Literature Reviews

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Salmonella spp. in the pork supply chain: a risk approach¤

Salmonella spp. en la cadena de producción porcícola: un enfoque de riesgo

Salmonella spp. na cadeia de produção de carne de porco: uma abordagem de risco

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Summary

The genus *Salmonella* contains approximately 2,579 serovars, most of which are zoonotic and transmitted by foods of animal origin, such as fresh pork and further processed by-products. Non-typhoid salmonellosis in humans manifests as gastroenteritis, septicemia, or can be asymptomatic during the carrier state. *Salmonella* spp. has a considerable impact in the pork industry due to economic losses resulting from diagnosis, treatment, reduced production, and because this pathogen constitutes a non-tariff barrier to food trade and a serious public health problem. The microorganism is usually introduced to farms through incoming breeding stock or pig feed and is subsequently spread by sick animals or asymptomatic carriers. Infection and/or dissemination of the microorganism may increase particularly during pre-slaughtering due to contaminated trucks, long periods of time spent in transit, stress during handling and fasting, or high animal density or time spent in corrals. Contamination during slaughtering is commonly associated with carcass de-hairing and polishing, evisceration and rectum separation, or from *Salmonella* present in skin, oral cavity, feces or lymphatic nodes. Pork contamination may also occur through contact with equipment or tools, handling, storage, or improper preservation during slaughter, post-slaughter, marketing, sale, or consumption. For this reason, *Salmonella* control, with a focus on the supply chain and risk assessment is fundamental for guaranteeing quality and food safety of pork products in Colombia, thereby contributing to public health and improving competitiveness. Studies directed at establishing baselines for the disease and the microorganism in each of the stages of the supply chain should be conducted, including identification of differential risks and establishing measures for monitoring, prevention and control.

Key words: *cross-contamination, farm, pigs, pork, slaughter.*

Resumen

El género *Salmonella* agrupa alrededor de 2.579 serovariedades, en su mayoría zoonóticas, transmitidas por alimentos de origen animal, como la carne de cerdo y sus derivados. La salmonelosis no tifoidea en humanos

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puede manifestarse como gastroenteritis, septicemia o estado portador asintomático. La presencia de *Salmonella* spp. es de gran impacto para la industria porcícola, por las pérdidas económicas por diagnóstico, tratamiento y disminución de la producción, y por constituir una barrera no arancelaria para la comercialización de alimentos y un grave problema de salud pública. El microorganismo se introduce en las granjas a través del alimento, el pie de cría o los cerdos para levante, y se disemina a través de enfermos o portadores asintomáticos. En el prebeneficio la contaminación de camiones, el tiempo de transporte, el estrés por manipulación, el ayuno, la alta densidad animal, y la permanencia en corrales pueden incrementar la infección y/o diseminación del microorganismo. Durante el beneficio la contaminación se asocia al depilado, pulido de los animales, a la evisceración y corte de recto o a la presencia del microorganismo en piel, cavidad bucal, heces o ganglios linfáticos. La contaminación de la carne también puede ocurrir por contacto con equipos o utensilios, por manipulación, almacenamiento o conservación inapropiada de los productos en etapas del beneficio, posbeneficio, comercialización, venta o consumo. Por tal razón el control de *Salmonella* bajo un enfoque de cadena productiva y evaluación de riesgo es un aspecto fundamental para garantizar la calidad y la inocuidad de los alimentos de origen porcino en Colombia, contribuyendo a la salud pública y a mejorar la competitividad de la cadena. Se deben realizar estudios orientados a establecer las líneas base de la enfermedad y del microorganismo en cada una de las etapas, identificando el riesgo diferencial y estableciendo medidas de monitoreo, prevención y control.

