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Inhibitory Effect of Plant Extracts on *Salmonella* spp.

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1. Introduction

Salmonella spp., facultatively anaerobic gram-negative rod-shaped bacteria (Krieg & Holt, 1984), is one of the most important food borne pathogens. If present in food, the bacteria do not affect the taste, smell or appearance of the food. Frequent hand washing, throwing out expired food, avoid eating raw or undercooked eggs, meats, seafood or poultry are the key to preventing *Salmonella* food poisoning. Antibiotics (such as ampicillin, chloramphenicol, streptomycin, sulfonamides and tetracycline) may be prescribed for moderate to severe cases of *Salmonella* food poisoning or when it occurs in a person who is at risk for complications. However, probably as a consequence of the extensive use of antibiotics, that the incidence and severity of human diseases related to *Salmonella* caused by antimicrobial resistant *Salmonella* is rising in many countries (Breuil et al., 2000). Furthermore, illness caused by resistant *Salmonella* can be more severe and difficult to control (Oliveira et al., 2006).

Presence of the bacterium *Salmonella* in food and the disease *Salmonella* food poisoning and typhoid fever continue to be a major public health problem worldwide. Millions of human cases are reported worldwide every year and the disease results in thousands of deaths. The increasingly resistance to antibiotics of food borne *Salmonella* (Breuil et al., 2000) drive much of the current interest on plant antimicrobial molecules. At the same time, increasingly consumer demand for more natural products has led to the food industry to consider the incorporation of the natural preservative in a range of products (Dorman & Deans, 2000; Elgayyar et al., 2001). Plants are complex chemical storehouses of undiscovered biodynamic compounds with unrealized potential for use in modern medicine (Plotkin, 1988). Several antimicrobial agents were isolated from plant including secondary metabolites as essential oil, terpenoides, phenols, alkaloids and flavanoids (Kazmi et al., 1994; Cosentino et al., 1999; Omulokoli et al., 1997). An important characteristic of these compounds is their hydrophobicity, which enables them to partition in the lipids of the bacterial cell membrane and mitochondria, disturbing the structures and rendering them more permeable (Burt, 2004). This chapter is undertake in order to investigate inhibitory effect of plant extracts on *Salmonella* spp., including a prevalence and control of *Salmonella* in foods and incidence of antibiotic resistant strains of *Salmonella.* Information on extraction methods and phytochemical compositions of medicinal plants can be found in this chapter. The current knowledge on potential of plant extracts for antibacterial activity against *Salmonella* spp. and its application in food processing or packaging will be discussed.

2. Prevalence of *Salmonella* in foods

Most *Salmonella* can survive for extended periods in food stored at refrigeration to ambient room temperatures (2-25°C). Some *Salmonella* strains can grow in high temperature as 54°C (Montville & Matthews, 2008). The *Salmonellla* are generally transmitted to humans through consumption of contaminated food of animal origin, mainly meat, poultry, eggs and milk. The prevalence of pathogenic serotypes associated with food-borne disease varies by geographical location (Watie & Yousef, 2010). The *Enteritidis*, *Typhimurium*, *Newport* and *Javiana* were the most prevalence serotypes in the United States in 2007. The symptoms and sign of *Salmonella* infection include diarrhea, abdominal pains, nausea, vomiting and chills, leading to dehydration and headaches (Richard et al., 2008).

