotic resistant microorganisms. Being natural foodstuffs, they appeal to consumers who tend to question the safety of synthetic chemical disinfectants (Sagdic, 2003; Sagdic and Ozcan, 2003). Essential oils are among the most studied plant derived antimicrobial compounds. They are GRAS (generally recognized as safe), and many of them may play a major role for the control of a wide range of pathogenic and spoilage bacteria associated with fresh-cut fruit and vegetables (Gutierrez et al., 2009). Hydrosols, also known as floral water, distillate water or aromatic water, are the co-products or the byproducts of hydro- and steam distillation of plant material. Hydrosols are quite complex mixtures containing traces of the essential oil and, of course, several water-soluble components as well. They have practically been used as a beverage for a long time in many areas of Turkey (Sagdic, 2003; Tajkarimi et al., 2010). Main advantages of hydrosols are that they are easy and inexpensive to produce and they do not have any health hazard for the human as is the case for essential oils. Although antibacterial effects of hydrosols of various spices were reported by some researchers (Sagdic, 2003; Sagdic and Ozcan, 2003; Chorianopoulos et al., 2008), there has been still limited information about the antibacterial effects of spice hydrosols. Antimicrobial activities of the hydrosols might be originated from their monoterpenic essential oil components and phenolic compounds. Again no research, to our knowledge, is present about their efficacy as a sanitizing agent when used to wash raw fruit and vegetables. The objective of this study was to determine efficacy of the hydrosols as natural food sanitizers in reducing *E. coli* O157:H7 and *S. Typhimurium* in inoculated shredded carrots and apples at different treatment times.

2. Materials and methods

2.1. Bacterial culture and inoculum preparation

S. enterica subsp. *enterica* serovar. Typhimurium ATCC 14028 and *E. coli* O157:H7 ATCC 33150 were used to determine the antibacterial activity of the hydrosols on carrot and apple samples. Bacterial cultures were obtained from Kayseri Agriculture Control Protection Management, Turkey. Frozen stock cultures were activated before the use for 24 h at 37 °C in Nutrient Broth.

2.2. Preparation and GC–MS analysis of plant hydrosols

Thyme (*Thymus vulgaris* L.), black cumin (*Nigella sativa* L.), rosemary (*Rosmarinus officinalis* L.), sage (*Salvia officinalis* L.) and bay leaf (*Laurus nobilis* L.) samples were purchased from a local spice market in Kayseri, Turkey. Hydrosols were produced following the method of Sagdic (2003). Approximately 50 g of each plant material was ground and placed into a flask (1 L) with 500 mL of distilled and hydrodistilled water (1:10 w/v) for 1 h with a Clevenger apparatus (Ildam, Turkey). After hydrodistillation, essential oil was separated through the cooling tunnels. Hydrosols were kept in covered sterile bottles overnight at 4 °C until use.

In the present study, first of all, it was verified that the various plant hydrosols obtained from thyme, black cumin, sage, rosemary and bay leaf were organoleptically (by sensory panel with eight people) acceptable as natural food grade sanitizers on fresh cut carrots and apples.

Gas chromatography–mass spectrometry (GC–MS) analyses of volatile components of five plant hydrosols were run according to the procedure of Vardar-Unlu et al. (2007) on an Agilent 7890A GC gas chromatograph system (Agilent, Avondale, USA) coupled to a mass selective detector (Agilent Technologies, Agilent, Avondale, USA) and HP-5MS column (0.2 mm × 50 m, film thickness 0.25 µm). Some

modifications were adapted to this method since hydrosols contain only a trace amount of essential oils and volatile components. The compounds adsorbed by the fibers were desorbed from the injection port for 15 min at 50 °C in the splitless mode. The oven temperature was held at 40 °C for 5 min, heated to 125 °C at 2 °C/min, from 125 °C to 230 °C at 5 °C/min, finally increased to 230 °C/min and held for 5 min. The carrier gas was helium with a flow rate of 1.0 mL/min. Qualitative analysis was based on the comparison of retention times and the computer mass spectra libraries using Wiley GC/MS Library and Nist, Tutores Libraries. The percentage composition was computed from the GC peak areas.

2.3. Preparation of apple and carrot samples and inoculation process

Fresh apple and carrot samples were purchased from a local supermarket in Kayseri, Turkey and stored at 4 °C. Firstly, apple and carrot samples were washed with cold tap water for 5 min to remove undesired residues and reduce native microbial load and cut into pieces (1 × 1 cm², approximately 1 g each) with a sterile knife. These fruit pieces were used in the experiments.

