2. LITERATURE REVIEW

2.1 Salmonella

2.1.1. Historical considerations

In the early 19th century, the association of human intestinal ulceration with a contagious agent was reported by clinical pathologists in France. The agent later was identified as typhoid fever. During the first 2 decades of the 20th century, a great step forward occurred with the serological detection of somatic and flagellar antigens within the *Salmonella* groups. An antigenic scheme for the classification of *Salmonellae* was first proposed by White (1926) and Kauffmann (1941); nowaday more than 2,500 serovars are included in the Kauffmann-White scheme (D' Aoust, 2001a).

2.1.2. Microbiology

Salmonella spp. is facultatively aerobic, gram negative rod-shaped bacteria belonging to the family *Enterobacteriaceae.* Most of the members of this genus are motile by peritrichous flagella except *Salmonella enterica* serovar Pullorum and *Salmonella enterica* serovar Gallinarum, and non-motile strains resulting from dysfunctional flagella (D' Aoust *et al*., 2001a).

Table 1: *Salmonella* species and subspecies (WHO, 2001)

***Salmonella* species and subspecies**	**No. of serotypes**
Salmonella enterica	2,480
S. enterica subspecies *enterica*	1,478
S. enterica subspecies *salamae*	498
S. enterica subspecies *Arizonae*	94
S. enterica subspecies *diarizonae*	327
S. enterica subspecies *houtenae*	71
S. enterica subspecies *indica*.	12
Salmonella bongori	21
TOTAL	**2,501**

Salmonellae are chemoorganotrophic, with the ability to metabolize nutrients by both respiratory and fermentative pathways (D' Aoust *et al*., 2001a). *Salmonella* grow at temperature of between 2 – 47 °C, with rapid growth occurring between 25 to 43 °C. The minimum temperature for growth prevails at neutral pH and increases sharply with increasing acidity or alkalinity of the suspending medium (D' Aoust, 2001b). The optimum pH for growing is between 6.5 and 7.5. At concentrations of ≥3% (w/v), NaCl generally inhibits the growth of Salmonellae (D' Aoust, 2001b).

Salmonella catabolizes D-glucose and other carbohydrates with the production of acid and gas. *Salmonella* are oxidase negative and catalase positive, grow on citrate as a sole carbon source, generally produce hydrogen sulfide, decarboxylate lysine and ornithine and do not hydrolyze urea. Many of these traits have formed the basis for the presumptive biochemical identification on Salmonella isolates (D' Aoust *et al*., 2001a).

2.1.3. Serotyping

Salmonella species are classified into serovars (serotypes) based on the lipopolysaccharide (O), flagellar protein (H), and sometimes the capsular (Vi) antigens. Within a serovar, there may be strains that differ in virulence.

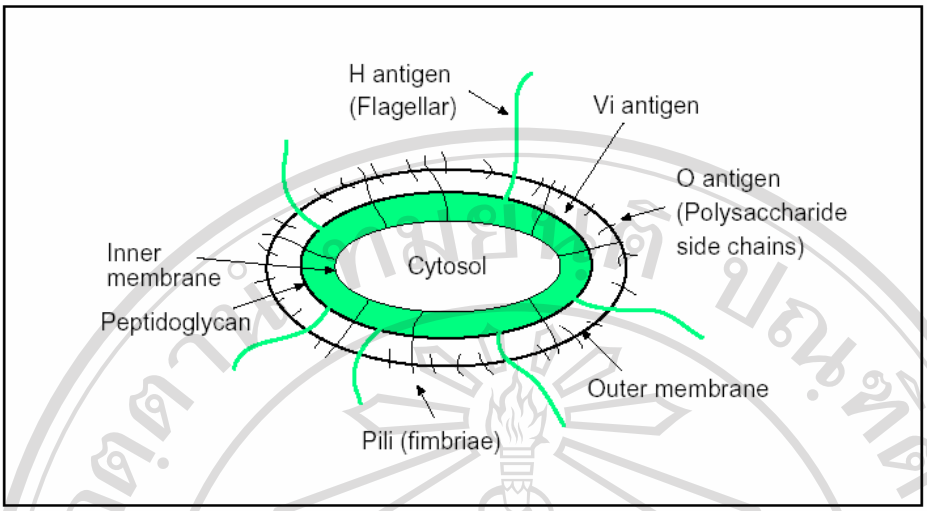


Figure 1. Schematic representation of the antigen structure of *Salmonella* Typhi showing the relative locations of O, H and Vi antigens (Axelsson and Sorin , 1997)