2.1 *Salmonella* in egg

In eggs, various *Salmonella* serovars can be found in the egg content, principally *S. enteritidis*, is the serovar most frequently with egg infection (Gast & Beard, 1990; Humphrey et al., 1991; de Louvois 1993). A few reported in human on outbreaks of *Salmonella* food poisoning related egg caused by *S. typhimurium* (EFSA, 2010a). Other *Salmonella* serovars, e.g., *S. mbandaka*, *S. livingstone*, *S. heidelberg*, *S. hadar*, *S. infantis* and *S. virchow*, also occur with low frequency in layers and consequently on egg surfaces (Chemaly et al., 2009). The risk assessment estimates the probability of human illness due to *Salmonella* following the ingestion of a single food serving of internally contaminated shell eggs, either consumed as whole eggs, egg meals, or product containing these ingredients such as cake or mayonnaise. The growth of *Salmonella* in egg albumen is eased at 20°C, while it is unable to grow at temperature less than 10°C (Gantois et al., 2009). Recently, an average prevalence of 0.5% eggs contaminated with *Salmonella* was reported across the member states of the European Commission (EFSA, 2010b).

2.2 *Salmonella* in meat

Pork and pork products are also recognized as one of the major sources of human *Salmonella* food poisoning. The commonly isolated non-typhoid *Salmonella* serovars in pigs, pork and humans is *S. typhimurium* (Astorga Marquez et al., 2007; Boyen et al., 2008; Perugini et al., 2010). During further processing of meat, such as cutting and mincing, *S. typhimurium* from contaminated pork cuts may then spread into pork preparations (Gonzales-Barron et al., 2010). The proportion of human *Salmonella* food poisoning attributable to pork has been estimated to be between 9 and 15% in Denmark and around 21% in Netherlands (EFSA, 2008; Hald et al., 2004). In Ireland, the pork meat has been identified as a significant source of *Salmonella* with an incidence of 2.9% as surveyed in processing plants (Gonzales-Barron, 2010b). A Belgian survey from 2000 to 2003 indicated that the mean prevalence values of S*almonell*a in 25 g samples of pork meat cuts and minced meat were 17.3% (95% CI: 15.0–19.7%) and 11.1% (95% CI: 9.4–13.0%) (Ghafir et al., 2007, 2005), respectively.

2.3 *Salmonella* in poultry

In the European Union, three of the top four serovars (*S. infantis*: 29.2%, *S. enteritidis*: 13.6%, *S. kentucky*: 6.2% and *S. typhimurium*: 4.4%, respectively) isolated from poultry are also found in the top four serovars (*S. enteritidis*: 58.0%, *S. typhimurium*: 21.9%, *S. infantis*: 1.1%

and *S. virchow*: 0.7%, respectively) isolated from humans (EFSA, 2010c). The *S. sofia* has rarely been reported to be isolated from poultry in Australia, which the very low prevalence of *Salmonella* food poisoning linked to *S. sofia* suggests low virulence for humans (Duffy et al., 2011). A large percentage of poultry is colonized by salmonellas during grow-out, and the skin and meat of carcasses are frequently contaminated by the pathogen during slaughter and processing. In Brazil, the remarkable increase in the incidence of *S. enteritidis* from foodborne outbreaks, human infections, nonhuman sources, broiler carcasses and other poultry materials has been reported since the 1990s (Peresi et al., 1998; Fuzihara et al., 2000; Tavechio et al., 2002). Of the 281 chicken meat samples in Austria, 46 were positive for the occurrence of *Salmonella* (prevalence of 16.4%) as described by Mayrhofer et al., 2004.

2.4 *Salmonella* in milk

One route of *Salmonella* transmission is via raw/unpasteurized milk and products made from raw milk (e.g. cheese) (Cody 1999). In a 2000 study of New York dairy herds, *Salmonella* were isolated from 1.5 percent of 404 milk filters. *Salmonella* contamination of bulk milk most likely occurs through fecal contamination, and mitigation through improved hygiene practices may be possible (Karns et al., 2005). Consumption of cheese contaminated with the mentioned pathogens can lead to serious health problems, which the outbreaks of *Salmonella* spp. in Mozzarella cheese can be seen since 1981 in Italy and USA (De Buyser et al., 2001). In 1985, D'Aoust et al. found that *S. typhimurium* was linked to Canadian foodborne outbreaks associated with the consumption of Cheddar cheese.