Palabras clave: *carne, cerdo, contaminación cruzada, faenado, granja.*

Resumo

O gênero *Salmonella* agrupa ao redor de 2579 sorovariedades, a maioria delas zoonóticas, transmitidas por alimentos de origem animal, como a carne suína e seus derivados. Em humanos, a salmonelose não tifoide pode se manifestar como gastroenterite, septicemia ou pode ser assintomática. A presença de *Salmonella spp*. é de grande impacto na indústria produtora de carne suína pelas perdas econômicas por diagnóstico, tratamento e diminuição da produção. Esta doença constitui também uma barreira não alfandegária para a comercialização de alimentos, sendo também um grave problema de saúde pública. O microrganismo é introduzido nas granjas pelas matrizes e reprodutores, animais na fase de crescimento ou a través do alimento. Tanto os animais doentes quanto os portadores assintomáticos podem ser fontes de contaminação. Na fase prévia ao abate podem ser citados alguns fatores que podem favorecer a infecção e disseminação do microrganismo: contaminação dos caminhões somado ao tempo de transporte em veículos com alta densidade animal, jejum e estresse. Durante o processamento da carcaça, a contaminação está associada à depilação e polimento dos animais, assim como evisceração, presença de microrganismos na pele, cavidade oral, ampola retal, fezes ou linfonodos. A contaminação da carne pode acontecer pelo contato com equipamentos ou implementos, manuseio, armazenamento e conservação inadequada dos produtos nas etapas do abate e após do abate, comercialização, venda ou consumo. Diante do anteriormente exposto, na Colômbia é de fundamental importância direcionar o controle da *Salmonella* considerando um enfoque abrangente da cadeia produtiva, incluindo a avaliação do risco. Este enfoque permitirá garantir a qualidade e inocuidade dos alimentos de origem suíno, redundado em benefícios para a saúde pública e o aprimoramento da competitividade da cadeia. Devem ser realizados estudos orientados ao estabelecimento dos indicadores da presença e impacto da doença em cada uma das etapas produtivas, identificando o risco diferencial, para sentar as bases de medidas de monitoramento, prevenção e controle.

Palavras chave: *abate, carne suína, contaminação cruzada, granjas.*

Introduction

Foodborne disease can be caused by a wide variety of biological, chemical and physical hazards (CDC, 2007). The main cause of foodborne diseases of bacterial origin is *Salmonella* spp., *E. coli* O157:H7, *Campylobacter* spp., among others (Swartz, 2002; CDC, 2005).

Prevention and control of pathogens that cause foodborne diseases should take place in each stage of the supply chain; that is, all actors should guarantee food safety according to the concept of ''*stable-to-table*'' or ''*farm-to-fork*'', preventing or controlling infection and/or contamination to protect the health of the consumer.

Non-typhoid serovars of *Salmonella* spp. decrease pig production yield and increase production costs. Contaminated finished products (carcass, fresh pork and further processed by-products) are considered a public health risk and are restricted for international trade (non-tariff barrier), affecting the industry competitiveness. The negative impact of Salmonellosis in humans is related to diagnostic, treatment, cost of cases and outbreaks, and reduced productivity due to absence from work.

Salmonella control has a high impact in Colombia's pork industry, which has shown growth within the national economy (DANE, 2003). Productivity of this sector has significantly improved in the last fifteen years (DNP, 2007; MADR, 2005; FAOSTAT, 2010). Although Colombia's per capita pork consumption is low compared with the world's average (16 Kg), it increased from 2.9 Kg in 2002 to 5.9 Kg in 2012. The total slaughter for that year was 2,939,181 pigs, which is 6.6% higher than the previous year (Asoporcicultores, 2009 – 2013).

This review discusses *Salmonella* focusing on the supply chain. Colombian law regulated the supply chain in this country in 2003. It was stated that the primary production sector should set up monitoring, prevention and control programs. The harvest (slaughter) and postharvest (deboning and meat products) should implement specific control measures regarding quality concepts and food safety. In pre-slaughter, pigs may become infected during the lairage and the carcass may become contaminated in different stages of the slaughter process. Unsuitable manipulation and cross contamination are the main sources of contamination risk during deboning.

Salmonella general characteristics

The genus *Salmonella* spp. comprises gram-negative coccobacilli of the *Enterobacteriaceae* family, which are flagellated, non-spore forming, and facultative anaerobes. The pathogen can be found in the gastrointestinal tract of homeothermic and poikilothermic animals. This microorganism grows at temperatures between 6 °C and 45 °C and can survive freezing and drying, and persists even for years in organic substrates. They are inactivated by heat, direct sunlight, and disinfectants such as phenols, chlorates and iodines (Schwartz, 1999; Grimont *et al*., 2000).