Based on the similarities in content of one or more O antigens, members of *Salmonella,* are placed in groups designated A, B, C and so on. Thus, *S.* Hirschfeldii, *S.* Choleraesuis, *S.* Oranienburg and *S.* Montevideo are placed in group C1 because they all have O antigens 6 and 7 in common. *S.* Newport is placed in group C2 due to its possession of O antigens K and 8. For further classification, the flagellar or H antigens are employed. These antigens are devided into 2 groups: specific phase or phase 1 and group phase or phase 2. Phase 1 antigens are shared with only a few other species or varieties of *Salmonella*; Phase 2 may be more widely distributed among several serotypes. Any given culture may consist of organisms in only one phase or of organisms in both flagellar phases. The H antigens of phase 1 are named with small letters, and those of phase 2 are designated by Arabic numerals. Thus, the complete antigenic analysis of *S.* Choleraesuis is as follow: 6, 6, c, 1, 5, where 6 and 7 refer to O antigens, c to phase 1 flagellar antigen and 1 and 5 to phase 2 flagellar antigens. (Table 2)

Table 2: Antigenic structure of some common Salmonellae. (Jay *et al*., 2005)

Group	**Serovars (serotypes)**	**O antigens***	**H antigens**	
			Phase 1	**Phase 2**
A	S. Paratyphi A	1, 2, 12	a	(1, 5)
B	S. Schottmuelleri	1, 4, (5), 12	b	1, 2
	S. Typhimurium	1, 4, (5), 12	i	1, 2
C1	S. Hirschfeldii	6, 7 (vi)	c	1, 5
	S. Choleraesuis	6, 7	(c)	1, 5
	S. Oranienburg	6, 7	m, t	-
	S. Montevideo	6, 7	g, m, s, (p)	(1, 2, 7)
C2	S. Newport	6, 8	e, h	1, 2
D	S. Typhi	9, 12, (Vi)	d	-
	S. Enteritidis	1, 9, 12	g, m	(1, 7)
	S. Gallinarum	1, 9, 12	-	-
E1	S. Anatum	3, 10	e, h	1, 6

***The italicized antigens are associated with phage conversion. () = May be absent.

2.2 Distribution of Salmonella in humans and pigs

Salmonella has been isolated from nearly all animal classes such as insects, reptiles, birds, mammals as well as from humans. The wide distribution of *Salmonella* reflects the flexibility of the bacterium to adapt to many different environments and therefore also its success as a multisource zoonotic agent for humans (Neilsen, 2004).

Salmonella multiply mainly in the intestine of animals. As intestinal forms, the organisms are excreted in faeces. Letellier *et al*. (1999) reported that *Salmonella* is a vertical contamination throughout the different production steps. The prevalence in pig production in Quebec, Canada, were replacement sow (15.9%) and finishing unit for gilts (21.9%). Kranker *et al*. (2003) studied the dynamics of *Salmonella*

Typhimurium in Danish Farrow-to-Finish Swine herds, there were no sows or piglets found shedding but some of them were seropositive. In addition the prevalence in culture peaked in the nursery and subsequently declined to undetectable levels before slaughter. The study of Korsak *et al*. (2003) in Belgium, demonstrated that in an integrated pig production system the percentage of *Salmonella* positive samples for pregnant sows (8.1%) was significantly higher than that for young and lactating sows (2.9%). In 2005, Nollet *et al*. (2005) reported that the prevalence of *Salmonella* excretion was <10% during gestation, around farrowing and during lactation, but a significant increase in the number of *Salmonella* excreting sows was found in some herds after weaning.

