BRAZILIAN JOURNAL OF FOOD TECHNOLOGY

ISSN 1981-6723
Online version

REVIEW ARTICLE

Salmonella spp. in non-edible animal products: a burden on the broiler industry

Salmonella *spp. em produtos animais não comestíveis: um ônus para a indústria de frangos*

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Cite as: Costa, W. L. R., Santos, E. T. S. R., Rodgers, M. S. M., Fernandes, L. M. B., & Nascimento, E. R. (2023). *Salmonella* spp. in non-edible animal products: a burden on the broiler industry. *Brazilian Journal of Food Technology*, *26*, e2022146. https://doi.org/10.1590/1981-6723.14622

Abstract

The slaughter process produces carcasses, which are of greater commercial value, and by-products, which can be separated into edible or non-edible products. The latter is intended for the preparation of products not fit for human consumption, such as animal meal. The use of animal meal as feed ingredients reduces the environmental damage caused by the waste from the slaughterhouses and supplies nutritional and economic characteristics in the poultry sector. However, contamination by microorganisms such as *Salmonella* spp. plays an important role in the spread of the pathogen in poultry farms. This in turn negatively impacts poultry performance and can be a consumer health risk. In this report, we review the process for extracting proteinaceous waste from these by-products and the risk of contamination by *Salmonella* spp. in the food chain of animal products.

Keywords: Slaughter process; Heat treatment; Microbiology; Poultry farms; Contamination; One health.

Resumo

O processo de abate produz carcaças, que são de maior valor comercial, e subprodutos, que podem ser separados em comestíveis ou não comestíveis. Estes últimos destinam-se à preparação de produtos impróprios para alimentação humana, como as farinhas de origem animal. A utilização de farinhas de origem animal como ingrediente da ração reduz os danos ambientais causados pelos resíduos dos frigoríficos e fornece possibilidades nutricionais e econômicas ao setor avícola. No entanto, a contaminação por microrganismos como *Salmonella* spp. desempenha um papel importante na disseminação do patógeno em granjas avícolas. Isso, por sua vez, impacta negativamente o desempenho das aves e pode ser um risco à saúde do consumidor. Neste relatório, revisamos o processo de extração de resíduos de proteináceos desses subprodutos e o risco de contaminação por *Salmonella* spp. na cadeia alimentar de produtos de origem animal.

Palavras-chave: Abate; Tratamento térmico; Microbiologia; Avicultura; Contaminação; Saúde única.

Highlights

- Studies on *Salmonella* spp. in by-products of animal origin as a raw material of feed and ready feed for broilers contributes to the improvement of its quality, reducing the risks of disease transmission
- Competent authorities and the professionals
- Food Safety and factors that influence contamination in industrial food production and its impacts on one health is a necessity in the world of today

1 Introduction

Meat processing for human consumption is an officially regulated process that is supervised by veterinarians in Brazil (Brasil, 2017). This process generated waste that is considered non-edible to humans and corresponds to about 45% of the slaughter product (Alao et al., 2017), *i.e.*, a large volume of by-products like meat trimmings, bones, blood, and viscera among others (Toldrá et al., 2016). To make this process more environmentally friendly and to cut down on waste products, waste by-products can be prepared into animal feed meals (Adhikari et al., 2018; Alao et al., 2017; Socas-Rodríguez et al., 2021). Meals produced through this method involve product grinding, heat treatment, and drying (Malav et al., 2018). Thermal processing can be used to reduce microbial contamination to safe levels in order to avoid the transmission of pathogens, such as *Salmonella* spp. in animal meals (Steghöfer et al., 2021). Nevertheless, the presence of this pathogen has still been detected in some samples, indicating inadequacies with this process (Liu et al., 2018). Infection by this bacterium affects a wide variety of hosts (Andino & Hanning, 2015; Wemyss & Pearson, 2019), but poultry is one of the most important reservoirs (Wessels et al., 2021). Contaminated poultry food products are capable of introducing the pathogen into the human food chain (Abebe et al., 2020), allowing a continuous cycle of dissemination through the poultry meat, eggs, and other by-products (Berchieri Júnior & Freitas Neto, 2015; Foley et al., 2013). Poultry and poultry products contain the highest frequency of isolation of this pathogen. Hence, a small number of infected animals can lead to contamination of the entire slaughter line. Cross-contamination of equipment and utensils used in production and storage leads to contamination of meals, which can aggravate when the sanitation control measures are insufficient (Corcoran et al., 2014). According to Beshiru et al. (2018), *Salmonella* spp. can remain adhering tobiotic or abiotic surfaces and thus hygiene measures have failed to eliminate the pathogen. Foodborne diseases stand out precisely because they take a relevant position in the context of health worldwide (Abebe et al., 2020). Even with technological development, improvements in sanitation standards, and the implementation of quality tools, the number of infections caused by this pathogen in humans and animals is still increasing (Ehuwa et al., 2021; Ferreira et al., 2013).