Dip inoculation was reported as the most appropriate and common method for such an inoculation process (Beuchat et al., 2003). In this study, initial inoculation concentration was approximately 10⁶ cfu/mL for both *S. Typhimurium* and *E. coli* O157:H7. Each inoculum suspension of *S. Typhimurium* and *E. coli* O157:H7 was prepared by transferring 20 mL of Nutrient Broth culture into 1:1 of Ringer solution (Merck, Darmstadt, Germany). Shredded apple and carrots (50 g each) were immersed into the inoculum solutions (sample:inoculum ratio 1:5 w/v) and shaken for 1 min to distribute the inoculum homogeneously and then kept in a biosafety cabinet for 1 h at 22 ± 2 °C.

2.4. Washing of apple and carrot samples

Washing of inoculated apple and carrot cuts was carried out by immersing shredded carrot/apple samples (50 g) in the sterile bottles containing 100 mL of each sanitizing hydrosol (thyme, black cumin, rosemary, sage and bay leaf) for 0, 20, 40 and 60 min. Control samples were immersed in sterile tap water. Bottles were covered following the addition of samples and subjected to gently shake at 5 min intervals for 30 s during the treatment period.

2.5. Enumeration of bacteria and calculation of inhibition levels

At the end of the hydrosol treatment, 10 g of carrot/apple sample was transferred into sterile bottles, combined with 90 mL of sterile Ringer solution and shaken vigorously by hand for 1 min. The solution (1 mL) was serially diluted in test tubes containing 9 mL of sterile Ringer solution. According to spread plate technique, decimal dilutions of samples were pour-plated to Brilliant-Green Phenol-Red Lactose Agar (Merck, Germany) and Sorbitol MacConkey Agar (Merck, Germany) for enumeration of *S. Typhimurium* and *E. coli* O157:H7, respectively. Then the plates were incubated for 24 h at 37 °C, and colonies were counted following the incubation.

Growth inhibition level (GIL) of *S. Typhimurium* and *E. coli* O157:H7 caused by each hydrosol treatment was determined using the following equation (Eq. (1)) applied by Sagdic (2003):

$$GIL(\%) = \frac{(P_C - P_T)}{P_C} \times 100 \quad (1)$$

where P_C and P_T are the microbial populations of the control and hydrosol-treated samples, respectively.

Table 1

Major volatile components, retention times (RT) and % peak areas of the hydrosols used in the study.

Hydrosol types	Major volatile components	RT	% Peak area
Bay leaf	Eugenol	57.19	4.02
	α -Curcumene	47.61	3.76
	β -Selinene	58.89	3.75
Black cumin	Cuminaldehyde	48.03	16.59
	Carvacrol	57.94	11.26
	p-Cymene	23.29	8.92
Rosemary	α -Terpineol	45.13	3.68
	4-Chlorobenzenesulfonamide,	55.11	3.02
	N-methyl-		
Sage	Eucalyptol	20.56	2.88
	Linalool	38.55	13.41
	δ -Cadinene	47.23	10.18
Thyme	Carvacrol	57.94	8.96
	Carvacrol	58.00	48.30
	Thymol	57.27	17.55
	(-)-Spathulenol	56.53	9.90

2.6. Statistical analysis

All experiments were repeated two times and performed in duplicate. Data were analyzed with Windows based S.A.S. 8.0 statistical analysis software (SAS Institute, Cary, North Carolina, USA) using two-way analysis of variance. Significant differences between means were verified by Tukey's multiple range test.

3. Results and discussion

3.1. Volatile components of plant hydrosols

GC–MS analyses of bay leaf, black cumin, rosemary, sage and thyme hydrosols resulted in the detection of 33, 12, 29, 24 and 23 different volatile components, respectively. Major volatile components, retention times and total peak areas of the plant hydrosols obtained by GC–MS analysis were presented in Table 1.