Patchanee *et al*. (2000) reported that the prevalence of *Salmonella* in pre-slaughter pigs in Chiang Mai was 69.5%. In comparison, Dorn-In (2005) reported that the prevalence of *Salmonella* in pre-slaughter pigs in Chiang Mai was 64.4% and 62.9% obtained from using sero-prevalence and faecal isolation respectively. For the serotypes, the most frequently found were *S*. Rissen (45.4%), *S.* Typhimurium (18.6%), *S.* Stanley (11.2%), *S*. Weltevreden (3.7%), *S.* Krefeld (3.1%), *S*. Anatum (2.4%) respectively.

2.3 Salmonellosis

2.3.1. Foodborne Salmonellosis

Salmonellosis is one of the main infectious causes of enteric disease in human being worldwide, and most cases are more likely to be related to food products of animal origin (Mejia *et al*., 2006).

The incubation period for *Salmonella* gastroenteritis is usually 12 hours to 3 days. Enteric fever usually appears after 7-28 days (D'Aoust *et al*., 2001a). Salmonellosis varies from a self-limiting gastroenteritis to septicemia. Clinical signs include diarrhea, nausea, abdominal pain, mild fever and chills. The diarrhea varies from a few thin vegetable-soup-like stools to a massive evacuation with

accompanying dehydration. Vomiting, prostration, anorexia, headache and malaise may also occur. The syndrome usually lasts for 2 to 7 days. Systemic infections sometimes occur, and usually involve the very young people, the elderly or the immuno-compromised. A fatal outcome is rare. Infected patients can excrete a large numbers of *Salmonella spp.* at the onset of illness and the number of the organism will decrease with the passing of time (Forshell and Wierup, 2006). Asymptomatic infections can also be seen.

In Canada, the three most frequently reported diseases were salmonellosis, campylobacteriosis and giardiasis. There were a total of 151 (31.3/100,000 person-years) reported cases of salmonellosis. Of these 151 cases, 22.5% (34) were related to travel, 26.5% (40) to outbreaks and 51% (77) were classified as endemic cases (16/100,000 person-years). Most endemic cases (61%) were reported from June to September 2005. Twenty-one serotypes were identified and the top three were S.*Typhimurium* (15), S.*Heidelberg* (10) and S.*Enteritidis* (6), which comprised 53% of serotyped isolates. The top three serotypes were S.*Typhimurium* (15), S.*Heidelberg* (10) and S.*Enteritidis* (6) (Public Health Agency of Canada, 2007).

In Thailand, The National *Salmonellas* and *Shigellas* Center of the national institute (Department of Medical Sciences, Ministry of Public Health; NSSC) has been working as the national reference laboratory for detection, identification and characterization *Salmonella* and *Shigella.* Parts of the annual reports for 2005 and 2006 are showed in table 3 and table 4.

Table 3: Top-ten *Salmonella* serovars from human sources in Thailand (2005)

Serovars	**Isolated**	**Percentage**
S.Stanley	456	12.43
S.Enteritidis	403	10.98
S.Weltevreden	331	9.02
S.Rissen	327	8.91
S.Corvallis	210	5.72
S.Cholerasuis	177	4.82
S.Anatum	176	4.8
S.Typhimurium	97	2.64
S.Virchow	84	2.29
S. I4,5,12:i:-	81	2.21
Others (106 serovars)	1327	36.17
Total	3669	100

(Source: http://narst.dmsc.moph.go.th/another/salmonella/Annual_Report_2005.pdf)

Table 4: Top-ten *Salmonella* serovars from human sources in Thailand (2006)

Serovars	**Isolated**	**Percentage**
S.Enteritidis	541	18.46
S.Stanley	313	10.68
S.Choleraesuis	233	7.95
S.Rissen	224	7.64
S.Weltevreden	202	6.89
S. I4,5,12:i:-	126	4.3
S.Corrallis	122	4.16
S.Anatum	113	3.86
S.Typhimurium	96	3.28
S.Kedougou	86	2.73
Others (93 serovars)	881	31.06
Total	2931	100

(Source: www.dmsc.moph.go.th/ifc_nih/applications/files/Annual_report_2006.pdf.)

