

## Individual and combination effects of Thai herb extracts and microwave treatment against *Salmonella* spp.

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### Abstract

The objective of this study was to investigate the inhibition of *Salmonella* spp. in microbiological media or minced chicken using herb extracts and/or a microwave method. Five Thai herbs, including cinnamon (*Cinnamomum cassia*), garlic (*Allium sativum*), lemongrass (*Cymbopogon citratus*), clove (*Eugenia caryophyllus*) and ginger (*Zingiber officinale*), were extracted by a simultaneous distillation-extraction for 5 h and examined for their antimicrobial activities using disc diffusion and microbroth dilution assays. The antimicrobial testing revealed that the cinnamon extract exhibited the highest inhibition against all of the studied *Salmonella* serovars, namely *Salmonella enterica* serovar Typhimurium, *S. enterica* serovar Typhi and *S. enterica* serovar Enteritidis. A concentration of 30  $\mu$ L cinnamon extract could produce a diameter inhibition zone of  $52.89 \pm 1.16$  mm against *S. Typhi*, while the minimum bactericidal concentration of the extract against the similar *Salmonella* serovar was 5  $\mu$ L/mL. For the effectiveness of a microwave method to decontaminate *S. Typhi* and *S. Enteritidis* in minced chicken, two power settings of medium (450 W) and high (850 W) and processing times of 0 to 30 s were investigated. It was found that *S. Typhi* could be reduced by more than 0.77 log cycles after a microwave treatment at the high power setting for 30 s, while a decrease of 0.55 log cycles in the *S. Typhi* was determined after processing the sample at the medium power level for 30 s. When cinnamon extract at a concentration of 30  $\mu$ L/25 g chicken meat was combined with a microwave heating at the high power level for 30 s, it was found that the combination treatment could decontaminate 3.56 log cycles of *S. Typhi* in fresh minced chicken. Finding in this study demonstrated that a combination of herb extracts and microwave process could be a useful method to control and/or inhibit the growth of *Salmonella* in food products, particularly chicken meat.

**Keywords:** herb extracts, microwave treatment, *Salmonella* spp., minced chicken meat

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## 1. Introduction

*Salmonella* remains a primary cause of food poisoning worldwide, and massive outbreaks have been witnessed in recent years. *Salmonella* spp. are Gram negative, heterotrophic, mesophilic bacteria that present in warm-blooded animal hosts and are an important human pathogen associated with poultry and poultry products. Up to now, *Salmonella* is the most commonly identified bacterial agent causing illnesses, such as typhoid fever in humans (Pathania et al., 2010). Natural extracts of herbs have been used for many years for different purposes and screened for their potential use as food preservatives. The antibacterial activities of herb extracts and oils can be useful for the preservation of raw and processed food (Michele et al., 2013). Clove, cinnamon and garlic are considered as the most common spices and herbs with strong antimicrobial activities. Their essential oils contain chemical compounds, such as carvacrol, cinnamaldehyde, eugenol and allicin that are identified as the major chemical components responsible for exerting antimicrobial activity (Nimsha et al., 2010; Sudarshan et al., 2010]. Ginger is widely used in food production and oriental medicine. The herb has been investigated to contain several bioactive compounds, including gingerols and shogaols, which have an activity against Gram positive and Gram negative bacteria (Sivasothy et al., 2011).

High frequency heating, especially in the microwave bands, can deliver high temperature in a very short time resulting in nutritional and sensorial advantages. The electromagnetic energies at the microwave frequencies can induce rotation and friction among water molecules in food, thus causing internal heat generation. In this way, microwave energies that penetrate into solid food can produce volumetrically distributed heating effects (Oliveira and Franca, 2002) and rapidly increase the internal temperatures of food. Studies have demonstrated that microwave heating can be used to kill microorganisms in food products (Huang and Sites, 2007). A report of D'Aoust (1989) showed that microwave processing was able to inhibit *S. Enteritidis* that could cause a person to ill by only a few cells of the pathogen. The main objective of this study was to determine the antimicrobial activities of some Thai herb extracts, such as clove, cinnamon, garlic, ginger and lemongrass, with and without microwave heating against 3 serovars of *Salmonella* in microbiological media or minced chicken meat.

