TITLE: Infection, colonization and shedding of Campylobacter and Salmonella in animals and their contribution to human disease: A review

AUTHORS: Rukambile, E; Sintchenko, V; Muscatello, G; Kock, R A; Alders, R

JOURNAL: Zoonoses and Public Health

PUBLISHER: Wiley

PUBLICATION DATE: 9 June 2019

DOI: https://doi.org/10.1111/zph.12611

Infection, colonization and shedding of *Campylobacter* and *Salmonella* in animals and their contribution to human disease: A review

Elpidius Rukambile[1-4*], Vitali Sintchenko[3,5], Gary Muscatello[1], Richard Kock[6], Robyn Alders[3,7,8]

[1] *School of Life and Environmental Sciences, Faculty of Science, The University of Sydney, Australia*

[2] *Charles Perkins Centre, The University of Sydney, Australia*

[3] *Marie Bashir Institute for Infectious Diseases and Biosecurity, The University of Sydney, Australia*

[4]*Tanzania Veterinary Laboratory Agency, Dar es Salaam, Tanzania*

[5]*Centre for Infectious Diseases and Microbiology - Public Health, Westmead Hospital and New South Wales Health Pathology, Sydney, Australia*

[6] *The Royal Veterinary College, University of London, United Kingdom.*

[7] *Kyeema Foundation, Brisbane, Australia*

[8]*Centre on Global Health Security, Chatham House, London, UK*

[*]Corresponding Author: erukambile@gmail.com

Acknowledgements

Financial support from the Australian Centre for International Agricultural Research (ACIAR; in the form of a John Allwright Fellowship for the lead author and support for field

work through project No. FSC/2012/023) and the University of Sydney Marie Bashir Institute Strategic Research Fund are gratefully acknowledged.

Abstract

Livestock meat and offal contributes significantly to human nutrition as sources of high-quality protein and micronutrients. Livestock products are increasingly in demand, particularly in low- and middle-income settings where economies are growing and meat is increasingly seen as an affordable and desirable food item. Demand is also driving intensification of livestock keeping and processing. An unintended consequence of intensification is increased exposure to zoonotic agents and a contemporary emerging problem is infection with *Campylobacter* and *Salmonella* spp. from livestock (avian and mammalian), which can lead to disease, malabsorption and undernutrition through acute and chronic diarrhoea. This can occur at the farm, in households or through the food chain. Direct infection occurs when handling livestock and through bacteria shed into the environment, on food preparation surfaces or around the house and surroundings. This manuscript critically reviews *Campylobacter* and *Salmonella* infections in animals, examines the factors affecting colonization and faecal shedding of bacteria of these two genera as well as risk factors for human acquisition of the infection from infected animals or environment and analyses priority areas for preventive actions with a focus on resources-poor settings.

Keywords: *Campylobacter* spp.; diarrhoea; foodborne pathogens; *Salmonella* spp.; zoonosis

Impact

1. Hosts, environments, bacteria and management-related factors determine *Campylobacter* and *Salmonella* species colonization in domestic and non-domestic animals with subsequent shedding of bacteria into the environments.
2. In resource-poor settings, infections with *Campylobacter* and *Salmonella* spp. are more likely transmitted through extended human-animal interactions, poor sanitation and hygiene services, unlike in areas with improved services where the infections are mostly acquired from contaminated animal-source foods.
3. Sustained exposure of susceptible humans to colonized animals predisposes humans to *Campylobacter* and *Salmonella* spp. infections; however, this interaction does not always result in clinical disease and/or infection in humans.

1. Introduction

Human campylobacteriosis caused by infection with different species of *Campylobacter* and non-typhoid salmonellosis due to infection with *Salmonella enterica* subsp. *enterica*, are amongst the top causes of foodborne gastroenteritis worldwide (Kirk et al., 2015). *Campylobacter* and non-typhoid Salmonellae are recurrently isolated from different types of animal-source foods, with most of them implicated in foodborne disease outbreaks (Friesema et al., 2014; Gharieb et al., 2015; Marotta et al., 2015; Olobatoke & Mulugeta, 2015; Taylor et al., 2013).

Campylobacter and *Salmonella* spp. infections in high-income countries are mostly acquired through consumption of the contaminated food of animal origin (Dallman et al., 2016; Taylor et al., 2013;), and the most common source of infection is poultry (EFSA, 2015). In contrast, in low- and middle-income countries (LMICs), the main sources of infection appear to be

contaminated environment, food, water and close contact with infected live animals (Coker et al., 2002; El-Tras et al., 2015; Lyimo et al., 2016). Clinically and silently infected animals harbour and shed bacteria in the environment and act as a source of infection to uninfected animals and susceptible humans through direct contact or indirectly through faecal-contaminated environments (Gopinath et al., 2012). Several factors including physiological stress and concurrent infection can aggravate prolonged infection and faecal shedding in infected animals, with subsequent environmental contamination (Cummings et al., 2009). Gastrointestinal microbiota plays a large role in the control of pathogenic microbes and a minor disturbance in normal microflora may result in even a pathogen of low virulence colonizing the gastrointestinal tract with subsequent faecal shedding (Gopinath et al., 2012).

This paper discusses the clinical signs of *Campylobacter* and *Salmonella* spp. infections in domestic animals. It examines the role of normal gastrointestinal flora and possible consequences associated with its imbalance. The factors predisposing animals to *Campylobacter* and *Salmonella* spp. colonization and subsequent faecal shedding are also reviewed. In addition, this paper explores the contribution of infected animals leading to human infections and the critical components which facilitate the movement of these bacteria from infected animals to humans.

2. Methods

A search was conducted to find the studies which cover the subject areas tackled by this review: "*Salmonella* infections", "*Salmonella* colonization", "*Salmonella* shedding", "*Campylobacter* infections", "*Campylobacter* colonization", "*Campylobacter* shedding", and "Non-typhoid *Salmonella"*. Searches based on these subject areas in BioOne, CAB ebook,

CAB abstract and Web of science databases, yielded 2766 results from 7th to 9th January 2019. The article titles were assessed for relevance in relation to infection, colonization and shedding in domestic and non-domestic animals and the terms "non-typhoid *Salmonella*" which eliminated 1924 titles. The remaining 842 publications were examined through thorough assessment of the abstracts whereby 673 articles were eliminated and the remaining 169 articles were included in the review. The first exclusion criteria was the host whereby studies conducted in insects, non human primates, acquatic animals and *in vitro* (cell culture) were not included in this review. All studies related to clinical signs of diseases in animals other than domestic animals, treatment of diseases, vaccine testing and studies conducted in more specialised production systems were also not included in the review. Google search, shelf literature and the reference lists of selected publications were used to source additional information relavant to the sub-topics under review.