2 Food-borne disease caused by *Salmonella* spp.

Today, foodborne disease represents a serious public health problem due to their high frequency, mortality, and the large number of microorganisms that may be involved in a simple epidemic event (World Health Organization, 2022). Several foodborne pathogens are known to cause disease, with bacteria being the most common (Abebe et al., 2020; Bintsis, 2017). In the last decade, there has been a 25% decrease in foodborne diseases caused by certain pathogens such as *Escherichia coli* O157H7 and *Campylobacter* spp., However, this has not been demonstrated with *Salmonella* spp. which continues to be a major cause of foodborne disease worldwide (Hunter & Watkins, 2017; Pal et al., 2015; Popa & Popa, 2021; World Health Organization, 2018). *Salmonella* infections stand out for their endemicity, high morbidity, and difficulty of adequate control measures. *Salmonella* spp. also displays high tolerance to environmental adversities, wide distribution, multi-resistance to antimicrobials, and increased adaptability (Chen et al., 2013; Silva et al., 2014; Tegegne, 2019). There are more than 2659 serovars of this genus (Issenhuth-Jeanjean et al., 2014).

The serovars *S*. Typhimurium, *S*. Enteritidis, and *S*. Newport are the ones most commonly involved in food-borne outbreaks by *Salmonella* spp. in humans (Alghoribi et al., 2019; Andino & Hanning, 2015; Moffatt et al., 2016; Popa & Popa, 2021). However, other serovars, such as *S*. Infantis, *S*. Alachua, *S*. Agona, *S*. Hadar, *S*. Heidelberg, and *S*. Virchow, have also been reported to cause infections in humans (Almeida et al., 2015; Dewey-Mattia et al., 2018; European Food Safety Authority, 2018; Hindermann et al., 2017; Jackson et al., 2013). *S*. Dublin, *S*. Muenster, and *S*. Choleraesuis are the serovars most associated with lethality in humans (Andino & Hanning, 2015). It is estimated that a variety of factors for each serovar is involved in the severity of infections by *Salmonella* spp. Including the host individual's ability to limit the infection at the gastrointestinal mucosa through immune responses (Wemyss & Pearson, 2019). After colonization and adaptation to the host, *Salmonella* spp. can present with asymptomatic forms that colonized the intestine (Dougan & Baker, 2014; Gunn et al., 2014; MacKenzie et al., 2017) or may present clinical manifestations (Singh, 2013). *Salmonella*´s infections present with enteric fevers caused by typhoid strains, mainly *S*. Typhi (typhoid fever) and *S*. Paratyphi A, B and C (paratyphoid fever) or infectious gastroenteritis, most often characterized by self-limiting diarrhea, and caused by a large number of non-typhoid *Salmonella* (Kagirita et al., 2017; Wain et al., 2015). Disease severity and localization depend on the serovar and virulence of the *Salmonella* spp. and the host's immune status (Wang et al., 2020).