## **2. Materials and Methods**

### **2.1 Bacterial strains and culture maintenance**

The pathogenic bacteria used in this study were *S. Enteritidis* DMST 16813 and *S. Typhi* DMST 22842 from the culture collection of the Department of Medical Sciences, Ministry of Public Health, Bangkok, Thailand and *S. Typhimurium* TISTR 292 from the culture collection of Thailand Institute of Scientific and Technological Research, Bangkok, Thailand. All the bacteria were maintained as frozen stocks in vials, containing Tryptic Soy Broth (TSB) (Criterion, USA) supplemented with 10% (v/v) glycerol at  $-60^{\circ}\text{C}$  (Juneja et al., 2001). During experiments, cultures were grown and maintained on Tryptic Soy Agar (TSA) (Criterion, USA) at  $4^{\circ}\text{C}$ . For the determination of antibacterial activity, each strain was cultivated in 10 mL TSB for 24 h at  $37^{\circ}\text{C}$  (Nimsha et al., 2010). The fresh cultures diluted with 9 mL of sterile 0.1% peptone water (Oxoid, England) were used to inoculate microbiological media or minced chicken meat sample (Govaris et al., 2010).

### **2.2 Dried Thai herbs**

Dried ground cinnamon, garlic, lemongrass, clove and ginger were purchased from a local market in Chiang Mai province, Thailand. Different dried ground herbs were determined for their moisture content and water activity using a moisture balance (Sartorius MA45, Germany) and an  $a_w$ -meter (AquaLab model CX3CE, USA), respectively. All determinations were done in triplicate.

### **2.3 Microwave source**

Microwave irradiation was performed in a household microwave oven (Samsung GE872, Malaysia). The oven was equipped with a rotating glass plate and operated at a frequency of 2,450 MHz and a power of 850 W.

### **2.4 Preparation of herb extracts**

To extract dried herb components, 40 g of herb samples in 300 mL distilled water were extracted in a simultaneous distillation extraction for 5 h, using a modified Likens and Nickerson apparatus with 40 mL of dichloromethane ( $\text{CH}_2\text{Cl}_2$ ) (BDH-Prolabo, France). Dichloromethane was utilized due to its high polarity and low boiling point of  $40^{\circ}\text{C}$  (Laohaprasit et al., 2011), causing the compound to have a good recovery rate for semi-volatile compounds (Chaintreau, 2001). An amount of 20 mL of dichloromethane was also added to fill the apparatus solvent return loop. After

cooling at room temperature for 10 min, the dichloromethane extract was collected and dried over anhydrous sodium sulfate (RCFL Limited, New Delhi) for 12 h. The herb extracts were further concentrated at 40°C and atmospheric pressure with a rotary evaporator (BUCHI Labortechnik AG, Switzerland) for 30 min (Chaintreau, 2001). The concentrated herb extracts, which were considered as 100% concentration, were collected into dark bottles and stored at 4°C until used.

## **2.5 Antimicrobial activity of herb extracts in microbiological media**

### **2.5.1 Disc diffusion assay**

The evaluation of antimicrobial herb extracts using a modified agar disc diffusion method was carried out by employing the procedure of Govaris et al. (2010). Suspension in TSB of the tested microorganism (0.1 mL of  $10^4$  cfu/mL) was spread on the solid TSB media plates. For the positive control, Penicillin G (10 µg) (Oxoid, England) was used, while a disc impregnated with 10 µL of sterile distilled water served as a negative control. The experiment was carried out in triplicate.