2.3.2. Salmonellosis in animals

Salmonella can be found worldwide, although the distribution of serovars may vary. Salmonellosis seems to be more common where livestock are intensively farmed. Some *Salmonella* serotypes are relatively host-specific such as *Salmonella* Pullorum in poultry, *Salmonella* Dublin in cattle and *Salmonella* Cholerasuis in pig. On the other hand, some serotype has a comparatively wide host range for instance *Salmonella* Typhimurium.

In most food animal species, Salmonellae usually established a clinically inapparent infection of variable duration, which is significant as a potential zoonosis. However, under various stress conditions, serovars that are usually non-pathogenic may also cause disease in food animal species.

In pig, *S.*Choleraesuis was first isolated by Salmon and Smith (1886), when they considered it was the cause of swine fever (hog cholera). After viral aetiology of swine fever was discovered, *S.* Choleraesuis was recognized as a primary pathogen that could cause several different disease syndromes. Pigs are also susceptible to *S.* Typhimurium which may be the more important pathogen in many countries. A wide variety of serovars have been isolated from pigs and although they may occasionally cause disease. In general, infected pigs remain health carriers and as a consequence, are the public health importance. Furthermore, it has also an economic impact (Fedorka-Cray *et al*., 2000).

There is no data available to give a true prevalence of *Salmonella* in animal production or to provide true comparisons between countries. Existing data indicate that the herd prevalence depends on animal species and region. Interestingly, Sweden, Finland and Norway have achieved virtually *Salmonella*-free animal production as the result of an intervention strategy, implemented some time ago, which proposed zero tolerance for *Salmonella* (Forshell and Wierup, 2006).

The NSSC annual report 2005 and 2006 reported *Salmonella* serovars isolated from animals, shown in table 5 and table 6.

Table 5: Top-ten *Salmonella* serovars from animals in Thailand (2005)

Serovars	**Isolated**	**Percentage**
S.Rissen	129	25.34
S.Anatum	63	12.38
S.Stanley	59	11.59
S.Amsterdam	49	9.63
S.Weltereden	41	8.06
S.Enteritidis	21	4.13
S.I 4,12:i:-	18	3.54
S.Schwarzengrund	16	3.14
S.Altona	9	1.77
S.Kerefeld	8	1.57
Other	96	18.86
Total	509	100

(Source: http://narst.dmsc.moph.go.th/another/salmonella/Annual_Report_2005.pdf)

Table 6: Top-ten *Salmonella* serovars from animals in Thailand (2006)

Serovars	**Isolated**	**Percentage**
S.Weltevreden	148	19.12
S.Corvallis	33	13.15
S.Enteritidis	31	12.35
S.Newport	16	6.37
S.Stanley	14	5.58
S.Brunei	11	4.38
S.Typhimurium	9	3.59
S. Virchow	8	3.19
S. Javiana	8	3.19
S. Amsterdam	8	3.19
Other	65	25.9
Total	251	100

(Source: www.dmsc.moph.go.th/ifc_nih/applications/files/Annual_report_2006.pdf.)

2.4 Salmonella Detection

2.4.1. Cultural isolation

In order to detect the presence of *Salmonella* in the animal production and food processing industries, many new methods has been developed. Traditional culture methods may take 3-5 days to complete. However, the culture of *Salmonella* is the standard by which all other methods are measured. The sensitivity of the culture method may also be affected by the phase of the infection. A large number of *Salmonella* are shed in the feces of acute Salmonellosis, while a low number of *Salmonella* are intermittently excreted in chronically infected pig or a carrier. Thus for clinical samples culture may suffice, whereas samples from chronically infected pigs or from the environment will almost certainly require pre-enrichment and selective enrichment (Wray, 2001).