3 Epidemiology of infections caused by *Salmonella* spp.

Considered the most widespread zoonosis in the world, salmonellosis has a transmission cycle that involves practically all vertebrates (Hossain et al., 2021). All *Salmonella* spp. are pathogenic to humans in some capacity (World Health Organization, 2018), although only approximately 50 of the 2659 existing serovars are regularly isolated from humans (Harvey et al., 2017). There are several factors that contribute to the emergence or increase of pathogenicity, among which the following factors stand out: the growing increase in the human population, the existence of vulnerable or more exposed population groups, the disorderly urbanization process, and the need for food production in large industrial scale (Radhakrishnan et al., 2018; Rohr et al., 2019). Some serotypes are considered host-specific, although the rate of adaptability varies according to the serotype and effects on the pathogenicity of humans and animals (Andino & Hanning, 2015; Evangelopoulou et al., 2013; Singh, 2013). This specificity depends on the ability of each serotype to adapt to the environment within the host. *Salmonella* Typhi and *S*. Paratyphi, which cause enteric fevers, are restricted to human hosts and are not normally pathogenic for animals (Chen et al., 2013; Feasey et al., 2012). *Salmonella* Pullorum and *Salmonella* Gallinarum are responsible for bird Pullorum disease and fowl typhoid, respectively, in poultry (Xiong et al., 2018). *Samonella* Dublin infects cattle (Uzal et al., 2016) and occasionally other species such as pigs, sheep, and horses (Uzzau et al., 2000). In general, serotypes that are highly adapted to animal hosts can cause mild symptoms in humans. *S*. Choleraesuis and *S*. Dublin, which infect pigs and cattle, respectively, can have severe consequences for human health (Harvey et al., 2017; Uzzau et al., 2000). However, most serovars of enteric subspecies are not host-specific and can infect several species of animals, including humans (Andino & Hanning, 2015; Uzzau et al., 2000). The species associated with the disease are typically transmitted by a food of animal origin (Heredia & García, 2018; World Health Organization, 2018). After elimination in animal feces, *Salmonella* spp. contaminates soil and water (Liu et al., 2018). Depending on the substrate on which these organisms are found, the resistance can be very high, especially if it is rich in organic matter. For example, Salmonella can remain in fecal material for years, being able to persist up to 28 months in poultry feces, 30 months in bovine feces, 280 days in cultivated soil, and 120 days in pasture (Brasil, 2011). Feces of infected animals can contaminate food and water, and most of them represent the primary source of human infection with this pathogen (Delahoy et al., 2018). Among the food involved in outbreaks of *Salmonella* spp. those of animal origin, such as meat (Zhou et al., 2019), milk (Castañeda-Salazar et al., 2021), and eggs (Li et al., 2020) are the most frequent, typically when they are consumed raw or thermally underprocessed (Ramirez-Hernandez et al., 2018). Additionally, undercooked eggs become contaminated due to the transovarian transmission of laying birds (New Zealand, 2015) or through contamination from cracks in the eggshell (Chousalkar & Roberts, 2012). Other vehicles include contaminated plant foods (Ehuwa et al., 2021), through irrigation with fecal contaminated water (Liu et al., 2018). Moreover, other important routes of transmission, where the agent can survive for long periods, have also been reported, and include contact with contaminated surfaces with organic matter, or with moist soil and water (Jechalke et al., 2019), contaminated injection devices, and transplacental transmission (Crump et al., 2015). In addition, infections also can happen through direct contact with carrier animals such as pets, birds, reptiles, and some other animals (Dróżdż et al., 2021; Vasconcelos et al., 2018). Veterinarians and animal keepers have a higher risk of contracting the disease through direct animal contact (Usmael et al., 2022). Nosocomial transmission and direct contact with infected people are less common means of infection (Lee & Greig, 2013). Due to this wide distribution of *Salmonella* spp. in the environment, birds or their eggs can become infected/contaminated from different sources, either through replacement birds, hatchery, breeding environment, food processing, people, biosecurity failures, management, handling, or through feeding. Contamination can occur at any stage of the production chain, from industrial production to transportation and/or storage on the farm, up to final consumer (Finn et al., 2013; Ha et al., 2018). Regarding dissemination through contaminated by-products, it was ratified by Socas-Rodríguez et al. (2021) that the various raw materials of animal origin used in the formulation of feed can lead to the transmission of *Salmonella* spp., including *S*. Enteritidis, to broiler creations. Although, there was a decrease in infections by *Salmonella* Enteritidis (Gupta et al., 2020). Costa et al. (2022) added that meat meal, one of the most used by-products in the manufacture of animal feed, is also one of those with the highest levels of contamination by *Salmonella* spp., implicated in the spread of the infectious agent. According to Vidyarthi et al. (2021), referring especially to *Salmonella* contamination, the processing temperatures of the by-products for animal feed eliminate most or even all bacterial contamination, however, the possibility of recontamination of these by-products after rendered is reported frequently. Thus, the authors included in their review study some additional biological safety measures required to ensure pathogen-free rendered products.