### **2.5.2 Minimum Inhibitory Concentration (MIC) and Minimum Bactericidal Concentration (MBC) of herb extracts**

The MIC and MBC of herb extracts were evaluated using a microbroth dilution based on the method of Chamdit and Siripermpool (2012). Bacterial strains were cultured overnight at 37°C in TSB. Test strains were suspended in TSB to give a final concentration of  $10^4$  cfu/mL and these were confirmed by viable counts. Penicillin G (10 µg) and TSB with 5% Tween 80 were applied as positive and negative controls, respectively. The MIC was defined as the lowest concentration of herb extracts that inhibited visible growth after 24 h of incubation and the MBC was determined from the lowest concentration of herb extract that inhibited the growth of *Salmonella* on TSA. All extracts were prepared and tested in triplicate.

## **2.6 Preparation of chicken meat**

Chicken breast meat was obtained from a local market in Chiang Mai, Thailand and transported to the laboratory under refrigerated conditions within 30 min. After removed the outer layer of the chicken, the inner part of chicken meat was minced in a dry and clean grinder (Solomakos et al., 2008a; 2008b). The minced chicken meat was kept at refrigerated temperature until used in an experiment.

## 2.7 The effect of microwave treatment on *Salmonella* spp. in minced chicken meat

An amount of 25 g of minced chicken meat was contaminated with either *S. Typhi* or *S. Enteritidis* that produced an initial inoculation level in the meat sample of  $3.8 \times 10^4$  cfu/g. The contaminated meat samples were homogenously mixed with a sterile spoon for 2 min at room temperature and placed in sterile zip bags. The chicken meat samples were then heated in the microwave oven operating at a power setting of high or medium power for 0, 10, 20 or 30 s (Jamshidi et al., 2009). Internal temperature of the chicken samples was taken directly after the microwave treatment with a sterile thermocouple. The microwave treated chicken meat samples were kept at chilled temperature before a microbiological analysis. Each treatment was prepared in triplicate. In the case that the reduction number of *Salmonella* population was given, the percentage reduction of the pathogen population was calculated according to the following equation (Joe et al., 2012):

$$\% \text{ reduction in } \textit{Salmonella} \text{ population} = \frac{N_0 - N}{N_0} \times 100$$

Where:  $N_0$  = population of *Salmonella* spp. before treatment (cfu/g) and

$N$  = population of *Salmonella* spp. after treatment (cfu/g).

## 2.8 The effect of microwave heating and herb types on *Salmonella* spp. in minced chicken meat

Fresh minced chicken meat (25 g) was inoculated with either *S. Typhi* or *S. Enteritidis* to obtain an initial inoculation level of  $1.4 \times 10^6$  cfu/g, added with cinnamon extracts at a concentration range of 0 to 30  $\mu\text{L}/25$  g chicken meat and homogenously mixed with a sterile spoon for 2 min at room temperature (Hayouni et al., 2008). Contaminated minced chicken meat samples were individually placed in a sterile zip bag and separately heated in the microwave oven at a high power level for 30 s. After the microwave treatment, the chicken meat samples were kept at low temperature storage until a microbiological analysis. Each treatment was done in triplicate.

## 2.9 Microbiological analysis

The enumeration of *Salmonella* spp. was carried out by the method of Hayouni et al. (2008). The *Salmonella* determination was done by transferring 25 g chicken meat into a sterile plastic bag containing 225 mL of 0.1% peptone water. The samples were homogenized for 1 min using a stomacher and incubated in a sterile bottle at 35°C for 24 h. From this pre-enrichment (for

the resuscitation of possible injured living cells), 1 mL of the peptone water solution was added into 9 mL of Selenite Cystine broth (SCB) (Criterion, USA) and incubated at 35°C for 24 h. On the following day, an amount of 0.1 mL or its dilution of the minced chicken meat samples in SCB were spread plated on a selective medium of Xylose lysine decarboxylase Agar (XLD) (Criterion, USA) in triplicate and incubated at 35°C for 24–48 h before being enumerated.

### 2.10 Statistical analysis

Collected data was statistically analyzed by variance in the general linear model using SPSS version 17.0 software (SPSS Inc, Chicago, IL, USA). Duncan's multiple range tests were used to assess the difference between treatment means. A probability level  $P < 0.05$  was used as a statistical significance of the sample treatments.