2.4.2. Serological method; Enzyme linked immunosorbent assays

Enzyme linked immunosorbent assays (ELISA) can be used to detect either the organism or a humeral immune response to the organism. Since culture may take 3-7 days to identify the organism, ELISA can detect the organism in a much shorter period of time, usually one day or less. The detection of antibodies to the O antigen of *Salmonella* has been used successfully in pigs (Neilson *et al*., 1994). The antibody ELISA using mixed purified lipopolysaccharide (LPS) from both S.Choleraesuis and S.Typhimurium has been used for routine screening in breeding, multiplying and slaughtering herds in Denmark since 1993 (Neilsen *et al*., 1995). For screening purposes, serological testing provides an indication of exposure to *Salmonella* (Lo Fo Wong *et al*., 2003).

2.4.3. Molecularbiological method; Polymerase Chain Reaction

The extraordinary ability of the polymerase chain reaction (PCR) to exponentially replicate a target DNA sequence has made it a very powerful tool in the armamentarium of the diagnostician, epidemiologist and molecular biologist. This assay is based on the ability of target (organism) specific primers which, through complementary DNA base-pairing, anneal only to the target sequence. Thermostable DNA polymerase recognizes the template primer complex as a substrate which results in the simultaneous copying of both strands of the segment of DNA between the two annealed primers. The denaturation annealing and elongation steps take place in a cyclical fashion relying on the thermostability of the Tag-polymerase until the target sequence is amplified to detectable amounts (Ehrlich and Sirko, 1994).

2.5 Public health and *Salmonella*

Consumers may suffer food poisoning or acquire infection with *Salmonellas* some of which may be antibiotic resistant. It is important to reduce this hazard at all steps in the production and preparation of food. In order to prevent negative consequences of *Salmonella* contaminated pork, the control of *Salmonella* is

necessary. The whole pork production chain should be free from Salmonella, including the pigs at the farm.

Food safety assurance strategies can be implemented at all levels of food production (i.e. pre-harvest, post-harvest, processing, retail). Monitoring, prevention and control efforts at the pre-harvest level are important elements of food safety assurance strategies to prevent or reduce the transmission at the harvest level of pork production (Mousing *et al*., 1997).