GC–MS analysis results (Table 1) revealed that the most abundant constituents of thyme hydrosol were carvacrol (48.30%) and thymol (17.55%). It was also reported that carvacrol, thymol, p-cymene and γ -terpinene were the major components of thyme essential oil (Porte and Godoy, 2008). Black cumin is an herbaceous plant which is traditionally used for flavoring of foods and medicinal purposes (Bourgou et al., 2008). The main components of black cumin hydrosol were cuminaldehyde (16.59%), carvacrol (11.26%) and p-cymene (8.92%) (Table 1). In a study conducted by Bourgou et al. (2010), it was shown that percentages of p-cymene and carvacrol were 60.5% and 2.4%, respectively. Results of GC–MS analysis of rosemary hydrosol (Table 1) indicated that the major components were α -terpineol (3.68%), 4-chlorobenzenesulfonamide, N-methyl- (3.02%) and eucalyptol (2.88%). However, Burt (2004) reported different major components for rosemary essential oil from those of our study results,

namely α -pinene, bomyl acetate, camphor and 1,8-cineole. It could be expected that volatile components of hydrosols were similar to essential oils with lower amounts. However, it was reported that compositions of essential oils from a particular plant could differ depending on several factors such as natural origin, harvesting time, genetic structure, plant part and essential oil isolation method from the above factors reported by Rasooli (2007). Major components of sage hydrosol (Table 1) were linalool (13.41%), δ -cadinene (10.18%) and carvacrol (8.96%).

Trombetta et al. (2005) speculated that antimicrobial effect of essential oil components (monoterpenes e.g. thymol, menthol and linalyl acetate) might be due to a perturbation of the lipid fraction of bacterial plasma membranes, resulting in alterations of membrane permeability and in leakage of intracellular materials. It can be hypothesized that antimicrobial activities of the hydrosols might be originated from the monoterpene essential oil components and phenolic compounds.

3.2. Antibacterial activity of plant hydrosols

Neither *S. Typhimurium* nor *E. coli* O157:H7 was detected on uninoculated samples. A preliminary study was conducted to determine the inoculum level on the surface shredded carrot and apple samples. Initial inoculation levels of *S. Typhimurium* were 5.81 log cfu/g for both apple and carrot samples (Table 2). Regarding *E. coli* O157:H7, inoculation levels were 5.90 log cfu/g and 5.70 log cfu/g on the surface of apples and carrots respectively after the inoculation (Table 3).

In this study, sterile tap water (approximately 18 °C) was used instead of washing solution as control treatment. Washing of inoculated apple and carrot samples with sterile tap water did not result in any significant reduction in *S. Typhimurium* counts ($P > 0.05$). It was noticed that first 20 min was the critical treatment time to reduce *S. Typhimurium* load, because significant reductions were obtained for the most treatments in this period ($P < 0.05$). Although no significant difference on *S. Typhimurium* counts was observed between 20 and 40 min treatments with all hydrosols ($P > 0.05$), treatment of apple samples with sage and rosemary hydrosols for 60 min resulted significant reductions compared to 40 min ($P < 0.05$) treatment (Table 2). Treatment of apple samples with thyme hydrosol showed the maximum reduction (1.08 log cfu/g) at the 60 min time period. Besides, the thyme hydrosol was still the most efficient agent on the carrot samples and resulted in 1.48 log cfu/g reduction in *S. Typhimurium* number (Table 2), at all treatment times.

There have been several *in situ* and *in vitro* studies which investigated the efficiencies of chemicals, spice extracts and organic acids etc. to inhibit the growth of *S. Typhimurium*. For instance, Gunduz et al. (2010) reduced *S. Typhimurium* population on tomatoes to undetectable levels using a treatment with 4% sumac (*Rhus coriaria* L.) extract for 5 min. Moreover, treatment of tomatoes with 100 ppm oregano essential oil also resulted in a significant reduction on *S. Typhimurium* count. In another study, water-soluble rosemary extract showed lower inhibitory effect on *Salmonella* than the one tested on

Table 2

Effect of plant hydrosols on the survival of *S. Typhimurium* on the shredded carrot and apple samples.