3. *Campylobacter* infection in domestic animals

Campylobacter spp. are often isolated from clinically healthy domestic animals (Corry, 2014; Döhne et al., 2012; Khan et al., 2013; Marotta et al., 2015; Rahimi et al., 2017). In most studies carried out, *C. jejuni* is commonly isolated followed by *C. coli* (Anderson et al., 2012; Mdegela et al., 2011; Nonga & Muhairwa, 2010). The chicken gastrointestinal tract, especially the caecum, is highly colonized by *Campylobacter*, particularly *C. jejuni* and *C. coli* (Rosenquist et al., 2006). The ability of these bacteria to grow at 42 ^{o}C reflects their adaptation to the gastrointestinal tract of birds (Crushell et al., 2004; Stanley & Jones, 2003). Although *Campylobacter* is considered commensal in both domestic and non-domestic birds, *C. jejuni* infection in intensively raised, modern, fast-growing breeds of chickens may elicit a strong inflammatory response leading to diarrhoea (Humphrey et al., 2014).

Campylobacter fetus subspecie *fetus* causes clinical campylobacteriosis in cattle and sheep and C. *fetus* subspecie *veneralis* causes clinical disease in cattle only. Clinical disease in cattle and sheep is characterized by infertility, abortion and foetal death, (Debruyned et al., 2008; Schulze et al., 2006; Truyers et al., 2014). However, *C. jejuni* has been also implicated in sheep abortion (Mannering et al., 2006). Cattle infected with species other than *C. fetus* remain asymptomatic and continue to shed bacteria through faeces (Abley et al., 2011). *C. jejuni, C. coli* and *C. upsaliensis* are commonly found in clinically asymptomatic as well as diarrhoeic and vomiting dogs and cats. Experimentally inoculated dogs do not show clinical signs of disease, suggesting a primary or opportunistic nature of *Campylobacter* infection in dogs and cats predisposed to several factors such as concurrent virus infections and stress (Macartney et al., 1988; Olson & Sandstedt, 1987; Sokolow et al., 2005).

4. *Salmonella* infection in domestic animals

More than 1,454 serotypes of *Salmonella enterica* subsp. *enterica* depend on warm-blooded animals and humans for habitat (Brenner et al., 2000; Grimont & Weill, 2007). Although almost all species of domesticated animals harbour *Salmonella*, poultry under intensive production systems, are represented more frequently (Akbarmehr, 2011; Paião et al., 2013, Vinueza-Burgos et al., 2016). Infections in birds by avian-adapted serovars, *S.* Pullorum and non-avian adapted *S.* Enteritidis result in clinical disease primarily in chicks, and in all ages in case of avian-adapted *S.* Gallinurum infections (Gast, 2013; Shivarprasad & Barrow, 2013). The faeco-oral is the main route of transmission with the exception of *S.* Enteritidis which can also be transmitted transovarially (Gast, 2013; Lutful Kabir, 2010; Ricke & Gast, 2014; Saha et al., 2012). The vertically or horizontally infected survivor chicks can remain

carriers until the adult stage, infecting subsequent eggs and continuing to shed bacteria in the environment (Ishola, 2009; Takata et al., 2003; Van Immerseel et al., 2004).

Salmonella are often isolated from healthy domestic pigs (Parada et al., 2017; Stevens & Gray, 2013). Occasionally, *Salmonella*-infected pigs may develop signs from transient fever to severe disease depending on strain virulence, immune resistance, route of infection and dose (Alsop, 2005; Schwartz, 1999). A wide range of serovars have been isolated in domestic ovines but only serovars Brandenburg, Arizonae and Typhimurium cause gastroenteritis, pneumonia and death, and sheep-specific serovar Abortusovis have been reported to cause epidemic abortion in healthy looking ewes during the third trimester, stillbirths, premature and nonviable lambs (Uzzau, 2013).

Cattle of all ages can suffer from clinical salmonellosis characterized by diarrhoea, but most serious disease occurs in newborns, young calves 2-6 weeks of age, and cows approaching calving. Bovine salmonellosis is mostly caused by serovars Newport, Typhimurium, Infantis, 4,5,12:i:-, Agona, Montevideo, Anatum, Mbadaka, Enteritidis and cattle-adapted serovar Dublin (Cummings et al., 2012; Ragione et al., 2013). Occasionally, adult cattle become carriers following recovery from the disease and continuously or intermittently shed pathogens through faeces for years or lifelong (Ragione et al., 2013).

5. Animal gastrointestinal microbiome

Gastrointestinal microbes contribute to the breakdown of food components and host nutrient acquisition through a symbiotic association with host and immune system education which enables the host to differentiate between normal flora and harmful bacteria (Callaway et al.,

2014; Hanning & Diaz-Sanchez, 2015). Well-developed normal flora protects the host through creating gastrointestinal resistance environments which prevent external pathogenic bacteria from colonizing the gut (Han et al., 2017; Monack, 2012). The microbial community in the gastrointestinal tract stimulates production, maintenance of normal structure and functioning of the mucosal lining, hence render the animal protection from pathogenic bacteria (Hanning & Diaz-Sanchez, 2015). Also, some gut commensals produce metabolites which inhibit growth of pathogenic organisms through disrupting intercellular metabolisms (Jacobson et al., 2018).

Stress factors, including starvation, changes in ration, overcrowding, age, pregnancy, parturition, intercurrent non-infective disease, and exposure to antibiotics and anthelmintics, may result in gut microflora disturbance and disbiosis which leads to pathogenic bacteria gut colonization and faecal excretion (Daniels et al., 1993). Some bacterial infections result in composition changes in commensal microbiota through depopulation of beneficial or competing bacteria which enable successful colonization of the gut by pathogenic organisms (Argüello et al., 2018). The detection of pathogenic bacteria in faeces of asymptomatic animals is referred to as shedding and is an indication of whole or partial gastrointestinal tract bacterial colonization (Ishola, 2009). Short duration faecal bacteria shedding, especially observed with bacteria which do not infect the gut is not considered as gut colonization (Barrow et al., 1988).

6. *Campylobacter* colonization and shedding in ruminants and suids

Campylobacter is frequently isolated in clinically healthy animals and, therefore, is considered as normal flora in domestic and non-domestic animals (Cummings et al., 2018;

Dong et al., 2014; Mdegela et al., 2011; Sproston et al., 2011). Host factors including species, age and physiological status determine the level of *Campylobacter* prevalence and shedding in animals. Higher *Campylobacter* faecal shedding was observed in cattle than in sheep exposed to the same environmental conditions (Sproston et al., 2011). A study conducted in beef herds reported nearly 100 times higher *Campylobacter* count in faecal samples from calves born free from infection at 60 days of age compared to adult animals (Stanley et al., 1998). However, no significant difference in shedding was observed between calves and adult dairy herds kept under high hygienic conditions (Merialdi et al., 2015). Stresses associated with lambing in ewes, calving and lactation in cattle and large herd sizes also increase *Campylobacter* prevalence and shedding (Grove-White et al., 2010; Stanley et al., 1998;). Feed type may alter the gastrointestinal microbiota which in turn impact the rate of colonization and faecal shedding of *Campylobacter*. Feeding pigs with a diet containing medium-chain fatty acids, lactic acid and oregano oil was reported to reduce the recovery rate from faecal and intestinal contents (Rasschaert et al., 2016).