## 3. Results and Discussion

### 3.1 Chemical properties of dried ground herbs and yield of herb extracts

The moisture contents of five Thai dried herbs used in this study were in the range of 7.09-8.32% with water activities between 0.61 and 0.65. The highest water activity was found in dried ground clove with a value of  $0.65 \pm 0.003$ . The yield of herb extracts obtained by a simultaneous distillation extraction is displayed in Table 1. Different types of herb significantly affected the yield of the herb extracts ( $P < 0.05$ ). The highest yield of the extract was found in clove, while the lowest one was in garlic.

**Table 1.** Yield of different herb extracts produced by a simultaneous distillation extraction method.

Common names	Scientific names	Part used	Yield (% , v/w)
Lemongrass	<i>Cymbopogon citrates</i>	Stem	$2.32 \pm 1.05^b$
Clove	<i>Eugenia caryophyllata</i>	Flower bud	$18.32 \pm 1.23^a$
Garlic	<i>Allium sativum</i>	Bulb	$0.67 \pm 0.09^c$
Ginger	<i>Zingiber officianale</i>	Rhizome	$1.02 \pm 0.13^c$
Cinnamon	<i>Cinnamomum cassia</i>	Bark	$4.34 \pm 0.27^b$

<sup>a-c</sup> Means within the same column followed by different letters were significantly different ( $P < 0.05$ ).

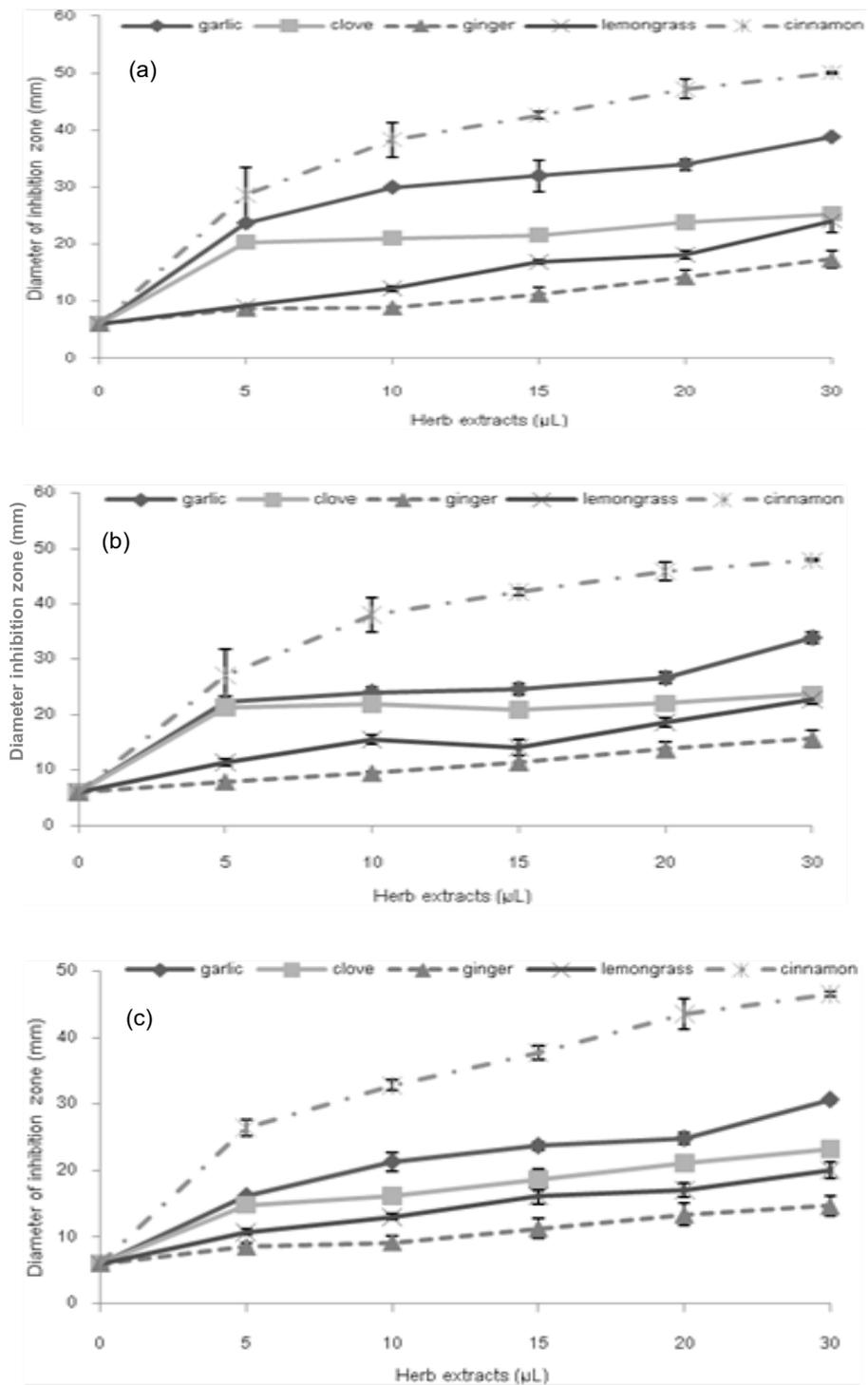
## 3.2 Antimicrobial activity of herb extracts