The genus *Salmonella* includes two species: *S. enterica* (pathogenic) and *S. bongori,* (considered non-pathogenic). The first of these species comprises six subspecies designated by Roman numerals or numbers where I. is *Salmonella enterica* subspecies *enterica*, II. *S. enterica* subsp. *salamae*, IIIa. *S. enterica* subsp. *arizonae*, IIIb. *S. enterica* subsp. *diarizonae*, IV. *S. enterica* subsp. *houtenae* and VI. *S. enterica* subsp. *indica*. For nomenclature purposes, serovars may be designated only by genus and serovar. For example, *Salmonella enterica* subspecies *enterica* serovar Typhimurium may be designated as *Salmonella* Typhimurium (Brenner *et al*., 2000; Heyndrickx *et al*., 2005).

The WHO Collaborating Center for Reference and Research on *Salmonella*'s last report generated by the Pasteur Institute in 2007 includes 2,579 *Salmonella* spp. serovars in a broad range of hosts (Grimont and Weill, 2007). Certain serovars are better adapted to a single host, as in the case of typhoidal *S.* Typhi and *S.* Paratyphi in humans, and non-typhoidals, such as *S.* Dublin in cattle, *S.* Enteritidis in poultry, and *S.* Choleraesuis in swine. These serovars may be opportunistic in other species. In this regard, pigs may be infected by a broad range of non-typhoid serovars, constituting a source of contamination for pork (Schwartz, 1999).

Salmonellosis in humans

Non-typhoid salmonellosis in humans may manifest as gastroenteritis, bacteremia or a carrier state. The main signs are nausea, vomit, and light to moderate diarrhea. Among the non-typhoid serovars involved are *S.* Enteritidis, *S.* Typhimurium, *S.* Newport, *S.* Hadar, *S.* Derby, *S.* Heidelberg, *S.* Agona, *S.* Infantis and, on rare occasions, *S.* Choleraesuis (Gebreyes *et al*., 2004; Boyle *et al*., 2007; Foley *et al*., 2008; Schwartz, 1999). Mortality is lower than 1%, and usually occurs in children younger than five years old, older adults or immuno-compromised people (CDC, 2006). For *Salmonella* Choleraesuis, mortality may exceed 20% (CFSPH, 2005), although there is

little association with contamination of carcasses and pork products (Schwartz, 1999).

Greig and Ravel (2009) estimated a worldwide association of 41.3% of foodborne disease with pork products consumption. Association between 5% and 25% of human salmonellosis cases with pork consumption has been reported in Europe and the United States (Borch *et al*., 1996; Berends *et al*., 1998; Lo Fo Wong *et al*., 2002; Hald *et al*., 2003; Wegener *et al*., 2003; CDC, 2005). One study showed that an average of 80.3 million cases occur globally each year, with 155,000 deaths, and incidence is 1,140 cases per 100,000 people (Majowicz *et al*., 2010).

Studies performed in recent years have estimated salmonellosis rates (per 100,000 people) of up to 23 in European countries, 17.7 to 28.1 in the United States (Swartz, 2002), 12.7 in Asia, 17.2 in Brazil (Helms *et al*., 2005) and almost 200 in Mexico (Gutiérrez-Cogco, Montiel-Vázquez *et al*., 2000). In general, it is thought that 22% of patients with salmonellosis are hospitalized and per each reported case there may be 38 unreported cases (Mead *et al*., 1999).

In the United States, the annual economic impact of the disease is estimated to be US $365 million in direct medical costs (CDC, 2011) and in US $3.3 billion in illness costs (Batz *et al*., 2011).

Salmonellosis in pigs

In pigs, the disease generates economic losses represented by morbidity and mortality, increase in the time needed to reach slaughter weight (90 Kg to 95 Kg), non-uniform batches, diagnostic expenditures and medications. In addition, the microorganism may persist in the farm environment due to continuous transmission between animals of all age groups (Schwartz, 1999). Regarding international trade, the presence of the microorganism represents a non-tariff barrier that restricts proper marketing and/or negotiation of pork products (Davies, 1997).