4 Poultry farming in Brazil

Broiler production has been impressive due to the dynamism and competence achieved in the last decades. World production reached the mark of 99.901 million tons of chicken meat in 2020. The United States of America (USA), followed by China and Brazil lead the world in poultry production (Associação Brasileira de Proteína Animal, 2022). There is an increase in concern about animal health and welfare with an emphasis on the establishment of new quality parameters and the adoption of international control methods. Among them, Hazard Analysis and Critical Control Points (HACCP) and the creation of the Scientific Consultative Commission on Microbiology of Animal Origin Products offer a summary of the efforts put forth by government agencies and the advanced microbiological logistics academy of the Brazilian inspection system (Brasil, 1998; Brasil, 2013). These methods aim to reduce environmental contamination by pathogenic microorganisms that contribute to production losses in the poultry chain and cause public health problems, such as food-borne diseases (Oloo et al., 2017; Rosak-Szyrocka & Abbase, 2020). However, meat quality intended for human consumption can undergo great influence in different stages of the production process, which ranges from handling the animal on rural property to moment of slaughter and processing (Rani et al., 2017). The quality of poultry meat production begins with the breeding of these animals, involving data of origin, health care to which they were subjected, characteristics and conditions of transportation, and even zootechnical particularities, involving the feeding and handling awarded by them. It is worth mentioning that the microbiological quality of the meat is the most important characteristic to be controlled during the slaughter phase and handling phases. Prior to the slaughter of the broilers, it is necessary to capture, cage, transport, and unload the caged animals at the processing site, where slaughter occurs under inspection by a veterinarian. During the slaughter and processing of broilers, pathogenic microorganisms, mainly from the intestine, skin, and feathers, can cause contamination of meat and its by-products. Certain steps such as bleeding, scalding, plucking, and evisceration play a fundamental role in the microbial distribution in the chicken carcass. Such steps support the colonization of tissues by deteriorating or even pathogenic microorganisms (Prache et al., 2022). Therefore, even before being conduced for slaughter, these animals are subjected to programs that aim to guarantee microbiological quality within the production chain (Rouger et al., 2017). The meat obtained later goes onto refrigeration, classification, packaging, and distribution (Arikan et al., 2017; Baltic et al., 2019; Janocha et al., 2022; Pareja Arcila et al., 2018). Contamination caused during this processing promotes changes in nutritional value and in sensory properties (color, odor, flavor, and texture). In addition, contamination may cause harm to the health of those who consume it. Many farm animals harbor in their body several microorganisms known as saprophytes, that is, incapable of causing them illnesses (Moënne-Loccoz et al., 2015). However, many of these microorganisms can represent an important level of pathogenicity when transmitted to humans (Balloux & van Dorp, 2017). The food provided to these animals and the indiscriminate use of veterinary products can contribute to the animal origin foods contamination, such as meat, milk, and eggs, or even resistance to antimicrobials (Hassan et al., 2021; Olasoju et al., 2021). Potentially pathogenic bacteria can be present in the meat, even when good manufacturing practices are applied followed by satisfactory hygienic-sanitary conditions during the slaughter and evisceration of animals (Elmali et al., 2015).