Hydrosol Types	Apple				Carrot			
	Before treatment	20th min	40th min	60th min	Before treatment	20th min	40th min	60th min
Control	5.81 ^{Ba} \pm 0.04	5.87 ^{Ba} \pm 0.07	5.92 ^{ABa} \pm 0.07	6.07 ^{Aa} \pm 0.10	5.81 ^{Ba} \pm 0.08	5.99 ^{Aa} \pm 0.11	6.02 ^{Aa} \pm 0.08	6.08 ^{Aa} \pm 0.03
Bay leaf	5.81 ^{Aa} \pm 0.04	5.15 ^{Bb} \pm 0.09	5.01 ^{Bbc} \pm 0.04	5.00 ^{Bbc} \pm 0.07	5.81 ^{Aa} \pm 0.08	5.68 ^{Aab} \pm 0.17	5.51 ^{Bb} \pm 0.23	5.39 ^{Bb} \pm 0.25
Black cumin	5.81 ^{Aa} \pm 0.04	5.04 ^{Bb} \pm 0.06	5.04 ^{Bbc} \pm 0.13	5.06 ^{Bb} \pm 0.24	5.81 ^{Aa} \pm 0.08	5.61 ^{Ab} \pm 0.05	5.57 ^{ABb} \pm 0.04	5.30 ^{Bb} \pm 0.03
Rosemary	5.81 ^{Aa} \pm 0.04	5.09 ^{Bb} \pm 0.16	4.97 ^{Bbc} \pm 0.08	4.77 ^{Ccd} \pm 0.05	5.81 ^{Aa} \pm 0.08	5.64 ^{Ab} \pm 0.04	5.67 ^{Ab} \pm 0.04	5.37 ^{Bb} \pm 0.08
Sage	5.81 ^{Aa} \pm 0.04	5.14 ^{Bb} \pm 0.11	5.10 ^{Bb} \pm 0.22	4.93 ^{Cbcd} \pm 0.12	5.81 ^{Aa} \pm 0.08	5.64 ^{ABb} \pm 0.11	5.44 ^{BCb} \pm 0.04	5.16 ^{Cb} \pm 0.05
Thyme	5.81 ^{Aa} \pm 0.04	4.81 ^{Bc} \pm 0.24	4.81 ^{Bc} \pm 0.26	4.73 ^{Bd} \pm 0.18	5.81 ^{Aa} \pm 0.08	4.82 ^{Bc} \pm 0.04	4.40 ^{Cc} \pm 0.06	4.32 ^{Cc} \pm 0.07

^{A–B} The same uppercase letters within the same line for each sample show that the results are not statistically significantly different ($P > 0.05$). ^{a–b} The same lowercase letters within the same column for each sample show that the results are not significantly different ($P > 0.05$).

Table 3Effect of plant hydrosols on the survival of *E. coli* O157:H7 on the shredded carrot and apple samples.

Hydrosol types	Apple				Carrot			
	Before treatment	20th min	40th min	60th min	Before treatment	20th min	40th min	60th min
Control	5.90 ^{Aa} ± 0.09	5.88 ^{Aa} ± 0.08	5.86 ^{Aa} ± 0.07	5.85 ^{Aa} ± 0.09	5.70 ^{Aa} ± 0.04	5.76 ^{ABa} ± 0.07	5.73 ^{ABa} ± 0.02	5.64 ^{Ba} ± 0.07
Bay leaf	5.90 ^{Aa} ± 0.09	5.20 ^{Bb} ± 0.01	4.97 ^{BCbc} ± 0.20	4.80 ^{Cc} ± 0.07	5.70 ^{Aa} ± 0.04	4.65 ^{Bb} ± 0.08	4.67 ^{Bb} ± 0.06	4.51 ^{Cb} ± 0.07
Black cumin	5.90 ^{Aa} ± 0.09	5.15 ^{Bb} ± 0.05	5.01 ^{Cb} ± 0.01	4.97 ^{Cb} ± 0.03	5.70 ^{Aa} ± 0.04	4.60 ^{Bb} ± 0.06	4.53 ^{Bb} ± 0.15	4.47 ^{Bb} ± 0.11
Rosemary	5.90 ^{Aa} ± 0.09	4.57 ^{Bd} ± 0.10	4.49 ^{BCd} ± 0.03	4.35 ^{Cd} ± 0.06	5.70 ^{Aa} ± 0.04	4.59 ^{Bb} ± 0.13	4.58 ^{Bb} ± 0.16	4.51 ^{Bb} ± 0.13
Sage	5.90 ^{Aa} ± 0.09	4.82 ^{Bc} ± 0.08	4.75 ^{Bc} ± 0.04	4.73 ^{Bc} ± 0.09	5.70 ^{Aa} ± 0.04	4.62 ^{Bb} ± 0.10	4.63 ^{Bb} ± 0.05	4.53 ^{Bb} ± 0.16
Thyme	5.90 ^{Aa} ± 0.09	4.48 ^{Bd} ± 0.13	4.44 ^{Bd} ± 0.13	4.44 ^{Bd} ± 0.05	5.70 ^{Aa} ± 0.04	4.73 ^{Bb} ± 0.12	4.58 ^{BCb} ± 0.09	4.37 ^{Cb} ± 0.17

^{A–B} The same uppercase letters within the same line for each sample show that the results are not statistically significantly different ($P > 0.05$). ^{a–b} The same lowercase letters within the same column for each sample show that the results are not significantly different ($P > 0.05$).

gram positive bacteria. This result was attributed to the lower surface permeability of *Salmonella* to phenolic compounds such as carnosic and rosmarinic acid (Klančnik et al., 2009). Sagdic and Ozcan (2003) did not detect any inhibitory effect of black cumin hydrosol on *S. Typhimurium* in an *in vitro* study. In our study, a significant ($P < 0.05$) reduction on *S. Typhimurium* number occurred with black cumin hydrosol treatment in both apple and carrot samples.