Salmonellosis is caused by numerous serovars, including Choleraesuis, Typhimurium, Derby, Saint Paul, Infantis, Heidelberg and Agona (Schwartz, 1999). The first serovar has been related primarily to septicemia in pigs (Gray *et al*., 1996; Chiu *et al*., 2004), while *S*. Typhimurium can cause enteritis, although it may also manifest in septicemia (Fedorka-Cray *et al*., 2000; Rostagno *et al*., 2003).

Salmonella spp. in farms

Most infected animals are asymptomatic carriers of various serovars (Giovannacci *et al*., 2001; Lo Fo Wong *et al*., 2002), meaning that the microorganisms may be transmitted constantly, thus making its control difficult and representing a potential source of indirect contamination of pork and pork products (Schwartz, 1999).

Between 30% and 60% of farms in the United States may be infected with at least one *Salmonella* serovar (Schwartz, 1999). In Canada, 83.3% of farms were reported positive, with 13.2% of pigs infected (Rajic *et al*., 2007).

Epidemiology focuses on microorganism introduction into the farm and transmission within the farm (Lo Fo Wong *et al*., 2002). The most important sources of infection are breeding stock and other pigs entering from other farms, followed by feed (Fedorka-Cray *et al*., 1997; Sauli *et al*., 2005; Österberg *et al*., 2010), water (Davies *et al*., 2004; Jensen *et al*., 2006), and other animals such as bovines, rodents, birds, insects, and pets (Fedorka-Cray *et al*., 2000; Hurd *et al*., 2002, Langvad *et al*., 2006; Fosse *et al*., 2009). The most important source of infection is the asymptomatic carrier pig (Schwartz, 1999), with fecal-oral route being the main form of transmission (Schwartz, 1999; Fedorka-Cray *et al*., 2000). *S*. Typhimurium has been isolated in feces up to 5 weeks after nose-nose contact with infected pigs (Proux *et al*., 2001).

Infection occurs rather quickly; *Salmonella* Typhimurium at a concentration of 1.5 x 10^3 UFC in feces can invade the gastrointestinal tract and the lymphatic nodes associated with the intestine (GALT: gut-associated lymphoid tissue) of exposed pigs in as little as 2 hours (Boughton *et al*., 2007). Three hours after experimental nasal inoculation, *S*. Typhimurium was detected in the cecum, and it was detected in

mesenteric lymph nodes and tonsils after 6 hours (Fedorka-Cray *et al*., 1995).

The main source of contamination in slaughterhouses is pigs from infected farms. However, the microorganism's ability to quickly infect animals allows for infection during transport and/or lairage.

Salmonella spp. can persist in the intestinal mucosa, mesenteric lymphatic nodes or tonsils (Berends *et al*., 1998; Vieira-Pinto *et al*., 2005, Methner *et al*., 2011). In studies of groups of pigs, researchers isolated *S.* Typhimurium daily from feces during the 10 days post-infection and frequently during the following 4 to 5 months. At 5 to 7 months, approximately 90% of pigs were positive for the microorganism in mesenteric lymph nodes, tonsils, cecum or feces (Dickson *et al*., 2002; Jensen *et al*., 2006). *S.* Newport was isolated from mesenteric lymph nodes for up to 28 weeks and *S.* Choleraesuis for at least 12 weeks (Gray *et al*., 1995). In moist feces, this microorganism survives for 3 months, and in dry feces between 6 and 13 months (Schwartz, 1999; Dickson *et al*., 2002). *S.* Typhimurium and *S.* Dublin were isolated after almost a year in a moist and warm environment (CFSPH, 2005).

Pigs can acquire the carrier state with 10^4 CFU of *S.* Typhimurium (Dickson *et al*., 2002), and with 10^8 CFU, pigs may develop persistent infection lasting 12 weeks (Fedorka-Cray *et al*., 1995). Ingestion of more than 10^3 CFU of *Salmonella* per gram of feces may cause acute infection in pigs (Loynachan and Harris, 2005). Pigs can excrete 10^6 *S.* Choleraesuis/g of feces or 10^7 in the case of *S*. Typhimurium (Wood and Rose, 1992; Schwartz, 1999).