2.5 *Salmonella* in other food

A recent *Salmonella* outbreak is also occur with other food products (Waite & Yousef, 2010). In United States, Columbia and Canada in 2008, there are estimated more than 1000 case of *Salmonella* food poisoning outbreaks by *S. saintpaul* in raw tomatoes, fresh cilantro, fresh jalapeno peppers and fresh Serrano peppers, whereas in 2007, the foodborne outbreaks was found in peanut butter, frozen pot pie and puffed vegetable snack in United States and boxed lunch in Japan. Other fruit product such as fruit salad and orange juice has been associated with occasional outbreaks of *Salmonella* food poisoning.

3. Control of *Salmonella* in foods

High temperatures used in cooking and in pasteurization processes have been regarded as the treatment of choice for the destruction of *Salmonella* in eggs, milk and meat products. Humphrey et al. (1980) showed that to kill *Salmonella* present in the egg yolk, the yolk temperature had to be raised to >8O°C. Boiling for over 6 to 10 min was required inactivate approximately 10^7 cfu *S. enteritidis* in the yolk of shell eggs, depending on the method of boiling (Chantarapanont et al., 2000). Kuo et al. (1997) determined that UV radiation significantly reduced *S. typhimurium* inoculated on shell eggs. Directional microwave technology resulted in more than 2-log reduction of *S. enteritidis* in shell eggs without causing any detrimental effects to quality reviewed by Lakins et al. (2008). The effectiveness of steam treatments on meat and poultry has been investigated, which the presence of a number of pathogens may be reduced by the application of steam to meat surfaces, mostly gram negative enteric pathogens, such as *Escherichia coli* O157:H7 and a number of

Salmonella serotypes (James et al., 2000; Phebus et al., 1997; Whyte et al., 2003). Following the published report by Porto-Fett et al., 2010, the fermentation and drying and/or high pressure processing of contaminated dry sausage or pork are effective for inactivating *Salmonella* spp. High-pressure treatment of milk is considered to be the most promising alternative to traditional thermal treatments. Metrick et al., (1989) indicated that the pressure treatments of 310 and 379MPa/15 min at ambient temperature were required for a 3-log reduction in colony forming units (cfu) of *S. seftenberg* 775W.

4. Antibiotic resistance *Salmonella*

The first reports on antibiotic resistant *Salmonella* had been indicated since 1960s and describe mainly case with monoresistance strain (Helmuth, 2000). In the late 1980s, the appearance multiple resistances against ampicillin, chloramphenicol, streptomycin, sulfonamides and tetracycline were found in serovar *Thyphimurium* definitive type 104 (DT 104) (Montville & Matthews, 2005). The main mechanism of bacteria exhibit resistance to antimicrobial agents can be due to many factors including drug inactivation, reduced drug accumulation, alteration of metabolic pathway and target site (Barbosa & Levy, 2000; Schwarz & Chaslus-Dancla, 2001). Much of the resistance to penicillins and cephalosporins by *Salmonella* spp. is attributable to the acquired ability of the strains to produce β-lactamase that can degrade the chemical structure of the antimicrobial agents (Bush, 2003).

In recent years, the prevalence of multidrug resistant *Salmonella* in foods has been reported in many parts of the world. Several clinical treatment failures with fluoroquinolones (such as ciprofloxacin) in cases of *S. typhi* showed in Europe, Asia, and Africa (Butt et al., 2003; Nkemngu et al., 2005). Shirakawa et al. (2006) claims that the resistance to nalidixic acid and decreased susceptibility to fluoroquinolone in the *S. enterica* serovar *Typhi* isolated in Katmandu, Nepal, in 2003 were completely correlated to the mutation at codon 83 of gyrA. Most antimicrobial-resistant *Salmonella* infections are acquired from eating contaminated foods of animal origin. During 2000-2006 in Taiwan, it was found that 30.5% of the raw chicken meat was contaminated with multidrug resistant *S. enterica* serovar *Schwarzengrund* (Chen et al., 2011). Among the 88 *Salmonella* isolated from 300 meat products (raw beef, chicken meat and street foods) in Kuala Lumpur, the highest resistance was to tetracycline (73.8%), followed by sulfonamide (63.6%), streptomycin (57.9%), nalidixic acid (44.3%), trimethoprim sulfamethoxazole (19.3%), ampicillin (17.0%), chloramphenicol (10.2%) (Thong & Modarressi, 2011). The most antimicrobial resistance *S. enteritidis* isolates from South of Brazil reported by de Oliveir et al. (2005) was found in poultry related samples, where all strains were resistant to at least one antimicrobial agent.