Temporal variation in *Campylobacter* prevalence and shedding occurs in various animal species and under different management systems. The highest peak in cattle and sheep in temperate countries has been reported during the summer months (Grove-White et al., 2010). During summer, *Campylobacter* faecal prevalence is higher in grazing than in housed dairy cattle, the variations were accounted for by the different types of feed eaten by the two herd categories which contribute to change in the gut microbial ecosystem (Grove-White et al., 2010). However, a study conducted in Italy revealed double peaks of *Campylobacter* faecal shedding in dairy cattle kept in-house throughout the year without a change in diet and water supply, suggesting a weak association between change in diets and seasonal variation in bacterial shedding (Merialdi et al., 2015). In Hungary, seasonal variation presented a different

picture whereby higher *Campylobacter* prevalence in cattle, poultry and pigs has been observed in colder autumn and winter months than in summer (Schweitzer et al., 2011).

7. *Campylobacter* colonization and shedding in birds

Birds are considered to be the primary reservoirs of *Campylobacter* spp. *Campylobacter* in chickens have been isolated from the gastrointestinal tract (Gomes et al., 2006; Jacob et al., 2011), mature and immature ovarian follicles (Cox et al., 2005); liver, spleen, gallbladder and thymus (Cox et al., 2006; Schmid et al., 2005; Simaluiza et al., 2015). *Campylobacter* spp. are also recorded in non-domestic birds including blackbirds, house sparrows, tree sparrows and crows which continue to maintain the bacteria in the ecosystem (Hald et al., 2016; Mdegela et al., 2006; Taff & Townsend, 2017). However, most of the strains found in non-domestic birds are host specific, hence, of less public health importance (Griekspoor et al., 2013).

Colonization of the gastrointestinal tract by *Campylobacter* in chickens is rapid and followed by abrupt faecal excretion of bacteria (Van Gerwe et al., 2005). Seventy percent of one-day-old chicks flock started shedding bacteria 48 hours post-exposure with the proportion of shedders dropping progressively, while 12.5% remained chronic shedders in the absence of repeated exposure (Achen et al., 1998). Carrier, non-shedding birds may become shedders under a range of circumstances including stress and changes in diet. The age at exposure in chickens determines the post exposure commencement of *Campylobacter* faecal shedding. Post-exposure faecal shedding occurs after 2-3 days in chickens exposed at an older age (≥21 days) compared to exposure at a young age (0-14 days) which may delay shedding up to 49 days (Yano et al., 2014). The proportion of birds shedding *Campylobacter* in faeces depends

on the age and specie of the bird. A study conducted in broilers under semi-intensive systems reported an increase in *Campylobacter* prevalence from 20% in week 5 to 88% in week 11 of age, after that the prevalence averaged 40% until week 63 (Colles et al., 2011). In free-range ducks, the opposite was observed whereby faecal shedding was reported to be significantly higher in adult ducks than in ducklings (Nonga & Muhairwa, 2010).

The interaction and alteration of the mechanical and immunological line of defence by chemical and other microorganisms affects the extent of *Campylobacter* colonization in birds. The penetration of the gastrointestinal mucus layer by *Campylobacter* is facilitated by mucin which is a component of mucus and has *Campylobacter* chemoattractant properties. The coliform bacteria, including *Lactobacilli,* frequently isolated during the entire period of chick growth as observed by Achen et al. (1998), inhibit *Campylobacter* gut colonization by competitive utilization of mucin as a growth substrate (Mead, 2002). Feeding chickens with a diet containing xylanases decreases mucus viscosity and hence, inhibits *C. jejuni* gastrointestinal translocation and colonization (Fernandez et al., 2000). Also, concurrent infection of chickens with the infectious bursal disease virus and *Campylobacter* results in increased colonization, faecal shedding and reduce clearance of the later in chickens through host immunosuppression which is a normal outcome of infections cause by the former (Li et al., 2018; Subler et al., 2006). The systemic immune response in chickens towards *Campylobacter* infection in resistant genetic lines is characterized by apoptosis and cytochrome c release from mitochondria which is lacking in susceptible genetic lines (Li et al., 2012). The presence of immune responses indicates the ability of some chicken genetic cell lines to tolerate *Campylobacter* infection which can be exploited through breeding to produce *Campylobacter*-resistant chicken genetic lines.

Biosecurity practices on poultry farms have an impact on *Campylobacter* prevalence in the flock. Poultry farms with a higher biosecurity score are found to have low *Campylobacter* infection prevalence compared to farms with a low biosecurity score (Smith et al., 2016). Nevertheless, in practical terms, it is difficult to attain a level which is considered appropriate to overcome the problem. Other factors including partial depopulation, slaughtering the birds in summer and autumn period and recent bird mortality in the flock are key factors for *Campylobacter* colonization at slaughter age (Lawes et al., 2012).

8. *Salmonella* colonization and shedding in ruminants and suids

Salmonella serovars are often isolated in asymptomatic cattle, sheep, pigs, and non-domestic ruminants and suids (Afema et al., 2016; Cummings et al., 2016; Eguale et al., 2016; Love et al., 2017; Zishiri et al., 2016). The magnitude and duration of colonization and shedding of *Salmonella* in animals varies along the different stages of infection or carriage and not all infected animals shed *Salmonella* in faeces continuously (Donoghue et al., 2006). The age of the animal is the important factor in prediction of shedding duration in cattle whereby adult can shed bacteria for up to 391 days post infection compared to 30 days observed in calves (Cummings et al., 2009). Pigs infected with *S.* Derby or detected as *Salmonella* positive at 10 weeks of age shed bacteria in faeces for a longer duration compared to pigs infected with other serovars or detected as *Salmonella* positive at 12 weeks of age (Pires et al., 2014).

The physiological status of an animal determines the rate of *Salmonella* faecal shedding in pigs. The rate of *Salmonella* shedding through faeces is relatively low in sows during gestation, around farrowing and during lactation but increases significantly in the first seven days post weaning (Nollet et al., 2005). The increase in faecal shedding rate is associated

with stresses resulting from reproductive hormonal changes after lactation ceases. Increase in catecholamine production mostly observed during stress conditions results in inhibition of gastric acid production which favours *Salmonella* colonization with subsequent faecal shedding (Schwartz, 1999). Also, cortisol, a glucocorticoid hormone produced during stress has immunosuppressive effects which favour the intracellular proliferation of *Salmonella* in macrophages with subsequent colonization in carrier animals (Verbrugghe et al., 2011).