Salmonella spp. in pre-slaughter

Transportation time, stress due to handling, fasting, high animal density, environmental contamination, social regrouping, and time spent in pre-slaughter pens (lairage) can increase infection and/or dissemination of the microorganism among pig batches (Lo Fo Wong *et al*., 2002, Bolton *et al*., 2013, Kich *et al*., 2011, Hernández *et al*., 2013).

Contamination of trucks and pens during and after pig transport increases the probability of infection (Hurd *et al*., 2002; Mannion *et al*., 2008 and 2011; Swanenburg *et al*., 2001, Lo Fo Wong *et al*., 2002, Oliveira *et al*., 2005). The longer the pigs remain in lairage, the greater the risk of infection. Accordingly, one strategy could be to reduce lairage time. However, it is necessary for the pigs to rest for at least 2 hours to avoid affecting the organoleptic quality of pork.

More than twenty years ago, it was shown that infection prevalence could increase by 50% for every 24 hours spent in the pen (Morgan *et al*., 1987). In recent studies, prevalence increased 3 to 10 times for slaughtering plant samples in comparison to those taken at the farm. Also, additional serovars were recovered from plant samples, suggesting the existence of infection sources external to the farm (Berends *et al*., 1996; Hurd *et al*., 2001; Hurd *et al*., 2002) whereby these findings have been linked to the lairage (Boyen *et al*., 2008). Beloeil *et al*. (2004) reported that risk was four times greater when the microorganism was isolated from the cecum of pigs that remained for more than 6 hours in the pens compared to those that remained less than 6 hours.

Contamination with *S. enterica* has been found in lairage and drinking water offered to pigs (Rostagno *et al*., 2003; Hurd *et al*., 2002; Arguello *et al*., 2012). In one study, among the sampled pens, there was at least one positive sample; all pig groups tested positive for *S. enterica* in ileocecal lymph nodes and cecal contents. From 586 pigs, truck, and pen isolations, 36 different *Salmonella* spp. serovars were isolated. From 353 isolations in pigs (109 of ileocecal lymph nodes and 244 of cecal nodes), 27% corresponded to the same serovars isolated in the trucks, and 19% were related to those from pens (Rostagno *et al*., 2003).

With regard to stress, when animals are transported in trucks for 2 to 4 hours, increased levels of circulating cortisol or beta-endorphins and neutrophils are found (McGlone *et al*., 1993; Geverink *et al*., 1998). Stress may influence the outcome of many bacterial infections. Exposure to various stressors increases fecal shedding of these pathogens. Theoretically, the relationship between animal welfare and food safety is an effect that should not be overlooked (Verbrugghe *et al*., 2012).

Salmonella spp. at slaughter

Pigs can carry the microorganism in their skin, oral cavity, feces or lymph nodes (Lo Fo Wong *et al*., 2002), meaning that cross-contamination of carcasses occurs mainly through bacteria redistribution originating from positive pigs during the various slaughter stages (Berends *et al*., 1997; Botteldoorn *et al*., 2004; Busser *et al*., 2011).

In the initial stage of the process, during scalding, water can enter the lungs and contaminate the oral cavity and the pharynx; later, during the removal of the lungs, this liquid can contaminate the carcass. The dehairing equipment can continuously become contaminated with feces due to the movement of the pigs by the equipment. After flaming and during polishing, knives may favor distribution of microorganisms that were not eliminated by flaming. Additionally, knives may become contaminated if left undisinfected between carcasses. Contact of gastric contents with abdominal and thoracic cavities should be avoided during evisceration. The highest risk of contamination occurs upon separating the rectum and removing the viscera which may be perforated, their contents being able to contaminate the carcass, utensils and/or gloves of the workers (Borch *et al*., 1996; Fedorka-Cray *et al*., 2000; van Hoek *et al*., 2012).

With regard to carcass contamination, 5 to 15% occur during polishing, 55 to 90% during removal of viscera and 5 to 35% during other processes, such as rectum separation, ventral opening of the carcass, and meat inspection (Hald *et al*., 2003; Botteldoorn *et al*., 2004).