The prevalence of extraintestinal *salmonella* infections caused by antibiotic resistant *Salmonella* spp. in several geographic areas of the world is increasing. Pokharel et al. (2006) demonstrated a 5% prevalence of multidrug resistance among *S. enterica* at a tertiary care hospital in Kathmandu, Nepal, with a higher rate of multidrug resistance among *S. paratyphi A* (7%) compared to *S. typhi* (3%). Rotimi et al. (2008) reported the serious problem of drug resistance in *Salmonella* spp. in Kuwait and United Arab Emirates that the non-typhoidal *Salmonella* spp. isolates from fecal samples of patients had 5-fold rise in resistant to cefotaxime and ceftriaxone compared with reported earlier.

5. Plant extract

Plant contain a variety of substance called "phytochemicals" (divided into two groups; primary and secondary metabolite), which are naturally occurring biochemicals in plants that give plants their color, flavor, smell and texture. Plant secondary metabolite differ from ubiquitous primary metabolite (e.g. carbohydrate, proteins, fats, nucleic acid) (Bako and Aguh, 2007), that have a scientifically proven effect on human health. The most important of these bioactive constituents of plants are alkaloids, tannins, flavonoids, anthraquinone, other phenolic compound and essential oil (Kisangau et al, 2007).

Extraction is the first important step for the recovery and purification of active ingredients of plant materials. Several extraction techniques and solvents are used for obtain antioxidant and antimicrobial extract from plant origin. The general techniques of medicinal plant extraction include maceration, percolation, hot continuous extraction (Soxhlet), solvent extraction, counter-current extraction, microwave-assisted extraction, ultrasound extraction (sonication), supercritical fluid extraction (Chen et al., 1992; Bicchi et al., 2000; Kaufmann and Christen, 2002). For solvent extraction method, polar solvents (such as organic acids), solvents of intermediate polarity (such as methanol, ethanol, acetone, and dichloromethane) and solvents of low polarity (such as hexane and chloroform) are used to extract plant secondary metabolites, which the extracts obtained from the same plant material with different solvent characteristics have distinct physical and biological properties. Lapornik, et al. (2005) reported that ethanol and methanol extracts of red and black currant contain twice more anthocyanins and polyphenols than water extracts, extracts made from grape marc had seven times higher values than water extracts. Among the five different Indian medical plants, methanol extract showed more antibacterial activity and moderate activity with aqueous, ethyl acetate and chloroform extract (Ashokkumar et al., 2010), while the more-polar solvent extracts (BuOH and water extracts) in Korean herbal medicines gave higher antioxidant activity than that of non-polar solvent extracts (hexane and EtOAC extracts) (Kang et al., 2003). Moreover, the chemical compound of extracts from particular plant species can vary according to the geographic origin, harvesting period and parts of the plant use. Nwokocha et al. (2011) found that all secondary metabolites analyzed were present in all tissues (leaf, stem, root and seed) studied but at different concentrations. A spatial and seasonal impact on the total phenolic content has been reported for *Poacynum henersonii* collected at three sites in China (Hong et al., 2003).