5 Control and prevention of *Salmonella* spp. in Brazilian industrial poultry farming

The Brazilian Poultry Health Program developed programs to control and prevent diseases focused on poultry and public health, such as Newcastle disease, salmonellosis, mycoplasmosis, and avian influenza (exotic in Brazil). This program provides procedures for the sanitary control of birds (Brasil, 1994). Brazilian Normative Instruction No. 20 of October 21, 2016, establishes the monitoring of *Salmonella* spp. in commercial poultry farming for broilers and turkeys and in the slaughter industry for broilers and turkeys registered with the Brazilian Federal Inspection Service (Brasil, 2016). The practice of inspecting meat from slaughterhouse animals is regulated by laws that aim to meet the quality standards in meat production, with attention to animal welfare, economic impact, and public health impacts. In Brazil, these standards are determined mainly by the Regulation of Industrial and Sanitary Inspection of Animal Origin Products - RIISPOA (Brasil, 2017). The absence of certain microorganisms such as *Salmonella* spp. from specific animal products is a requirement of national and international regulations (Brasil, 2022). Meat inspection regulations follow a set of steps carried out in a slaughterhouse, which can begin with the confinement of the animal to be slaughtered in order to ensure that these establishments comply with sanitary requirements before destinating the carcasses of these animals to human consumption. The main objective of meat inspection is to protect the health of consumers against threats, such as foodborne pathogens (Huneau-Salaün et al., 2015). The growth of potentially pathogenic bacteria can be inhibited by storage conditions and by proper temperature storage (Hoel et al., 2017). The growing interest in researching bacteria of this genus in different food industry segments, both in products and in the production environment, is due to the need to meet the food identity and quality standards required by Brazilian and importing countries (Camino Feltes et al., 2017). *Salmonella* spp. is among the main microorganisms that cause foodborne diseases worldwide (Bintsis, 2017; Heredia & García, 2018). Meat is the predominant source of contamination, with poultry involved in numerous cases of human infections (Wessels et al., 2021).