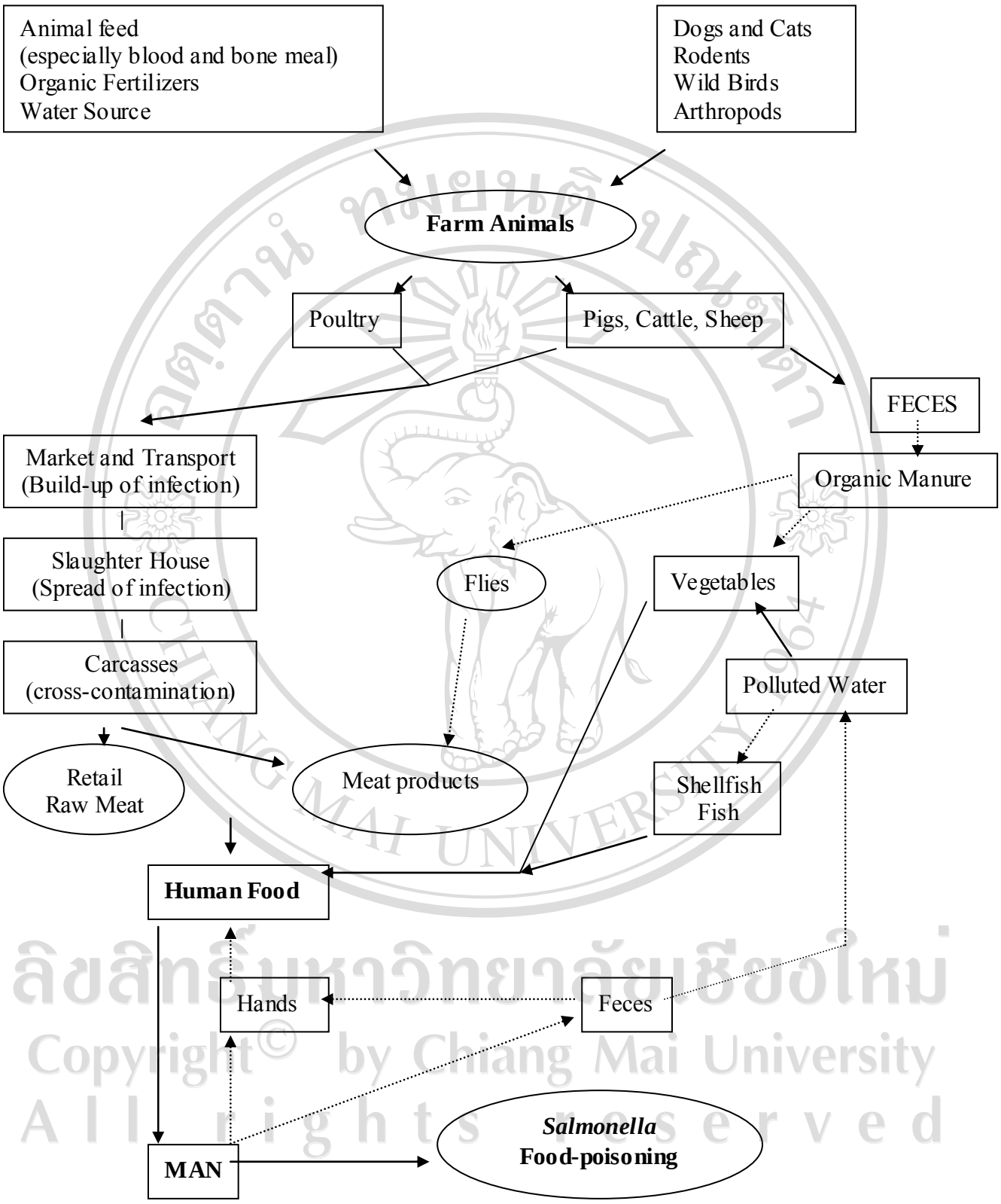
Several studies showed that the implementation of preventive measures could reduce the prevalence contamination level. In 1998, The Netherlands was able control effectively *Salmonella* in pig and pork by codes of good manufacturing practices (GMP) from farm to cutting/retail, which could reduce the levels of *Salmonella*-positive pigs and pork by 50-60%. Moreover, for specific pathogen-free (SPF) pigs, GPM could reduce the *Salmonella* prevalence by 95% (Berends *et al*, 1998).

In Canada, Public Health Agency of Canada had introduced C-EnterNet, a multi-partner initiative facilitated by the Public Health Agency of Canada and funded by Agriculture and Agri-Food Canada through the Agricultural Policy Framework initiative for supporting activities that will reduce the burden of enteric (gastrointestinal) diseases, by comprehensive sentinel site surveillance implemented though local public health units (Public Health Agency of Canada, 2007).

In order to avoid any major risk, many countries now impose regulations that require producers, processors and distributors of foodstuffs to set up more frequent and efficient testing plans for the systematic control of at-risk products.

2.6 The Pork production chain and *Salmonella* contamination

Salmonella infections in pigs are of particular epidemiological importance because infected animals may either periodically or temporarily shed bacteria when they are under stressful conditions (e.g. transportation, starvation). Most of *Salmonella* infected pigs are inappearent or non-visibly infected which poses a serious food hygiene problem (Figure 2).



Source: Quinn et al. (1999)

Figure 2: Spread of *Salmonella* and sources of contamination for human food

The main factors influencing Salmonella contamination of finishing pigs reported are

2.6.1. Level of hygiene

2.6.1.1 Controlling for birds, flies and rodents (Letellier et al., 1999)

While Rodents and wildlife are known as vector for *Salmonella*, flies may be involved in the dissemination of *Salmonella* in the environment as carrier of microorganisms because flies were positive for *Salmonella* on the highly contaminated farms. Letellier et al. (1999) suggested that disposal of dead animals in specific sites with no risk of premise recontamination is an important feature of a biosafety program. In addition, disinfection combined with implementation of strict sanitary measures and control of rodents and flies on the farm are indicated in order to reduce contamination by *Salmonella*.