The types and particle size of feeds have synergistic effects on *Salmonella* shedding in animals. Pigs fed with diets consisting of small-particle pellets shed more *Salmonella* than their counterparts fed with larger-size pellet diets and mash types of diet singly or in combination (Lebel et al., 2017). Coarse feeds stimulate the release of gastric acid resulting in lowered stomach pH which creates an unfavourable environment for *Salmonella* survival (Mikkelsen et al., 2004). Also, the combination of medium-chain fatty acids, lactic acid and oregano oil or organic acids, phytochemicals and a permeabilizing complex in feeds significantly reduce *Salmonella* faecal shedding in pigs (Rasschaert et al., 2016; Ruggeri et al., 2018).

In most temperate countries, *Salmonella* faecal shedding in cattle is observed more frequently during the summer than other periods of the year (Edrington et al., 2004; Hanson, 2015). However, in studies conducted in United States, no significant seasonal variations were observed in samples collected in harvest-ready feedlots and poorly productive culled beef and dairy cattle (Brichta-Harhay et al., 2011, Kunze et al., 2008) . High bacterial shedding during summer is not only reported in domestic animals but also in wild pigs (Cummings et al., 2016), and correspond with an increase in *Salmonella* infections in humans (Cummings et al., 2012). Hot conditions as observed in summer in temperate areas favour pathogen survival

and virulence and is associated with seasonal changes in human behaviour which increase the interactions between pathogens and humans (Ravel et al., 2010).

Studies conducted in pigs reported genetic control over *Salmonella* spp. colonization and faecal shedding. The expression, and single nucleotide polymorphisms, of some genes were found to have a direct association with *Salmonella* shedding and colonization in pigs (Ainslie-Garcia et al., 2018; Kommadath et al., 2014; Uthe et al., 20110. Exploitation of links between *Salmonella* faecal shedding and host genetic variation is a breakthrough towards production of animals resistant to *Salmonella* infection through marker-assisted breeding, hence improving food safety.

9. *Salmonella* colonization and shedding in birds

Salmonella colonization in birds is not restricted to the gastrointestinal tract but also includes extra-gastrointestinal organs including the liver, spleen, ovaries, oviducts and muscles (Ainslie-Garcia et al., 2018; Aragaw et al., 2010; Babu et al., 2018; Gast et al., 2016). Wild birds also become infected and high mortality may be encountered in infections caused by some genotypes (Hughes et al., 2010). Migratory birds believed to be the reservoir of *Salmonella* spp. infections to human, and a similar strain of *Salmonella bongori* 48:z_{35}:–, has been isolated from migratory birds and humans in Italy (Foti et al., 2009). The physiological condition of birds, including starvation, affects *Salmonella* invasion of intestinal tissues. Gastrointestinal tissue colonization and faecal shedding in chickens experimentally exposed to *S.* Enteritidis is higher in food-deprived than in well-fed chickens (Holt et al., 2006, Moore & Holt, 2006). The effect of feed withdrawal on *Salmonella* gastrointestinal colonization and faecal shedding has public health implications as most farms withdraw feed from chickens

prior slaughtering which may result in increased in carcass contamination during slaughter. The physical form of the diet and additives significantly affects the rate of *Salmonella* colonization and shedding in chickens. *S.* Enteritidis-infected chickens fed on finely milled diets mixed with whole wheat grains cleared bacteria from caecal contents and liver at a higher rate and had lower cloacal swab recovery than chickens fed with fine or coarse ground feeds under experimental conditions (Ratert et al., 2014). Inclusion of various chemicals additives in poultry feeds reduce *Salmonella* in gastrointestinal tract and extra-gastrointestinal organs colonization and faecal shedding in chickens (Adhikari et al., 2017; Adhikari et al., 2018; Rattanawut et al., 2017). Also, *Lactobacillus plantarum* given as a probiotic to chicks has proven successful in reducing *Salmonella* colonization mediated by colon-induced intestinal barrier disruption through regulating expression of tight junction genes and inflammatory responses (Wang et al., 2018).

Salmonella colonization in chickens is complex and not much is known regarding the pathogen-related determinants of gut colonization. Chicken-isolated *S.* Typhimurium, Enteritidis, Heidelberg, Hadar and Kentucky possess genes encoding adhesins, flagellar proteins, Type III secretion systems (T3SS), iron acquisition systems, and antibiotic and metal resistance genes that may account for their colonization capability and persistence in chickens (Dhanani et al., 2015). However, haemagglutination, motility and virulence-associated plasmids have been tested and found nonessential in *Salmonella* gut colonization in chickens (Barrow et al., 1988). Also, the role played by the genes encoding fimbrial units in gut colonization have been examined in *S.* Enteritidis whereby only plasmid-encoded fimbriae (*faeA*) gene was found to have an association with *Salmonella* caecal colonization in chickens (Clayton et al., 2008).

Poultry husbandry systems which allow expression of normal behaviours in chickens accompanied by low stocking density decrease the gut and extra-gastrointestinal organs *Salmonella* colonization. The gut and extra-gastrointestinal organs of the chicken kept at low stocking density in colony cages enriched with perches are less colonized by *Salmonella* as compared to those kept in conventional cages at high stocking density (Gast et al., 2016). This trend of colonization and shedding of chickens in relation to type of cages and stocking density may vary depending on the *Salmonella* serovar infecting the birds (Gast et al., 2017). Access of broilers to non-starch polysaccharide, as seen in litter-floored houses, stimulates the gizzard and proventriculus mechanically and acts as a vehicle for competitive exclusive microorganisms against *Salmonella* reducing bacterial colonization (Santos et al., 2008). However, no difference was observed in *Salmonella* colonization among chickens with high and low diversity of intestinal microbiota (Nordentoft et al., 2011).

10. Public health risks associated with animals colonised and shedding *Campylobacter* and *Salmonella*

Infected domestic and non-domestic animals are potential sources of human *Campylobacter* and *Salmonella* infections. Human campylobacteriosis and salmonellosis acquired from animals colonized and shedding *Campylobacter* and *Salmonella* can be categorized into three types: (i) infections acquired from the consumption of contaminated animal products such as meat or eggs (Bertasi et al., 2016; Marshall et al., 2018; Nielsen et al., 2006; Schildt et al., 2006) (ii) infections acquired from close contact with infected animals (Behravesh et al., 2014; Gaffga et al., 2012; Gras et al., 2013); and (iii) infections acquired from environments contaminated with faeces from infected animals shedding bacteria. Although the environment is the main source of *Campylobacter* and *Salmonella* contamination of animal foods due to

unhygienic handling, the potential of accidental intestinal contents spillage and extra-gastrointestinal colonization as a source of contamination should not be underestimated (Humphrey & Williams, 2017). The extended interactions between human and animals mostly observed with pet animals and their owners, extensive animal husbandry, animal handlers and wildlife habitat encroachment predispose humans to animal-associated infections (Afema & Sischo, 2016; Behravesh et al., 2014; Holmberg et al., 2015). Animals shedding *Campylobacter* and *Salmonella* contaminate environments including soil, manure, aquatic environments and water sources which increase the risk of humans acquiring infection when hygiene practices are not well-observed (Whiley et al., 2013) (Table 1).