Essential oils are a volatile liquid aromatic compound which extracted from plant cell. The cells are location in specific parts of the plant such as bark, flowers, leave, seed, peel and root. Table 1 shows the plant organ contains essential oil and their essential oil constitutes. Distillation (water distillation, water and steam distillation, steam distillation) is the most commonly used method for produces essential oils on the commercial basis (Rasooli, 2007). Some volatile oils cannot be distilled without decomposition are thus are usually obtained by expression (such as lemon oil or orange oil). The effect of diffrent distillation methods on oil content and composition of aromatic plants have been reported. The water-distillation of the rose-scented geranium (*Pelargonium* sp.) gave a higher oil yield (0.16–0.22%) than did water-steam-distillation (0.09–0.12%) or steam-distillation methods (0.06–0.18%) (Kiran et al., 2005). The oil of *Satureja rechingeri* Jamzad in full flowering stage obtained by hydro-distillation, water- and steam-distillation and direct steam-distillation consisted of twenty, seventeen and twenty-two compounds, respectively, which the major constituents were carvacrol and p-cymene (Sefidkon et al., 2007).

Plant organ	Plant	Main chemical composition
Flower	Neroli, rose, jasmine, rosemary, lavender, chamomile	Linalool, citronellol, bezyl acetate, α-pinene, α-bisabolol
Leaves	Eucalyptus, tea tree, patchouli, verbena	Eucalyptol, 1,8-cineole, terpinen-4-ol, patchoulol, geranial
Aerial part	Basil, peppermint, spearmint	Linalool, manthol, carvone
Fruit	Bergamot, juniper, lemon, mandarin	Limonene, α-terpineol, citral, limonene
Seed	Coriander, caraway, nutmeg, fennel, angelica	linalool, carvone, sabinene, (E)-anethole, β-Phellandrene
Bark and wood	Cinnamon, cedarwood, sandalwood, pine	Cinnamaldehyde, Thujopsene, α-santalene, α-pinene
Rhizomes	Ginger, galanga, calamus, curcuma, kaempferia,	Zingiberene, 1,8-cineole, β-asarone, turmerone, methylcinnamate
Roots	Vetiver, saussurea, valerian	Khusimol, α-selinene, bornyl acetate

Table 1. Essential oils in each plant organ (Base on Krishnasamy, 2008)

6. Anti-*Salmonella* activity of plant extract

Chemical compound of the plant extract or essential oils has revealed the presence of several ingredients, most of which posses important antimicrobial properties (Botsoglou et al., 2003; Exarchou et al., 2002). Many studied claim that the phenolic compound in herb and spice significantly contributed to their properties (Hara-Kudo et al., 2004). Twenty-five extracts (accounting for 54% of the 46 test extract as 20 dietary spices and 26 medical herbs) reported by Shan et al. (2007) showed inhibitory activity against *S. anatum* (mean=7.2 mm; 4.7–19.2 mm) with correlate the content of phenolic compound at R^2 value of 0.86. Based on the results of chemical composition of the essential oil from *Zataria multiflora* Boiss, can also conclude that the anti-*S. typhi* ATCC 19430 nature of the essential oil studied is apparently related to its high phenolic contents, particularly carvacrol and thymol (Sharififar et al., 2007). Acidic environment enhanced the antibacterial activity of *Filipendula ulmaria* extract when it was tested against *S. enteritidis* PT4, which water-methanol extract from *F. ulmaria* contains a variety of phenolic compounds, such as caffeic, p-coumaric, vanillic acid and myricetin, etc, which demonstrate antibacterial activity (Boziaris et al.,2011).