2.6.1.2 Handling the manure (Davies et al., 1997)

An all-in/all-out management of barns with open-flush gutters flushed with recycled effluent should not be expected to be highly effective with respect to control of enteric organisms, assuming survival pathogens in the recycled effluent. Although exposure to recycled effluent may not directly lead to high prevalence of infection, it is a likely source of infection and open-flush gutters may facilitate transmission within and among pens.

2.6.2. Herd management

2.6.2.1 Size of herd (van der Wolf et al., 2001a)

Herds with a small to moderate herd size (less than 800 finishers) were associated to higher *Salmonella* seroprevalence than herds that were larger, perhaps due to the fact that larger farms are more hygiene-concious than smaller farms.

2.6.2.2 Production system (free range or intensive systems) (van der Wolf et al., 2001b)

The prevalence of *Salmonella* in free range finishers was higher than in intensively housed finishers.

2.6.2.3 Housing (type of floor) (Nollet et al., 2004)

The type of flooring was related significantly to the prevalence. The lower the prevalence of *Salmonella*, the higher the percentage of slatted floors in the pig houses.

2.6.3. Feeding practices

2.6.3.1 Groundness and pH of feed (van der Wolf et al., 2001a; Sauli et al., 2005)

The groundness and pH of feed were related to the level of *Salmonella* contamination. Non-pelleted feed can be considered a protective factor with regard to *Salmonella* infection. The addition of organic acids was shown to enhance the destruction of *Salmonella* during heat treatment.

2.6.3.2 Types of feeding (wet versus dry) (Leontides et al., 2003)

Pigs fed non-pelleted dry or wet ration had 11 and 9 times respectively lower odds of seropositivity than those fed pelleted ration.

2.6.3.3 Feed additives (Potassium diformate; KDF) (Papenbrock et al., 2005)

The combination of a coarse grinding of the main ingredients (cereals) and a KDF was addition able to reduce *Salmonella* shedding and duration of *Salmonella* excretion in infected piglets.

2.6.4. Health disorders

2.6.4.1 Parasite infestation (van der Wolf et al., 2001a; Steenhard et al., 2002)

Pigs with dual infections of nematodes and bacteria excreted significantly higher amounts of *Salmonella* Typhimurium in feces, compared with nematode-free pigs.

2.6.4.2 Use of antibiotics (Leontides et al., 2003)

The prolonged feeding of antibiotics for growth promotion appears not only to influence the resistance patterns of *Salmonella* but also to adversely affect the resistance of the pigs' intestine to colonization.

2.6.4.3 Health status of the herd (Oliveira et al., 2005)

The prevalence of *Salmonella* Typhimurium at slaughter might be high if pigs originate from a batch previously affected by Salmonella–enterocolitis outbreak at the pre-harvest pork production chain.

There are other factors reported in the literature such as various concurrent infections e.g. *Lawsonia intracellularis* or porcine reproductive and respiratory syndrome virus (PRRSV) (Beloeil et al., 2004). So, pre-harvest control could play a critical role in reducing *Salmonella* in the pork production chain.

2.7 Control of *Salmonella* in pigs

In general, the control of Salmonella is based upon the implementation of preventive actions throughout the whole production chain. More specifically, measures should be addressed to (i) the prevention of introduction of Salmonella into the herd, (ii) the prevention of in-herd transmission, and (iii) the increase of the resistance to the infection.

In 1980, the World Health Organisation (WHO) had already formulated 3 lines of defence against *Salmonella* which approaches to risk mitigation.

- the first line focuses on the control of Salmonella in the food producing animal (Pre-harvest control)
- the second line deals with improvement of hygiene during slaughter and further processing of meat (Harvest control)
- the third line concentrates on measures during the final preparation of the food and the education of the industry and the consumer concerning the application of effective hygienic measures (Post-harvest control).