### 3.2.1 Disc diffusion assay

The results of diameter inhibition zones (DIZ) produced by different herb extracts against *Salmonella* spp. are presented in Fig. 1. The cinnamon, garlic and clove extracts strongly inhibited the growth of *Salmonella* spp. Higher amount of the herb extracts produced greater DIZ. For the 3 tested serovars of *Salmonella*, the relative inhibitory effects of different herb extracts were as followed: cinnamon > garlic > clove > lemongrass > ginger. The DIZ of penicillin G at a concentration of 10 µg against *S. Typhi*, *S. Enteritidis* and *S. Typhimurium* were  $20.71 \pm 1.18$ ,  $20.64 \pm 1.00$  and  $19.90 \pm 0.36$  mm, respectively. The DIZ of cinnamon, garlic and clove extracts at the concentration of 30 µL were higher than those of penicillin G. Tajkarimi et al. (2010) had reported that cinnamaldehyde and eugenol extracted from cinnamon and clove were effective against *Salmonella* spp.

### 3.2.2 The Minimum Inhibitory Concentration (MIC) and the Minimum Bactericidal Concentration (MBC) of herb extracts

The results of MIC and MBC determination for different Thai herb extracts can be seen in Table 2. The MIC values of the herb extracts were within the range of 5 to 15 µL/mL. Garlic, cinnamon, clove and lemongrass extracts could prevent the growth of *Salmonella* spp. at a level of 5 µL/mL. On the other hand, the MBC values of the herb extracts were within the range of 5 to more than 30 µL/mL. The most effective herb extract to inhibit *S. Typhi* was cinnamon, while the growth of *S. Typhimurium* and *S. Enteritidis* could be completely prevented by 10 µL/mL of the cinnamon extract. The clove and garlic extracts could completely inhibit the growth of *Salmonella* spp. at 15 µL/mL, while the lemongrass extract needed a concentration of 30 µL/mL. Ginger extract could not completely prevent the growth of *Salmonella* spp. at the studied concentrations.



**Figure 1.** Diameter inhibition zone (mm) of different herb extracts against *S. Typhi* (a), *S. Enteritidis* (b) and *S. Typhimurium* (c) in the disc diffusion assay.

**Table 2.** The Minimum Inhibitory Concentration and Minimum Bactericidal Concentration of different herb extracts against *Salmonella* spp.