However, not all strains found in animals are of equal public health importance. *S.* Typhimurium Phage types DT2 and DT99 appear to be specific to pigeons, phage types DT8 and DT46 adapted to ducks and DT40 to wild birds (Helm et al., 2004; Rabsch et al., 2002; Rabsch, 2007). The analysis of diverse strains of *Campylobacter jejuni* from a wide range of domestic ruminants, pigs, birds, dogs, cats and wild birds by multi-locus sequence typing (MLST) demonstrated that clonal complex (CC) 179, sequence type (ST) 637 and 1341 were found only in pigeons and gulls (Ogden et al., 2009). In Gambia, clonal differences in *Salmonella* among children and animals were reported in households with extended human-animal interactions which suggests predominance of human-related source of infections as compared to animal source (Dione et al., 2011).

10.1. Sources of infections related to foods of animal origin

Animals infected with and shedding *Campylobacter* and *Salmonella* are major sources of meat, milk and egg contamination (Cox et al., 2012; Gast et al., 2013; Nollet et al., 2005;

Schildt et al., 2006). Isolation of *Campylobacter* and *Salmonella* is common in animal-source food products including poultry meat (Anihouvi et al., 2013; Bertasi et al., 2016; Inns et al., 2015; Suzuki & Yamamoto, 2009; Trongjit et al., 2017). As a result, eating raw or undercooked meat especially from poultry (Colette et al., 2018; Doorduyn et al., 2010; WHO, 2012) and drinking unpasteurized milk (Burakoff et al., 2018; EFSA; 2015; Studahl & Andersson, 2000; Taylor et al., 2013) are the most important risk factors for human *Campylobacter* and *Salmonella* infections of animal origin (Table 1). The potential sources of contaminated animal products include bacterial extra-gastrointestinal colonization, intestinal contents spillage during evisceration, environmental contamination during processing and transportation and cross contaminations among carcases during food processing (Anihouvi et al., 2013; WHO, 2012; Wilfred et al., 2012; Simaluiza et al., 2015).

Animal food products are implicated in human *Salmonella* infection outbreaks related to local and multinational food distribution networks (EFSA & ECDP, 2017; Dallman et al., 2016; Zenner et al., 2014), and international in-flight catering (Rebolledo et al., 2014). The isolation of *Campylobacter* strains from chicken carcases similar to those frequently isolated in humans is not uncommon and signifies the importance of animals in human infections (Devane et al., 2013; Nielsen et al., 2006; Stone et al., 2013). Offal are potential sources of affordable animal-source food which can contribute sinificantly to nutrition security in resource-poor settings (Williams, 2007). Despite its importance, preparation of offal should be accompanied by thorough cooking especially intestines as they may harbour a large number of gastrointestinal pathogens (Humphrey & Williams, 2017). Frequent exposure to raw meat, particularly observed in kitchen, butchery and slaughterhouse workers, predispose humans to *Campylobacter* and *Salmonella* infections originating from animals (Table 1). Therefore, consumption of contaminated animal products is not the only predisposing factor

for acquiring infections of animal origin (Doorduyn et al., 2010). The complex surface attachment mechanism (Nguyen et al., 2012), and effective adaptation to environmental changes (Humphrey, 2004; Spector & Kenyon, 2012) demonstrated by *Campylobacter* and *Salmonella*, respectively, make these bacteria highly successful foodborne pathogens. Infection acquired from contaminated animal-source food can be prevented through discouraging eating raw or insufficiently cooked food and through adequate cooking and proper hygiene practices.

Table 1: Risk factors associated with live animals, animal products and environmental derived human *Salmonella* and *Campylobacter* infections

	Risk factor	Example	References
1	Unhygienic food handling	• Poor hand washing • Poor hygienic conditions at slaughterhouse and butcheries • Improper storage facilitating bacteria multiplication • Safety of water used for washing meat • Spillage of intestinal contents onto meat • Cross contaminations of carcasses	(Anihouvi et al., 2013; Fahrion et al., 2014; Wilfred et al., 2012)
2	Eating raw or under cooked food	• Lifestyle trends with increased consumption of raw and under cooked food • Inadequate food safety measures at farm level	(Colette et al., 2018; Najwa et al., 2015)
3	Animal production systems	• Improper slurry disposal and treatment which predispose environment to contamination. • Extensive animal keeping which increases human-animal interactions	(Afema et al., 2016; Clark et al., 2003; Dione et al., 2011; Najwa et al., 2015)
4	Use of animal slurry for crop	• Rain water run-off washes slurry into water sources	(Pornsukarom & Thakur, 2016; You et

	production	• *Salmonella* spp. can stay dormant in soil for long periods resulting in crop contamination especially vegetables	al., 2006)
5	Sharing water sources with animals	• Animal faecal contamination of water sources • Drinking untreated water from shared sources	(Kusiluka et al., 2005; Lyimo et al., 2016)
6	Animal husbandry practices	• Type, physical status of the feed and feeding system • Feed withdrawal before slaughter in poultry • Partial depopulation in poultry • High stocking density	(Gast et al., 2016; Holt et al., 2006; Lawes et al., 2012; Lebel et al., 2017; Ratert et al., 2014)
7	Contact with live animals	• Close contact between pet animals and humans • Animal farm workers and animal attendants (occupational hazard)	(Behravesh et al., 2014; Leahy et al., 2016)
8	Contact with raw animal food products	• Slaughterhouse workers (occupational hazard) • Chefs and butchery workers (occupational hazard)	(Ibrahim et al., 2013; Kantsø et al., 2014; Wright et al., 2005)
9	Season of the year	• Most infections occur in human and animals during hot weather in temperate countries • Increase in temperature which favours bacterial multiplication and increased outdoor meals may be driving force for this trend	(Cummings et al., 2012; Hanson, 2015; Ravel et al., 2010, Zhang et al., 2009)
10	Wild-domestic animals interactions	• Act as the source of infection to each other which predispose the environment to contamination	(Cummings et al., 2016; De Lucia et al., 2018; Glawischnig et al., 2017; Hald et al., 2016)
11	Faecal	• Use of untreated water from shared	(Bell et al., 2015; Lyimo

environmental contamination by domestic and wild animals	sources • Rain water run-off which washout the faeces from the range land towards the water sources • Presence of faeces in human house and children playgrounds	et al., 2016)

10.2. Sources of infections related to interactions between humans and live animals

Often in resource-poor settings animals are kept in close proximity with humans, including access to every part of the house during the day and sharing the same spaces during the night (Dione et al., 2011; Msami, 2008). Frequent contact with poultry, sheep and cattle increases the risk of contracting *Campylobacter* infections (Kapperud et al., 2003; Studahl & Andersson, 2000). A study conducted in backyard poultry in Egypt reported increases of more than three times in *Campylobacter* infections in children from households keeping *Campylobacter*-infected poultry as compared to children in households with *Campylobacter* free flocks (El-Tras et al., 2015). Nonetheless, chicken corralling in resource-poor settings was reported to increase the risks of *Campylobacter* infections in children as compared to free-range kept chickens in Peru (Oberhelman et al., 2006). Therefore, promoting the building of appropriate animal shelters in resource-poor settings may not reduce the risk of animal and environmentally-related gastrointestinal infections if the use of shelter is not accompanied by good hygiene practices in both animal shelters and human dwellings.