6 What is it, and how are animal origin meals made?

Slaughter, as well as other industrial meat processing, is regulated by regulations, that aims to ensure a safe product for consumer's health. Thus, slaughters have their activities supervised by veterinarians and agents from official inspection bodies (Brasil, 2020). Therefore, animals submitted to slaughter must be free of infections (Alao et al., 2017; Brasil, 2020). Except for the meat, which is considered of greater economic value, the other parts derived from the slaughter process are considered by-products and the description may differ depending on the intended use of such products in each country (Alao et al., 2017). In most countries, such as Brazil, these by-products are classified as edible and non-edible. Some of these by-products are also important for the medical field and are classified as pharmaceutical products and can also be used in other areas, such as in the production of biodiesel, biogas, dietary products (chitosans), natural pigments (after extraction), and cosmetics, such as collagen (Fayemi et al., 2018; Jayathilakan et al., 2012; Malav et al., 2018; Mathi et al., 2016; Okanović et al., 2009). Animal origin meal is defined as a non-edible by-product resulting from the processing of animal waste, not intended for human consumption, which comply with the pre-established identity and quality standard, in the sanitary, technological, and nutritional aspects (Brasil, 2008). The raw materials used in the production of these meals are residues from animal slaughter operations such as residues from the toilet of carcasses and offal, non-edible parts of the animals, parts condemned in *post-mortem* inspection, bones, fat shavings, meat boning, and meat processing residues (Malav et al., 2018). The use of animal waste, also known as animal recycling, is an activity carried out worldwide and is considered essential for the sustainability of the animal protein production chain. This avoids that the slaughterhouse waste would end up incinerated or disposed of in landfills or dumps (Associação Brasileira de Reciclagem Animal, 2018). Additionally, it is important that the residues from the slaughter process of animals are returned to nature in a non-wasteful manner, without impact on the environment, and the utilization of animal by-products can alleviate the prevailing costs and scarcity of feed material (Alao et al., 2017; Socas-Rodríguez et al., 2021). One way to take advantage of residues generated in the slaughter of animals is to manufacture meal from the slaughter waste by-products (Vidyarthi et al., 2021). Thus, it is necessary to use technological resources and evaluation of the most suitable recycling and manufacturing processes to guarantee the safety of by-products intended for animal consumption (Socas-Rodríguez et al., 2021). The residues must be processed within a maximum of 24 hours from the harvest or slaughter, with the use of hair, bristles, hooves, horns, blood, feces, stomach contents, residues of animals slaughtered prohibited in unauthorized establishments and risk specific materials including animal waste for the processing of meat meal and/or bone or fatty products (Brasil, 2008). It is also prohibited to use dead animals, which must be incinerated or destined for composting (Al-Gheethi et al., 2021; Irfan et al., 2020). The production of animal origin meals is carried out through a process called rendering (Figure 1). Rendering is based on the physical and chemical transformation of the product, using different equipment and process steps (Leiva et al., 2018). It consists of converting the non-edible animal product into three final products: solid proteinaceous, melted fat, and water (Malav et al., 2018). The process takes place through mechanical stages of grinding, mixing, pressing, decanting, and separating, where the fat is drained, pressed, or centrifuged and the solid residue is ground into meal. Then it undergoes thermal processing by cooking, evaporation, or drying, as well as chemical processing, such as solvent extraction (Malav et al., 2018). Cooking that may or may not be pressurized takes place in digesters installed in the rendering sector of slaughterhouses that reach high temperatures in the manufacturing process, approximately from 115 to 145 °C for 40 to 90 minutes depending on the type of system or composition of the product to be treated. The binomial time and temperature of thermal processing is a critical point and is a determinant of the microbiological quality of the final product (Brasil, 2008). The digester promotes heat treatment by heat transfer from the inner walls and the shaft to the non-edible products of animal origin to be treated. It is important that the equipment is sanitized periodically in order to avoid the appearance of internal crusts which impair the heat exchange and cause inefficiencies in the process (Ferroli et al., 2000). In Brazil, through Normative Instruction No. 34 of May 28, 2008 from the Ministry of Agriculture, Livestock and Supply, it is recommended that the binomial to be used to treat these residues cannot be lower than 133 °C, for at least 20 minutes, without interruption at a pressure (absolute) of not less than 3 (three) bar, produced by saturated steam (Brasil, 2008). Temperatures above the recommended temperature are unnecessary and are avoided due to their negative impacts on the decrease of nutritional value and digestibility (Meeker, 2009). This process gives rise to flours that are used in formulations of feed ration. The main meals of animal origin are hydrolyzed feather meal, viscera meal, bovine meat and bone meal, and blood meal (Matias et al., 2012; Mézes et al., 2015). The use of meal of animal origin brings important contributions in terms of economic, health, and nutritional aspects. Utilizing meat by-products in meal reduces costs in the production of feed rations and consequently in animal production, by providing treatment and utilization of animal slaughter residues which reduces waste and recycles energy, amino acids and minerals from animal by-products (Carvalho et al., 2012; Silva et al., 2018; Okanović et al., 2009; Staroń et al., 2017). Brazilian breeding companies routinely use animal meal in feed for non-ruminants, poultry (Ebling et al., 2013; Sari et al., 2016; Thyagarajan et al., 2013), and dogs as a source of protein (Loureiro et al., 2017; Meeker & Meisinger, 2015), macronutrients such as phosphorus, potassium, magnesium, and micronutrients such as iron, copper, zinc and manganese (Staroń et al., 2017). This is a lower cost alternative since these non-edible by-products can be an alternative to sustainable products for agriculture and industry. The use of these animal by-products, in addition to providing cost reduction, can alleviate the scarcity of raw materials for animal feed that present high competition with human consumption as well (Alao et al., 2017).

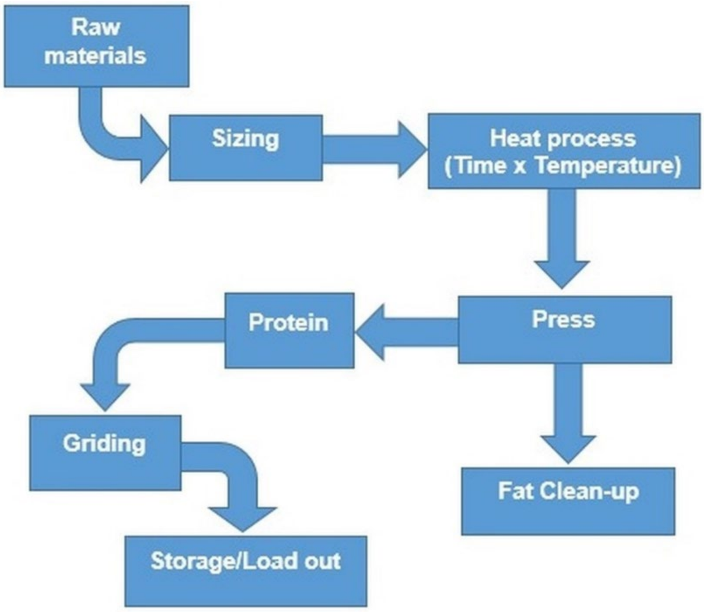

Figure 1. Basic rendering process flowchart. (Source: adapted from Hamilton, 2004).