Table 3 shows the inhibiting effect of plant hydrosols on *E. coli* O157:H7 population. Again, the sterile tap water washing resulted in no significant ($P > 0.05$) reduction on *E. coli* O157:H7 counts in apple and carrot samples. Singh et al. (2002) also concluded that water washing alone was ineffective to eliminate *E. coli* O157:H7 from shredded lettuce leaves and baby carrots' surfaces.

When apple and carrot samples were treated with plant hydrosols for 20 min, significant ($P < 0.05$) reductions were observed on *E. coli* O157:H7 numbers. The highest *E. coli* O157:H7 reductions in apple samples were observed through the treatments with rosemary and thyme hydrosols at the 60 min treatment, by the levels of 1.55 and 1.46 log cfu/g reductions, respectively. It was observed that treatment times 20 and 40 min did not improve the inhibitory effects of all the hydrosols on *E. coli* O157:H7 for carrot samples ($P > 0.05$). However, increasing of treatment time of apple with black cumin from 20 min to 40 min resulted in an additional significant reduction in *E. coli* O157:H7 counts at the apple samples ($P < 0.05$). Bay leaf hydrosol treatments for 60 min reduced *E. coli* O157:H7 loads of apple and carrot samples significantly ($P < 0.05$) compared to treatments for 20 min. Thyme hydrosol exhibited its highest inhibition on *E. coli* O157:H7 in the first 20 min of the treatment (Table 3).

Again, many researchers investigated the efficiencies of several chemicals and organic materials to inhibit *E. coli* O157:H7. Sagdic (2003) observed the antimicrobial activity of thyme hydrosol on *E. coli* O157:H7 by disc diffusion method. However, it was showed that the inhibitory effects of *Origanum onites*, *O. vulgare* and *O. majorana* hydrosols were higher than that of the thyme hydrosol in reducing *E. coli* O157:H7 counts. Singh et al. (2002) reported that thyme essential oil was the most effective sanitizer for *E. coli* O157:H7 reduction, followed by aqueous ClO_2 and ozonated water. In another study, Sagdic and Ozcan (2003) investigated antibacterial activities of 16 different spice hydrosols on 15 bacteria species by agar diffusion method, and they found that oregano and black cumin hydrosols showed the highest antimicrobial activities (19 mm inhibition zone each) against to *E. coli* O157:H7. In contrast, in our study thyme and rosemary hydrosols reduced *E. coli* O157:H7 loads on shredded apple and carrot samples more than that of the black cumin hydrosol.

In general, the plant hydrosols showed significant reduction levels on *S. Typhimurium* and *E. coli* O157:H7 loads of fresh cut apple and carrot samples (Figs. 1 and 2). It could be seen that the thyme hydrosol caused the highest reduction on *S. Typhimurium* counts, and the other hydrosols showed similar inhibition levels (Fig. 1). However, extending the treatment time of apple samples with thyme and sage hydrosols did not increase the inhibition efficiency for *E. coli* O157:H7 (Fig. 2).

Overall, results obtained in this study showed that the first 20 min of treatment processes caused significant reductions on the tested pathogen bacteria, however increasing treatment time did not always result in additional inhibitory effects. The most effective sanitizing agent tested in this study was the thyme hydrosol. Thyme hydrosol treatments on shredded apple and carrot reduced *S. Typhimurium* and *E. coli* O157:H7 levels more than 1 log cfu/g. However, other plant hydrosols showed fairly low inhibitory effects on *S. Typhimurium* counts when compared to thyme hydrosol while their efficiency rates were relatively similar against *E. coli* O157:H7 loads.