Kissing or snuggling with pet birds as mostly practiced by children has been associated with human *Salmonella* outbreaks (Basler et al., 2016; Behravesh et al., 2014; Gaffga et al., 2012). *Campylobacter* and *Salmonella* shedding in cats and dogs is more of a public health concern due to the companion nature of these animals to human (Andrzejewska et al., 2013;

Holmberg et al., 2015; Leahy et al., 2016; de Massis et al., 2018). Several studies report indistinguishable *Campylobacter* strains from dogs and their owners (Gras et al., 2013), *Salmonella* and *Campylobacter* strains from human and chickens (Anderson et al., 2012, Elgroud et al., 2015; Kagambega et al., 2013), indicating cross infections between these hosts. Guinea pigs and turtles kept as pets are asymptomatic carriers of *Salmonella* spp. and have been implicated in multistate outbreaks of *Salmonella* infections in humans in the United States (Gambino-Shirley et al., 2018; Koski et al., 2018; Robertson et al., 2018). Pests, including rodents, can also be infected by *Salmonella* and *Campylobacter* spp. and serve as a source of compound, food and kitchen bacterial contamination through faeces or mechanical movement of the bacteria (Meerburg & Kijlstra, 2007; Ribas et al., 2016).

Human *Campylobacter* and *Salmonella* infections associated with live animals are acknowledged as occupational hazards which predispose animal handlers on farms and in veterinary facilities to the risk of infection (Ibrahim et al., 2013; Kantsø et al., 2014; Wright et al., 2005). Also, dry pet foods have been implicated as a source of *Salmonella* infections in pet animal handlers, children in the household and animal themselves (Behravesh et al., 2010).

10.3. Source of infections related to environmental animal faecal contamination

Campylobacter and *Salmonella* are recurrently isolated from soil, water bodies, animal houses and effluents (Afema et al., 2016; Lyimo et al., 2016; Mhongole et al., 2017; O'Mahony et al., 2011). Free-range or extensive systems of animal husbandry mostly practised in rural resource-poor settings, poor slurry management on animal farms and in slaughterhouses results in environmental bacterial contamination (Figure 1) (Afema et al.,

2016). Also, *Campylobacter* and *Salmonella* spp. have been isolated in non-domesticated mammals and birds making these species another potential source of environmental contamination through faecal shedding (Carbonero et al., 2014; Jurado-Tarifa et al., 2016). Under favourable temperature, humidity and pH, *Salmonella* can survive in the natural environment including soil and water for several weeks without significant multiplication which makes shedding animals and poor slurry disposal of public health concern (Chouhan, 2015; Jensen et al., 2006). High ruminant and poultry density and presence of large poultry slaughterhouses have a strong association with higher *Campylobacter* incidences in humans suggesting pathogen movement among humans, domestic animals and environments (Arsenault et al., 2012a; Arsenault et al., 2012b;).

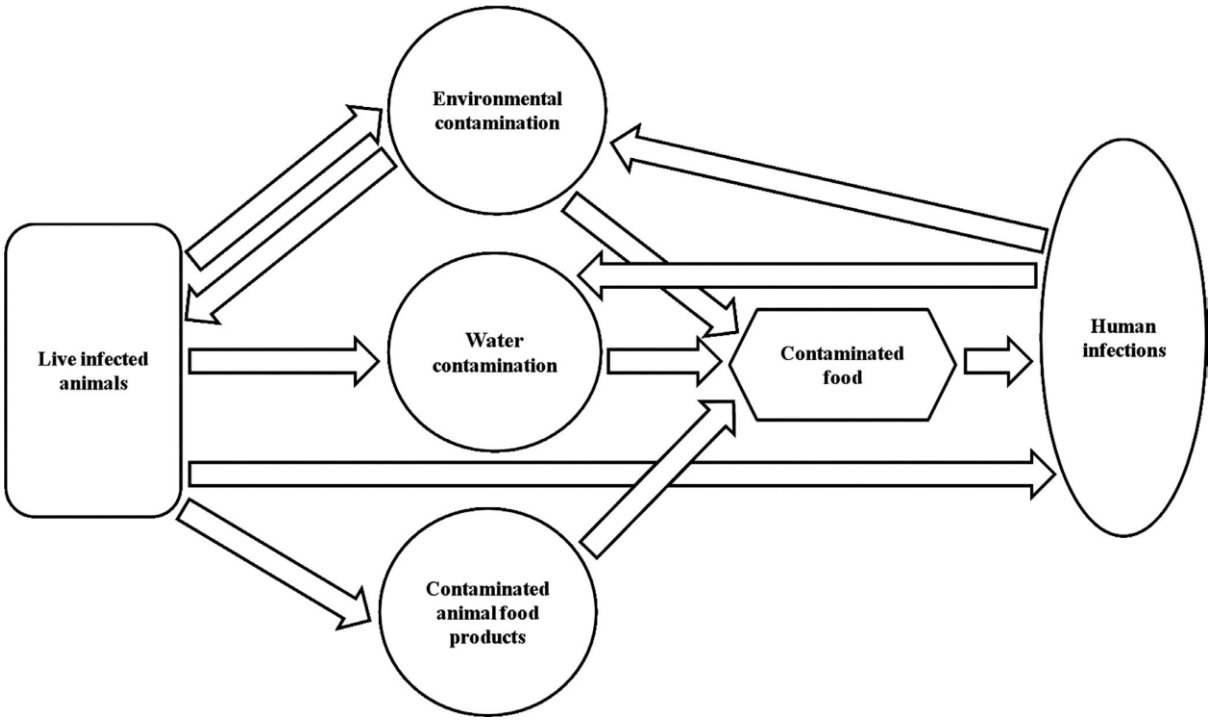

Figure 1: Schematic presentation of *Salmonella* and *Campylobacter* cycle among animals, human and environments

Isolates of *Salmonella* serovar 4,[5],12:i:- with similar phage type, pulse field gel electrophoresis (PFGE) and multilocus variable analysis (MLVA) profiles were reported from cattle, pigs and human faeces indicating a key role of animals in human *Salmonella*

infection (Ido et al., 2015). The correlation of *Campylobacter* strains in humans and animals is not only restricted to the type of strain but also their temporal occurrences. The prevalence of sequence type (ST) 45 strain of *Campylobacter* is higher during the summer months in humans, cattle and broiler chicken faeces which suggests cross-infection between these hosts (Grove-White et al., 2011; Jorgensen et al., 2011; McCarthy et al., 2012). With increased encroachment and destruction of wildlife habitat by human activities, and keeping wild animals in captivity and as pets, the possibility of humans acquiring infection from wildlife is expected to increase. However, out of 50 *Salmonella* outbreaks reported in United States between 2006 - 2013, only five were related to non-domesticated animals (Gaydos, 2014).