Herb extracts	The Minimum Inhibitory Concentration/Minimum Bactericidal Concentration ( $\mu\text{L}/\text{mL}$ )		
	S. Typhimurium	S. Enteritidis	S. Typhi
Lemongrass	5/30	5/30	5/30
Clove	5/15	5/15	5/15
Garlic	5/15	5/15	5/15
Ginger	15/>30	15/>30	15/>30
Cinnamon	5/10	5/10	5/5

Based on the results of disc diffusion assay and microbroth dilution, it could be clearly seen that cinnamon extract exhibited the highest antimicrobial activity against different *Salmonella* serovars, followed by garlic and clove extracts. Finding in this study was in an agreement with the report of Wannissorn et al. (2005) that an amount of 15  $\mu\text{L}$  of the *Cinnamomum bejolghota* essential oil could produce 21.5 mm inhibition zone against *S. Typhimurium* TISTR 292. Fabio et al. (2003) reported that the antimicrobial activity of cinnamon was attributed to cinnamaldehyde (80-90%), which possessed antifungal and antibacterial properties. Inhibition of cinnamaldehyde, the active compound of cinnamon extract, against bacteria could be due to binding of the compound to the microbial cell surface and then penetrating to the target sites. Inside the cells, there were several possible antibacterial mechanisms of the compound, such as inhibition of proton motive force, inhibition of substrate oxidation and active transport and disruption of synthesis of DNA, RNA, protein, lipid and polysaccharides (Nychas, 1995; Shan et al., 2007). For garlic, the major antimicrobial compound in the herb extract was allicin (allyl 2-propene thiosulphinate) (Marques et al., 2008). Feldberg et al. (1998) found that the bacteriostatic inhibition of allicin against *S. Typhimurium* was due to delayed and partial inhibition of DNA and protein synthesis and an immediate inhibition of RNA synthesis.

The antibacterial activity of clove was attributed to eugenol (2-methoxy-of 4-allyl phenol), which was present at a high level (70-90%) in clove bud oil. It was reported that the eugenol had a wide spectra of antimicrobial effect, including the growth inhibition of enterobacteria (Hoque et al., 2008). In this study, ginger extract was found to have the lowest activity to prevent the growth of

*Salmonella* spp. Suresh et al. (2004) reported that ginger extract had a moderate activity against *S. Enteritidis*. A similar finding for ginger was also discovered by Wannissorn et al. (2005). They showed that 15  $\mu$ L of the essential oil of *Z. officinale* Roscoe could only produce an inhibition zone of 14 mm against *S. Typhimurium* TISTR 292.

### 3.3 The effect of microwave treatment on *Salmonella* spp. in minced chicken meat

The inactivation of *S. Enteritidis* and *S. Typhi* in minced chicken meat samples by microwave treatments is shown in Table 3. The collected data clearly displayed that the high power level caused more destruction to *Salmonella* spp. compared to those processed at the medium power level. *S. Typhi* was found to be more sensitive than *S. Enteritidis* in the microwave processing. At the high power level, reductions in the *S. Typhi* population for 29.15, 51.08 and 82.89% could be achieved after processing the minced chicken meat for 10, 20 and 30 s, respectively. On the other hand, the medium power level could only decrease the *S. Typhi* population by 16.86, 46.02 and 68.43%, respectively. The highest destruction for *S. Enteritidis* of 55.66% was accomplished at the high power level for 30 s.

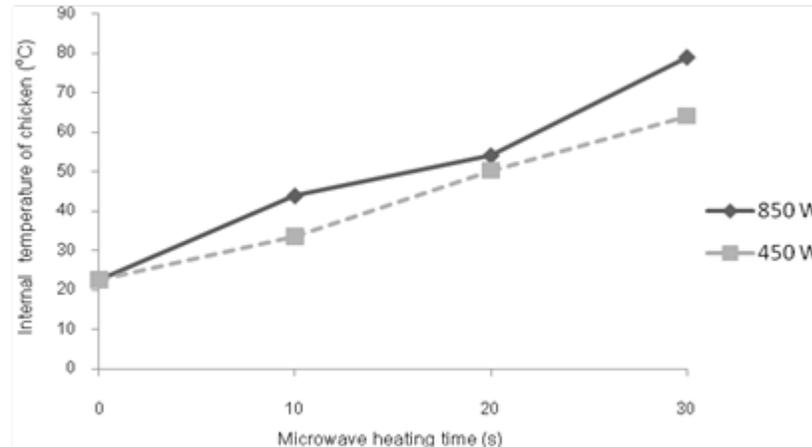
**Table 3.** Inactivation of *Salmonella* spp. (log cfu/g) in minced chicken meat by different power levels and processing times of microwave heating.