During the slaughter process, *Salmonella* spp prevalence was 6.3% (Zerby *et al*., 1998), 10.5% (Bouvet *et al*., 2003), 12.9% (Vieira-Pinto *et al*., 2005), 30% (Berends *et al*., 1997), and even as much as 37% (Botteldoorn *et al*., 2003) in carcass samples, and 24% (Bouvet *et al*., 2003) and as much as 53% (Botteldoorn *et al*., 2003) in environmental samples. These values may have resulted from increased infected animals during extended lairage. It is thought that as much as 30% positivity for *Salmonella* spp. may be due to cross-contamination during slaughter (Berends *et al*., 1997) and meat cutting (Lo Fo Wong *et al*., 2002). A prevalence of 18.8% has been found in mesenteric lymph nodes and in ileum, 13.9% (Vieira-Pinto *et al*., 2005).

Pigs from farms with higher positivity in fecal samples become the most contaminated carcass in the slaughterhouse (Foley *et al*., 2008). Thus, an initial strategy that can be implemented in plants is slaughtering first the animals from sero-negative farms to reduce the cross-contamination risk (Swanenburg *et al*., 2001). It is also possible to improve carcass decontamination processes by using products based on organic acids (Buncic, 2011).

The safety of pigs entering the slaughter process will determine the presence of the organism in subsequent stages. However, carcass contamination during harvest can originate from facilities, equipment, tools, staff, or even from other carcasses.

Salmonella spp. in post-slaughter

The most influential factors in meat cross-contamination with human pathogens are handling, storage, and product preservation when sufficient precautions and correct hygiene (e.g. washing and disinfecting hands, clothes and utensils) have not been taken. It should be assumed that carcasses do not conclude the process with absolute food safety in the slaughterhouse; so one or more carcasses may have a higher load of pathogenic bacteria with respect to the others and thus increase the probability of cross-contamination occurring (Berends *et al*., 1997; Gomez *et al*., 2012).

A study of Belgian cutting plants, which process 48% of the pig production in the country, found presence of *Salmonella* in 0% to 50% of meat samples in a single plant (Delhalle *et al*., 2009). In Ireland, prevalence reached up to 2.6%, with *S*. Typhimurium being the most common serovar (Prendergast *et al*., 2009), and in a study from New Zealand, the prevalence was 3.6% (Wong *et al*., 2009).

Salmonella can remain in the submaxillary lymph nodes or tonsils of living animals; therefore, when the head is separated from the carcass, microorganisms can come into direct contact with utensils or gloves, which subsequently represent a contamination risk

(Borch *et al*., 1996; Scherer *et. al*., 2008; Vieira-Pinto *et al*., 2005). European studies reported that microorganism prevalence in these tissues was 9.3% to 12.9% in nodes and 9.9% to 19.6% in tonsils (Swanenburg *et al*., 2001; Vieira-Pinto *et al*., 2005).

Ready-to-eat pork products commonly contain low price cuts such as meat of the arms and neck, and back fat. Such materials undergo considerable handling during transport and cutting, increasing the risk of cross-contamination. In spite of the fact that cutting plants and plants that elaborate ready-to-eat pork products depend to a certain degree on the microbial quality of the raw material, they also have responsibility for assuring the quality of their end-products.

The thermal process should eliminate the presence of *Salmonella* spp. during preparation of ready-to-eat products; so, theoretically, such products would be free of the pathogen. In spite of this process, evidence of *S*. Typhimurium prevalence has been reported in sausages in Ireland (Boughton *et al*., 2004).

The proportion of wholesale market for pork in Colombia; that is, hypermarkets and supermarkets, is smaller than that of small pork distributors. Some wholesalers have their own cutting plants and distribute the meat directly to the sale points. Some large distributors supply smaller ones, and they cut or sell pieces to small butchers. In addition, not all slaughtered animals at a plant are destined for consumption in the same city or region, meaning that the product may be transported long distances, increasing the risk of contamination due to improper handling and preservation.