Surface water bacterial contamination frequently occurs through rainwater run-off washing animal faeces in the environment towards water sources (Bell et al., 2015; Levantesi et al., 2012). Indistinguishable strains connected to *Campylobacter* waterborne outbreaks occurring during heavy rains were documented in humans, cattle and manure implying water source contamination by water run-off from animal farms (Clark et al., 2003). In resource-poor settings, water-sources sharing between humans and animals is not uncommon resulting in use of water contaminated by animal faeces (Kusiluka et al., 2005; Lyimo et al., 2016; Strauch & Almedom, 2011). The isolation of similar *Salmonella* strains in domestic and non-domestic animals in rural and urban surface water further confirms animals as reservoirs for environmental and water bacterial contamination (Thomas et al., 2013). Water treatment at public sources have been proven effective in preventing infections which may emerge from contaminated water (Maponga et al., 2013). Unfortunately, there is limited or often no reticulated or borehole water supply system in resource-poor settings, making water treatment difficult or impossible; hence, the promotion of drinking boiled or home chemical treated water become the only effective options (Diouf et al., 2014; Mengistie et al., 2013).

The use of water contaminated with animal faeces for irrigation and manure for soil fertilisation, poses risks to consumer health and environmental contamination (Pornsukarom & Thakur, 2016). *Salmonella* can survive in manure mixed with soil for 332 days which may result in crop and environmental contamination (You et al., 2006). Garden irrigation using water from sources receiving slaughterhouse slurry and rainwater run-off has been implicated in fresh vegetable *Salmonella* contamination (Bell et al., 2015; Najwa et al., 2015). Human *Salmonella* and *Campylobacter* infections of animal origin acquired from horticulture contaminated products are rising due increases in fresh vegetable consumption globally fuelled by urbaniation and globalisation (Evans et al., 2003; Hussain & Gooneratne, 2017). This necessitates promotion of the use of physical, chemical and biological treatment methods to reduce pathogen population in manure despite costs and environmental pollution challenges associated with use of these methods (Manyi-Loh et al., 2016).

Livestock shedding bacteria are also a source of infection to non-domestic animals which then may continue to sustain the bacteria in the ecosystem (Hald et al., 2016). Isolation of livestock-associated strains and unique strains of *C. jejuni* in non-domestic birds and absence of unique non-domestic bird strains in livestock suggest the direction of infection to be predominantly from livestock to non-domestic birds (Hughes et al., 2009), Also, cattle-derived *Salmonella* Dublin and pig-derived *S.* Typhimurium DT193 have been isolated in red foxes (*Vulpes vulpes*) and non-domestic birds, respectively; the former most probably acquired through ingestion of infected cattle materials such as abortion tissues (De Lucia et al., 2018; Glawischnig et al., 2017).

Conclusions

The consumption of food of animal origin, extended human-animal contacts, exposure of humans to animal faeces through faecal contaminated environment, water and food (through inappropriate horticultural practices) are the drivers for animal associated-human campylobacteriosis and salmonellosis. The risk of acquiring infection through consumption of food of animal origin especially poultry in low-income countries is lower as compared to high-income countries since food of animal origin are less frequently consumed in low-income countries (Ritchie & Roser, 2018). Keeping poultry of the same age and type/breed under intensive conditions as mostly practised in high-income countries favours bacterial multiplication and transmission with subsequent poultry product contamination. It is very difficult to achieve zero bacteria colonization at farm level, therefore, in addition to appropriate management, proper hygiene practices, adequate cooking of food from unsafe sources should be immediate strategies towards reducing magnitude of animal-origin human *Campylobacter* and *Salmonella* spp infections. Human-animal interaction including sharing the same house with animals does not always result in animal-related human sub-clinical and clinical *Campylobacter* and *Salmonella* spp. Frequent exposure to animals can enhance development of immune systems that are less allergic and more adaptive and responsive to common pathogens (Lambrecht & Hammad, 2017; Stein et al., 2016). Nonetheless, sharing living spaces with animals should be practised understanding that animals are potential sources of infections through bacterial faecal shedding and modifications made to mitigate these potential risks. However, the literature to date suggests that the risks of pathogen transfer from human–human contact are probably much greater than those from animals. Increases in environmental temperature over certain ranges, can increase bacterial colonization and shedding in animals, favour pathogen survival and multiplication in the environment and increases pathogen-human interaction due to increases in outdoor activities

contributing to increases in infection in humans especially in temperate countries. As animal-source food remains an important component of human diets, achieving safe and sustainable production systems will require interdisciplinary research and development tailored to local conditions.

Conflict of Interest

The authors declare that there is no conflict of interest

References

Abley, M. J., Wittum, T. E., Zerby, H. N., & Funk, J. A. (2011). Quantification of *Campylobacter* and *Salmonella* in cattle before, during, and after the slaughter process. *Foodborne Pathogens and Disea*se, 9, 113-119. *doi*:10.1089/fpd.2011.0931

Achen, M., Morishita, T. Y., & Ley, E. C. (1998). Shedding and colonization of *Campylobacter jejuni* in broilers from day-of-hatch to slaughter age. *Avian Diseases, 42*, 732-737. *doi*:10.2307/1592708

Adhikari, P., Cosby, D. E. Cox, N. A., Franca, M. S.,Williams, S. M., Gogal, J. R. M., Ritz, C. W., & Kim, W. K. (2018). Effect of dietary fructooligosaccharide supplementation on internal organs Salmonella colonization, immune response, ileal morphology, and ileal immunohistochemistry in laying hens challenged with *Salmonella enteritidis*. *Poultry Science,* 97, 2525-2533. *doi*:10.3382/ps/pey101

Adhikari, P., Cosby, D. E., Cox,N. A., & Kim,W. K. (2017). Effect of dietary supplementation of nitrocompounds on Salmonella colonization and ileal immune gene expression in laying hens challenged with *Salmonella* Enteritidis. *Poultry Science,* 96, 4280-4286. *doi:*10.3382/ps/pex221.