In 1992, the European Union adopted a directive to monitor and control *Salmonella* infections in breeding flocks of domestic fowl (Council Directive 92/117/EC of 17 December 1992), as a consequence the committee recommended to improve the existing control systems for specific zoonotic agents. In November 2003, the following legislation was implemented for

- The monitoring of zoonoses: Directive 2003/99/EC of the European Parliament and of the Council of 17 November 2003 on the monitoring of zoonoses and zoonotic agents, amending Council Decision 90/424/EEC and repealing Council Directive 92/117/EC, replacing the monitoring and data collection systems established by Directive 92/117/EEC

- The control of zoonoses: Regulation (EC) No 2160/2003 of the European Parliament and of the council of 17 November 2003 on the control of *Salmonella* and other specified food-borne zoonotic agents.

According to European Regulation (EC) 2160/2003, *Salmonella* contamination rate of less than 1 bacterium per 25 grams is a condition in fresh meat. This intentionally means a total absence of the organism in practice. Furthermore, it is not only the presence of *S.*Typhimurium or *S.*Enteritidis, but also the presence of any type of *Salmonella* is not desirable.

The European Food Safety Authority (EFSA) was established by the European Parliament in 2002 following a series of food scares in the 1990s (BSE, dioxins….) which undermined consumer confidence in the safety of the food chain. In 2006, the European Commission required EFSA for quantitatively assess the public health risks of *Salmonella* in pigs. The work will consist of a Quantitative Microbiological Risk Assessment (QMRA), which provides a quantitative estimate of the existing risk factors and likely effects of proposed measures to reduce those factors. Analyses include an assessment of the sources of infection for slaughter pigs at farm level, the impact of slaughter processes on contamination of pig carcasses and the expected effect of reducing *Salmonella* in slaughter pigs on *Salmonella* prevalence in pig meat and *Salmonella* food poisoning cases in people (EFSA, 2007).

Ministry of Agriculture, Fisheries and Food Scottish Executive Rural Affairs department launched a Code of Practice for the prevention and of *Salmonella* on pig farms. This voluntary code of practice has been drawn up in consultation with the National Assembly of Wales, Food Standard Agency, National Pig Association, the Meat and Livestock Commission and the Pig Veterinary Society. In short, 10 Salmonella control points were determined (unit, stock, staff, pest control, visitors, feed, bedding, water, animal waste and equipment) and 2 conditions (keeping *Salmonella* out of farm and controlling the spread of *Salmonella*) which was to be considered as a guideline for controlling *Salmonella* (DEFRA, 2007).

To prevent the *Salmonella* carrier-state in pigs, new intervention strategies need to be investigated. Competitive exclusion, a normal intestinal flora protects the host against pathogens, is one approach which has been use successfully with poultry (Bailey and Line, 2001). The use of competitive exclusion has also been reported to give positive result for controlling *Salmonella* in pigs (Genovese *et al*., 2003).

The use of vaccines should be considered as one of measures to control *Salmonella* on the farm. Since most of *Salmonella* infections are sub-clinical, the use of vaccines will reduce *Salmonella* shedding in carrier pig (Wray, 2001). The ideal vaccine against *S*.Typhimurium prevent

-colonization

-shedding of *Salmonella* bacteria in the environment

-the development of carriers

-clinical Salmonellosis and promotes elimination of *Salmonella* bacteria from the infected porcine host

Considering a protection against *Salmonella* infections, live vaccines strains are better than inactivated vaccines strains, probably due to cellular immune response and induction of mucosal I_gA production (Haesebroick *et al*., 2004).

In early 2006, the Agricultural Research Service (ARS) under the United States Department of Agriculture (USDA) and Iowa State University conducted a research project of Genetic profiling of Salmonella-carrier pigs to improve food safety and decrease pre-harvest disease. Due to Salmonella-carrier pigs are difficult to identify and serve as a major food safety problem through the contamination within herd as well as slaughter plant facilities. Characterizing the gene expression of swine that are naturally resistant to *Salmonella* may identify polymorphic traits that reduce colonization. This information could be useful not only to identify potential Salmonella-shedders within swine herds, but also to breed a *Salmonella*-resistant line of pigs (ARS, 2007).