Out of all the three solvent (hexane, dichloromethane and methanol) used for extract Mauritians flora, the methanol extracts showed relative good anti-bacterial activities, most particularly against *S. enteritidis* (Rangasamy et al., 2007). The aqueous extract of leaf of *Coccinia indica* could be used against *Salmonella*, while no activity was shown by solvent extract (ethanol, petroleum ether and chloroform) (Hussain et al., 2010). From twenty-two medicinal herb species traditionally used in Korea to treat gastrointestinal infections studied, only the aqueous and methanolic extracts of *Schizandrae fructus* exhibited

antibacterial activity against all three *Salmonella* serotypes (*S. typhi* ATCC 19943, S. *paratyphi* A and *S. gallinarum* ATCC 9184) (Lee et al., 2006).
In India, Mahida & Mohan (2007) described that the methanol *Manilkara hexandra*, *Wrightia tomentora* and *Xanthium strumarium* extracts displayed MIC value of 2 mg/mL for *S. paratyphi* A whereas the methanol *Schrebera swietenoiides* and *Wrightia tomentora* showed MIC value of 4 mg/mL for *S. typhi*. The result studied by N'guessan et al. (2007) showed bactericidal effect of the aqueous extract of *Thonningia sanguinea* for all the multiple drug resistance *Salmonella* strains (*S. typhi*, *S. hadar* and *S. typhimurium)* and sensitive tested strains (*S. enteritidis*). The *S. typhimurium* strain was also found to be sensitive to extracts of *Acacia nilotica*, *Syzygium aromaticum* and *Cinnamum zeylanicum*, in Khan et al. (2009). The petroleum ether extract of *Pedalium murex* Linn exhibits the activity at 300-500 mg/disc against the *S. paratyphi A* and at 500 mg/disc against the *S. paratyphi B* (Nalini et al., 2011). Furthermore, the root of the *Euphorbia balsamifera* has high activity against the *S. typhimurium* when compared with the leaves and stems extracts (Kamba & Hassa, 2010). In contrast, the extract of eucalyptus from root, leave and stem had exhibited activity against *S. typhi* (Evans et al., 2002).

7. *Salmonella* control in food product and food packaging by plant extract

Nowadays, the foodborne outbreaks *Salmonella* food poisoning and the prevalence of antibiotic resistant *Salmonella* in humans, animals and food are increasing (Rabsch et al., 2001; Angulo et al., 2000; O'Brien, 2002). Consumers are also concerned about the safety of food containing synthetic preservative. Therefore, there has been growing interesting in using natural antibacterial extract from herb or spice for food conservation (Smid & Gorris, 1999; Fasseas et al., 2008; Gutierrez et al., 2008). Particular interest has been focused on the potential application of plant extract or essential oils as safer additives for meat, poultry, milk, fruit and vegetable.
The combination of the oregano essential oil at 0.6% with nisin at 500 IU/g showed stronger antimicrobial activity against *S. enteritidis* in minced sheep meat than the oregano EO at 0.6% but lower than the combination with nisin at 1000 IU/g (Govaris et al., 2010). The minimum inhibitory concentration of the Capsicum extract to prevent the growth of *S. typhimurium* in minced beef was 1.5 mL/100 g of meat; the addition of 1%, 2%, 3% and 4% w/w of sodium chloride did not have any additional inhibitory effect on *Salmonella* (Careaga et al., 2003). Ravishankar et al. (2009) suggest that the food industry and consumers could use apple-based edible films containing cinnamaldehyde or carvacrol as wrappings to control surface contamination by foodborne pathogenic microorganisms, which at 23°C on chicken breasts, films with 3% antimicrobials showed the highest reductions (4.3 to 6.8 log cfu/g) of both *S. enterica* and *E. coli* O157:H7. Moreover, the lowest concentration of trans-cinnamaldehyde (10 mM) reducing *S. enteritidis* populations inoculated on chicken cecal contents by approximately 6.0 log(10) cfu/mL after 8 h and >8.0 log(10) cfu/mL after 24 h of incubation (Johny et al., 2010). The carvacrol vapour was effective at preventing growth of *Salmonella* on agar and in significantly reducing viable numbers on raw chicken at temperatures ranging from 4°C to 37 °C (Burt et al., 2007). The results by Shan et al. (2011) showed that the five spice and herb extracts (cinnamon stick, oregano, clove, pomegranate peel, and grape seed) were effective against *S. enterica* in cheese at room temperature (~23°C), which the clove showed the highest antibacterial activity.