There is always a risk of contamination during food handling. Cross-contamination can occur when using contaminated kitchen implements in foods that do not require cooking before consumption, for example, when the meat is cut on a board with a knife and the knife is later used to cut vegetables that will be consumed as salad. In addition, proper cooking time and temperature should be used. The supply chain ends when the product is consumed.

Salmonella and international trade

The presence of non-typhoid *Salmonella* spp. serovars in food affects its safety and thus its international trade. The WTO (World Trade Organization) considers food safety a fundamental subject integrated into commerce to protect consumers in any part of the world where the product may be marketed. The FAO (Food and Agriculture Organization) and the WHO (World Health Organization) establish directives through the *Codex Alimentarius* to guarantee the marketing of safe foods. Likewise, the WTO recognizes OIE (currently World Organization for Animal Health) guidelines as the international reference.

The SPS agreement (Sanitary and Phytosanitary Measures) of the WTO establishes the guiding principles to protect the health and life of people and animals and to preserve plants for international trade. The CONPES 3458 framework of 2007 established the political guidelines on animal health and food safety for the pork supply chain in Colombia.

Although studies toward establishing a baseline for this microorganism have been conducted, health status regarding *Salmonella* spp. is still not known in Colombia. Therefore, future studies and projects should investigate non-typhoid *Salmonella* prevalence in each stage of the supply chain. In addition, further molecular and genomic studies are needed for epidemiological purposes to determine the current serovars present in the country and the clonal relationships among stages.

A productive approach would include inspection, surveillance, and control by official agencies in each stage of the chain, and voluntary programs should be established for monitoring, controlling, and implementing quality and safety systems (Good Practices, HACCP, ISO Standards) to ensure production of safe food under the concept of "stable to table". This way, consumer health would be protected, generating confidence in the product and improving market competitiveness.

In 2007 the Ministry of Health and Social Protection of Colombia issued Decree 1500 (normalized by

resolution 4282 of the same year), which regulates inspection, monitoring and control of fresh pork and further processed by-products. Article 51 describes the performance standard for *Salmonella* spp.

As a part of the policy framework mentioned in the CONPES document, the College of Veterinary Medicine and Animal Science of the Universidad Nacional de Colombia completed in 2011 the project entitled "Isolation and molecular characterization of *Salmonella* strains, antimicrobial susceptibility and microbiological risk assessment of contamination in carcass, cuts and pork products, strategies for prevention and control in slaughterhouse and processing plants". This project was funded by the Colombian Ministry of Agriculture and Rural Development to establish the presence of the organism in pre-slaughter, slaughter and post-slaughter stages in Colombia. The results are currently in publication process.

Perspectives

Control of *Salmonella* with a focus on the supply chain and risk assessment is fundamental for guaranteeing the quality and food safety of pork products in Colombia, which, in turn, contributes to public health and increases competitiveness of the chain. This goal is attainable; it has already been achieved in Denmark, which began a *Salmonella* control program in 1993 with an emphasis on primary production. Initial investment for that year was $15.5 million and managed to reduce the incidence of human salmonellosis from 24 to fewer than 5 cases per 100,000 people in 2001. If the program had not been implemented, the estimated losses due to contamination would have been $41 million per year (Wegener *et al*., 2003).

Studies should be conducted to establish baselines for *Salmonella* contamination in each stage of the pork supply chain in Colombia, identifying the differential risks and establishing measures to monitor prevention and reduction in the relevant processes. Controlling the microorganism will require the coordinated actions of each actor in every stage of the supply chain. It also requires implementing quality and food safety systems, official and voluntary adoption, and also the integrated participation of industry with the official and academic sectors.

Salmonella results obtained in the pork supply chain could be related to isolates from human cases in our country, which would allow more targeted and specific strategies.

Achieving these goals should allow improving scientific, technical and operational capacity of official laboratories. It would also help improving diagnostic and university laboratories to develop research projects by implementing reference techniques.

Validation and transfer of research results will enable authorities to focus on national programs aimed at discussing food safety issues on international trade and public health.

Prevention and control of *Salmonella* in foods of animal origin requires participation and interaction of all actors in the production chain: the official, the production, and academic sectors. This will contribute to improved competitiveness of the chain and encourage the opening of new markets under the Sanitary and Phytosanitary Measures framework agreement.

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