Microwave power level	Time (s)	Population of <i>Salmonella</i> spp. (log cfu/g)	
		<i>S. Typhi</i>	<i>S. Enteritidis</i>
High (850 W)	0	4.14 $\pm$ 0.02 <sup>Ga</sup>	4.13 $\pm$ 0.20 <sup>Ea</sup>
	10	3.98 $\pm$ 0.09 <sup>Da</sup>	4.04 $\pm$ 0.03 <sup>Db</sup>
	20	3.83 $\pm$ 0.02 <sup>Ca</sup>	3.87 $\pm$ 0.32 <sup>Aba</sup>
	30	3.37 $\pm$ 0.06 <sup>Aa</sup>	3.77 $\pm$ 0.05 <sup>Ab</sup>
Medium (450 W)	0	4.14 $\pm$ 0.01 <sup>Ea</sup>	4.13 $\pm$ 0.19 <sup>Ea</sup>
	10	4.06 $\pm$ 0.04 <sup>Fa</sup>	4.03 $\pm$ 0.29 <sup>Da</sup>
	20	3.87 $\pm$ 0.05 <sup>CDa</sup>	4.00 $\pm$ 0.13 <sup>CDa</sup>
	30	3.59 $\pm$ 0.25 <sup>Ba</sup>	3.93 $\pm$ 0.41 <sup>BCa</sup>

<sup>A-G</sup> Means within the same column followed by different letters were significantly different (P<0.05).

<sup>a-b</sup> Means within the same row followed by different letters were significantly different (P<0.05).

The internal temperature of minced chicken meat samples that was directly measured after a microwave treatment is presented in Fig. 2. Applying a high power level for 10, 20 and 30 s produced an internal temperature of 43.9, 54.3 and 79.0°C, respectively, while temperatures of 33.6, 50.1 and 64.1°C, respectively, were determined after processing the minced chicken meat samples at a medium power level. The measurement of the internal temperature of the samples clearly demonstrated that an increase in the temperature of the meat samples could be the crucial factor that caused destruction in the *Salmonella* population. It was reported that *Salmonella* is a heat sensitive bacterium. Most cooking procedure would specify a minimum internal temperature of 70°C for poultry meat products to produce a fast inactivation of the bacteria (Marriott, 1999). In this study, a destruction of 0.77 log cycle could be achieved after processing the minced chicken meat samples for 30 s at the high power level. The result in this study was in an agreement with the finding of Pucciarelli and Benassi (2005), who investigated the effect of microwave heating (800 W) on *S. Enteritidis* inoculated on fresh chicken thighs. They found that there was a destruction of 3 log cycles after processing the chicken thighs in the microwave at a high power level (level 10) for 70 s, that had an internal temperature at about 70°C, and 6.4 log cycles after 95 s at the high power level, which had an internal temperature of around 85°C. The study also showed that a destruction of *S. Enteritidis* for 5 log cycles could be done after processing the chicken thigh for 140 s at a medium power setting, which had an internal temperature of 85°C. However, the internal temperature of the minced chicken meat in this study was higher than the one reported by Göksoy et al. (2000) for the effect of short time microwave exposure on *Escherichia coli* K12 and *Campylobacter jejuni* on fresh skin-less chicken breasts. They discovered that the maximum temperature that could be achieved by processing the chicken sample at full power (IEC 1138.8 W) of a microwave for 30 s was only 46.7°C. A different finding about the internal temperature in this study could be affected by differences in the microwave power and types of the chicken samples. It has been reported that microwave heating could create hot and cold spots, which would depend on several parameters during high frequency heating, such as geometry and composition, dielectric properties and thermal properties of food products (Aymerich et al., 2008).



**Figure 2.** Internal temperature (°C) of minced chicken meat sample directly after microwave treatments at different power levels.