Tornuk et al. (2011) indicated that the thyme hydrosol (contain carvacrol: 48.30% and thymol: 17.55%) was the most efficient agent on the carrot samples with resulted in 1.48 log cfu/g reduction in *S. typhimurium* number. The 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 (Trombetta et al., 2005). Both concentrations of carvacrol and trans-cinnamaldehyde, and 0.75% eugenol decreased *Salmonella* counts on tomatoes by ~6.0 log cfu/mL at 1 min (Mattson et al., 2011). Treatment of seeds at 50 degrees C for 12 h with acetic acid (100 and 300 mg/L of air) and thymol or cinnamic aldehyde (600 mg/L of air) significantly reduced *Salmonella* populations on seeds (>1.7 log10 cfu/g) without affecting germination percentage (Weissinger et al., 2001).

The use of edible films to release antimicrobial constituents in food packaging is a form of active packaging. Seydium & Sarikus (2006) reported that the whey protein based edible films containing oregano essential oil was the most effective against *S. enteritid*is (ATCC 13076), at 2% level than those containing garlic and rosemary extracts ($P < 0.05$). Incorporation of garlic oil up to 0.4% v/v in alginate film, the clear zone of inhibition was not observed with *S. typhimurium*. However, incorporation of garlic oil at higher than 0.1% v/v revealed a weak inhibitory effect, indicated by minimal growth underneath film discs (Pranoto et al., 2005).

8. Conclusion

Prevalence of *Salmonella* infection has increased markedly in both humans and domestic animals. Probably as a consequence of the extensive use of antibiotics surveillance networks have indicated that the incidence of human *Salmonella* food poisoning caused by antimicrobial resistant *Salmonella* is rising in many countries. In present, the anti-*Salmonella* spp. properties of plant extract/essential oils from a variety of plant have been assessed. It is clear from these studies that these secondary plant metabolites have potential as alternative antibacterial in food conservation. The phenolic compounds are most active and appear to act principally as membrane permeabilisers. In addition, consumers are also demand for food preservation from natural source. Therefore, the incorporating plant extracts in or onto food packaging materials to against foodborne pathogen, especially *Salmonella* spp., is of increasing interest.

9. Reference

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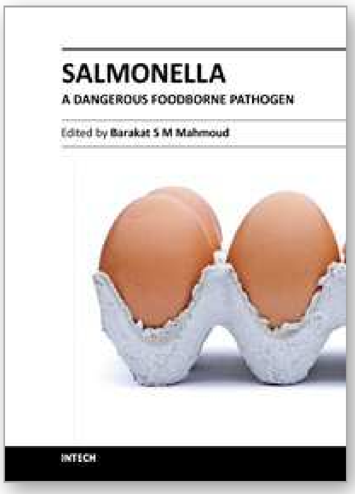

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More than 2,500 serotypes of Salmonella exist. However, only some of these serotypes have been frequently associated with food-borne illnesses. Salmonella is the second most dominant bacterial cause of food-borne gastroenteritis worldwide. Often, most people who suffer from Salmonella infections have temporary gastroenteritis, which usually does not require treatment. However, when infection becomes invasive, antimicrobial treatment is mandatory. Symptoms generally occur 8 to 72 hours after ingestion of the pathogen and can last 3 to 5 days. Children, the elderly, and immunocompromised individuals are the most susceptible to salmonellosis infections. The annual economic cost due to food-borne Salmonella infections in the United States alone is estimated at $2.4 billion, with an estimated 1.4 million cases of salmonellosis and more than 500 deaths annually. This book contains nineteen chapters which cover a range of different topics, such as the role of foods in Salmonella infections, food-borne outbreaks caused by Salmonella, biofilm formation, antimicrobial drug resistance of Salmonella isolates, methods for controlling Salmonella in food, and Salmonella isolation and identification methods.