7 Quality of the raw material used in the production of animal feed rations

Vidyarthi et al. (2021) in their review reported that it is extremely important the quality of the raw material used in the preparation of feed ration. Risks may also increase during the milling process as a result of using different raw ingredients from different national and international sources, where there may be a combination of material contaminated by *Salmonella* spp. or free of them (Gosling et al., 2022). There are large amounts of harmful bacteria in raw materials in rendering plants that can survive on stainless steel surfaces of equipment and cause recontamination in a continuous process. Hence, the investigation of the presence of pathogens by drawing samples at each stage of the rendering process is essential for insight into possible cross-contamination (Liu et al., 2018). There may be reservoirs of these strains in specific parts of the equipment in the feed mill, but these microorganisms can be spread in this environment through dust from contaminated equipment (Gosling et al., 2022). Even with the use of high temperatures in the treatment of the animal meals, above, including the thermoresistance of many microbiological contaminants, the product can present viable microorganisms, including *Salmonella* spp. (Liu et al., 2018). For microbiological control purposes, Brazilian legislation recommends that periodic analysis of *Salmonella* spp. be provided in order to guarantee its absence in 25 g of the finished product (Brasil, 2008). Rabelo et al. (2014) stated that by-products originating from meat and meat products must undergo specific processing to minimize the risks of pollution to the environment. An example with the use of the blood by-product which can be sent to the rendering sector for the production of blood meal, and then used in the preparation of animal feed rations and fertilizers, therefore ceasing to be a risk to the water ecosystem. Likewise, other slaughter by-products and effluents must be processed and treated with adequate final destination according to the validity of health and environmental laws and standards. Whether in the processing of meat products, in the various forms of use from the rendering sector, or in the release of effluents to the environment with reduced organic load (Alao et al., 2017; Rabelo et al., 2014; Socas-Rodríguez et al., 2021). Barros & Licco (2007) and Rebouças et al. (2010) reiterated that the rational use of by-products and meat residues from the rendering sector, in addition to presenting economic importance in the meat cost, is of fundamental importance in terms of environmental and one health concepts. Thus, if they were not used, they could contribute to the formation of conditions conducive to the attraction and accumulation of biological vectors, appearance degradation and environmental pollution. Regarding public health, the possibility of cross-contamination caused by the proximity of materials for human consumption to decomposing organic matter is considered, which could lead to the spread of diseases in the community through contaminated food.

8 Conclusion

Salmonella spp. in poultry products is a major source of foodborne disease worldwide. Thus, it is crucial that quality tools applied at an industrial level avoid contamination of food products to prevent threats to consumer health. An important step in the industrial process is the use of residues of these slaughtered animals, as it represents high nutritional and alternative value as a source of protein and reduces waste products in the environment. In this sense, these tools, especially the HACCP plan, must be implemented with an emphasis on the possibility of thermal subprocessing or post-processing contamination of animal meals used in the preparation of feed rations for animals. These tools are used worldwide, but the production conditions and the safety measure themselves are different from one country to the next. There is a need for an international methods standard, with special emphasis on the production of meals made with non-edible products of animal origin. Although much is known about the epidemiology of salmonellosis and existing measures to reduce pathogens, it is still necessary to clarify its origins in the production environment, aiming to guide prevention and control measures. In this context, it is necessary that the surveillance of pathogens of importance in foodborne diseases be continuous and more comprehensive to account for every stage of production. *Salmonella* spp. continues to pose a great danger and requires a comprehensive health strategy in order to effectively reduce disease burden.

Acknowledgements

We thank Paula Mischler-Kong for her assistance in reviewing the English translations.

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Funding: None.

Received: Dec. 17, 2022; Accepted: Apr. 28, 2023

Associate Editor: Felipe Alves de Almeida.