### 3.4 A combination effect of microwave heating and herb extract on *Salmonella* spp. in minced chicken meat

In this section, the microwave heating at a high power level (850 W) for 30 s and cinnamon extract at levels between 0 to 30  $\mu\text{L}$  were applied together to understand their collective effect to decontaminate *S. Typhi* and *S. Enteritidis* in minced chicken meat samples. Data of the microbiological analysis exhibited that the combined effect of microwave treatment and cinnamon extract (Table 4) produced more decontamination of *Salmonella* compared with those treated only by the microwave treatment (Table 3).

**Table 4.** Inactivation of *Salmonella* spp. (log cfu/g) in minced chicken meat by microwave heating at high power level (850 W) for 30 s at different addition levels of cinnamon extract.

Cinnamon extract ( $\mu\text{L}$ )	Population of <i>Salmonella</i> spp. (log cfu/g)	
	<i>S. Typhi</i>	<i>S. Enteritidis</i>
0	6.57 $\pm$ 0.19 <sup>C</sup>	6.59 $\pm$ 0.14 <sup>C</sup>
15	4.03 $\pm$ 0.46 <sup>Ba</sup>	4.06 $\pm$ 0.32 <sup>Ba</sup>
20	3.20 $\pm$ 0.05 <sup>Aa</sup>	3.97 $\pm$ 0.34 <sup>Bb</sup>
30	3.01 $\pm$ 0.06 <sup>Aa</sup>	3.25 $\pm$ 0.31 <sup>Aa</sup>

<sup>A-C</sup> Means within the same column followed by different letters were significantly different ( $P < 0.05$ ).

<sup>a-b</sup> Means within the same row followed by different letters were significantly different ( $P < 0.05$ ).

A combination of microwave and cinnamon extract at levels of 15, 20 and 30  $\mu\text{L}$  could reduce the population of *S. Typhi* by 99.60, 99.95 and 99.97%, respectively, while the number of *S. Enteritidis* were decreased by 99.65, 99.71 and 99.80%, respectively. This finding showed that the presence of cinnamon extract in the minced chicken meat could significantly enhance the destruction effect of heating during the microwave treatment on the *Salmonella* population. The cumulative effect was significantly increased in the decontamination of *S. Enteritidis*, which was improved by 99.65% in the presence of 15  $\mu\text{L}$  of cinnamon extract. This effect might also reduce the concern regarding the uneven heat distribution on product surface during the microwave heating (Mudgett, 1989). The ability of cinnamon extract, particularly cinnamaldehyde, to completely diffuse in the minced chicken meat might also contribute to the enhanced effect of the extract and microwave treatment. Helander et al. (1998) has reported that cinnamaldehyde could inhibit the growth of *Staphylococcus aureus*, *E. coli* O157:H7 and *S. Typhimurium*. In this study, the antimicrobial effect of cinnamon extract was improved with the application of microwave heating and was able to reduce for around 50% of the population of *S. Typhi* and *S. Enteritidis* with an initial microbial population of 6.57 log cfu/g. This could have a significant implication to reduce the possibility of *Salmonella* outbreak, which was quoted to be caused by approximately  $10^5$  cells (Bell and Kyriakides, 2002).

#### 4. Conclusion

Results of this research clearly showed that Thai herb extracts, including cinnamon, garlic, lemongrass and clove, were effective to inhibit the growth of *Salmonella* spp. in microbiological media. The best herb extract to completely prevent the growth of *Salmonella* spp. was cinnamon extract. Microwave heating could reduce the population of *Salmonella* spp., which was depended on heating times and power levels. The destruction of *Salmonella* spp. was more evident at a high power level than those at a medium power level. A combination of 30  $\mu\text{L}$  cinnamon extract and microwave treatment at the high power level for 30 s was effective to significantly reduce *S. Typhi* and *S. Enteritidis* in minced chicken meat by 99.97 and 99.80%, respectively. This finding suggested that the cumulative effect of cinnamon extract and microwave heating had a potential to be used as a hurdle treatment to increase the safety of food products, particularly chicken meat, from *Salmonella* and/or extend its shelf life.

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