The major advantages of plant hydrosols are that they are cheap, safe and readily available. It could be expressed that hydrosols obtained

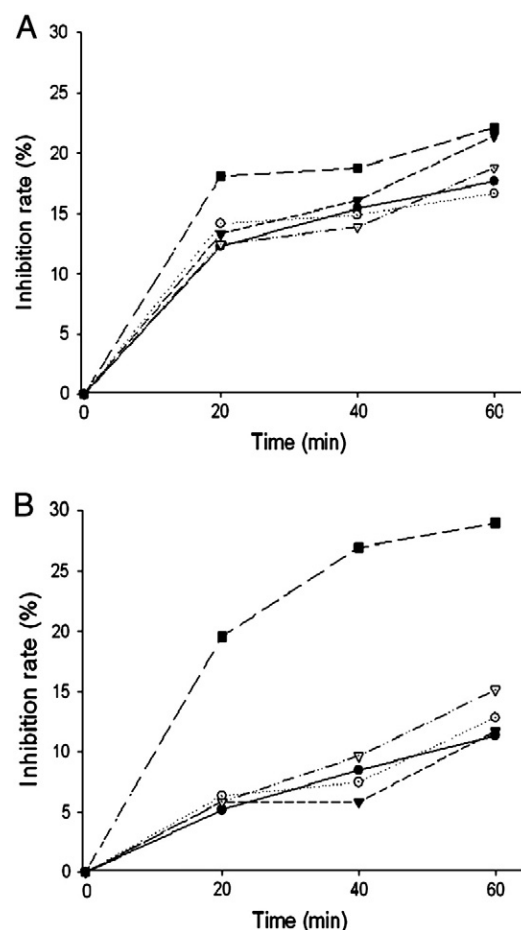


Fig. 1. Growth inhibition levels of *S. Typhimurium* on apple (A) and carrot (B) samples by treatments of apples with (—●—) the hydrosols of bayleaf, (.....○.....) black cumin, (---▼---) rosemary, (---▽---) sage and (—■—) thyme hydrosol.

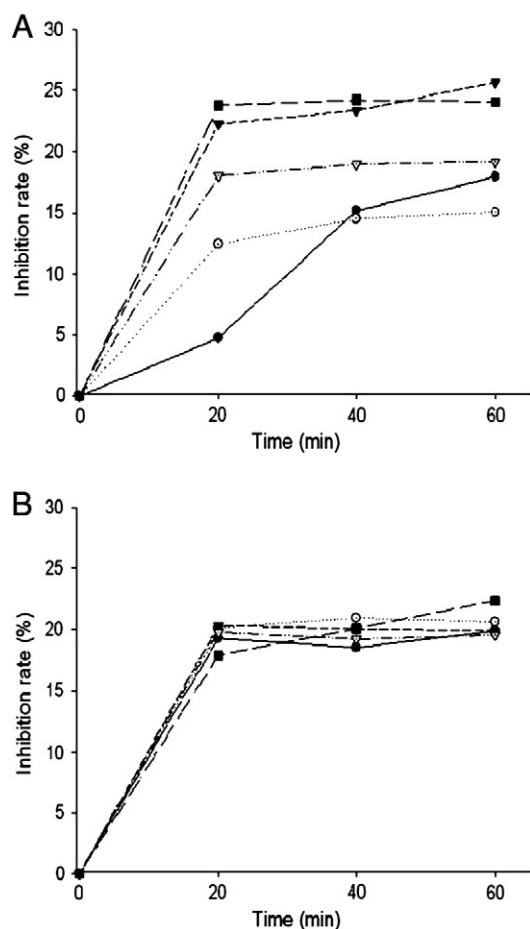


Fig. 2. Growth inhibition levels of *E. coli* O157:H7 on apple (A) and carrot (B) samples by treatments of apples with (—●—) the hydrosols of bayleaf, (.....○.....) black cumin, (---▲---) rosemary, (—▴—) sage and (—■—) thyme hydrosol.

from several parts of spices and/or other edible plants could have antibacterial effects against foodborne pathogens. In conclusion, it might be stated that plant hydrosols have a potential as natural food sanitizing agents to wash fresh cut fruits such as shredded apples and carrots. They may prevent foodborne outbreaks resulted from consumption of fresh-cut fruits and vegetables. Hydrosols have potential to cover the demands of industry for natural antimicrobials to be used as a washing solution for domestic fresh produce. Effects of plant hydrosols on organoleptic properties of the washed products might also be regarded since hydrosol treatment may have influence on sensorial properties of fresh-cut products in some extent. Therefore, further studies should be carried out to determine antimicrobial effects of alternative plant hydrosols as well as their combined effects should be also considered.

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