Afema, J. A., Byarugaba, D. K., Shah, D. H., Atukwase, E., Nambi, M., & Sischo, W. M. (2016). Potential sources and transmission of *Salmonella* and antimicrobial

resistance in Kampala, Uganda. *PLoS One,* 11, e0152130. *doi*:10.1371/journal.pone.0152130

Afema, J. A., & Sischo, W. M. (2016). *Salmonella* in wild birds utilizing protected and human impacted habitats, Uganda. *EcoHealth, 13*, 558-569. *doi*:10.1007/s10393-016-1149-1

Ainslie-Garcia, M. H., Farzan, A., Jafarikia, M., & Lillie, B. N. (2018). Single nucleotide variants in innate immune genes associated with Salmonella shedding and colonization in swine on commercial farms. *Veterinary Microbiology,* 219**,** 171-177. *doi*: https://doi.org/10.1016/j.vetmic.2018.04.017

Akbarmehr, J. (2011). A survey on the prevalence of poultry salmonellosis and detection of different *Salmonella* serovars isolated from poultry in broiler chicken farms. *African Journal of Microbiology Research,* 5, 5950-5954. *doi*:10.5897/AJMR11.996

Alsop, J. E. (2005). An outbreak of salmonellosis in a swine finishing barn. *Journal of Swine Health and Production,* 13, 265-268. Retrived from https://www.aasv.org/shap/issues/v13n5/v13n5p265.html

Anderson, J., Horn, B. J., & Gilpin, B. J. (2012). The prevalence and genetic diversity of *Campylobacter* spp. in domestic 'backyard' poultry in Canterbury, New Zealand. *Zoonoses and Public Health,* 59, 52-60. *doi:*10.1111/j.1863-2378.2011.01418.x

Andrzejewska, M., Szczepańska, B., Klawe, J., Śpica, D., & Chudzińska, M. (2013). Prevalence of *Campylobacter jejuni* and *Campylobacter coli* species in cats and dogs from Bydgoszcz (Poland) region. *Polish Journal of Veterinary Sciences,* 16, 115-120. doi:10.2478/pjvs-2013-0016

Anihouvi, D. G. H., Kayodé, A. P. P., Anihouvi, V. B., Azokpota, P., Kotchoni, S. O., & Hounhouigan, D. J. (2013). Microbial contamination associated with the processing of tchachanga, a roasted meat product. *African Journal of Biotechnology,* 12, 2449-2455. *doi*:10.5897/AJB12.2917

Aragaw, K., Terefe, L., & Abera, M. (2010). Prevalence of *Salmonella* infection in Intensive poultry farms in Hawassa and isolation of *Salmonella* species from sick and dead

chickens. *Ethiopian Veterinary Journal,* 14 , 115-124. Retrived from http://www.ajol.info/index.php/evj/article/download/63888/51697

Argüello, H., Estellé, J., Zaldívar-López, S., Jiménez-Marín, Á. Carvajal, A., López-Bascón, M., Crispie, F.,. O'Sullivan, O., Cotter, P. D., Priego-Capote, F., Morera, L., & Garrido, J. J. (2018). Early *Salmonella* Typhimurium infection in pigs disrupts microbiome composition and functionality principally at the ileum mucosa. *Scientific Reports,* 8, 7788. *doi*:10.1038/s41598-018-26083-3

Arsenault, J., Berke, O., Michel, P., Ravel, A., & Gosselin, P. (2012a). Environmental and demographic risk factors for campylobacteriosis: do various geographical scales tell the same story? *BMC Infectious Diseases,* 12, 1-12. *doi*:10.1186/1471-2334-12-318

Arsenault, J., Michel, P., Berke, O., Ravel, A., & Gosselin, P. (2012b). Environmental characteristics associated with campylobacteriosis: accounting for the effect of age and season. *Epidemiology and Infection,* 140, 311-322. *doi*:10.1017/S0950268811000628

Babu, U. S., Proszkowiec-Weglarz, M., Sharma, G. M., Pereira, M., & K. V., Balan (2018). In vivo and in vitro evaluation of tissue colonization and survival capacity of Salmonella Oranienburg in laying hens. *Poultry Science,* 97, 3230-3235. *doi*:10.3382/ps/pey189

Barrow, P. A., Simpson, J. M., & Lovell, M. A. (1988). Intestinal colonization in the chicken by food- poisoning *Salmonella* serotypes; Microbial characteristics associated with faecal excretion. *Avian Pathology,* 17, 571-588. *doi*:10.1080/03079458808436478

Basler, C., Nguyen, T., Anderson, T. C., Hancock, T., & Behravesh, C. B. (2016). Outbreaks of human *Salmonella* infections associated with live poultry, United States, 1990–2014. *Emerging Infectious Disease journal,* 22, 1705-1711. *doi*:10.3201/eid2210.150765

Behravesh, C. B., Brinson, D., Hopkins, B. A., & Gomez, T. M. (2014). Backyard poultry flocks and salmonellosis: A recurring, yet preventable public health challenge. *Clinical Infectious Diseases,* 58, 1432-1438. *doi*:10.1093/cid/ciu067

Behravesh, C. B., Ferraro, A., Deasy, M., Dato, V., Moll, M., Sandt, C., Rea, N, K., Rickert, R., Marriott, C., Warren, K., Urdaneta, V., Salehi, E., Villamil, E., Ayers, T., Hoekstra, R. M., Austin, J. L., Ostroff, S., & Williams, I. T. (2010). Human infections linked to contaminated dry dog and cat food, 2006–2008. *Pediatrics,* 126, 477. *doi*:10.1542/peds.2009-3273

Bell, R. L., Zheng, J., Burrows, E., Allard, S., Wang, C. Y., Keys, C. E., Melka, D. C., Strain, E., Luo, Y., Allard, M.W., Rideout, S., & Brown, E. W. (2015). Ecological prevalence, genetic diversity, and epidemiological aspects of *Salmonella* isolated from tomato agricultural regions of the Virginia Eastern Shore. *Frontiers in Microbiology,* 6, 1-15. *doi*:10.3389/fmicb.2015.00415

Bertasi, B., Losio, M. N., Daminelli, P., Finazzi, G., Serraino, A., Piva, S., Giacometti, F., Massella, E., & Ostanello, F. (2016). Seasonal variability of thermophilic *Campylobacter* spp. in raw milk sold by automatic vending machines in Lombardy Region. *Italian Journal of Food Safety,* 5, 131-133. *doi*:10.4081/ijfs.2016.5848

Brenner, F. W., Villar, R. G., Angulo, F. J., Tauxe, R., & Waminathan, B. (2000). *Salmonella* Nomenclature. *Journal of Clinical Microbiology,* 38, 2465-2467. Retrived from https://www.ncbi.nlm.nih.gov/pmc/articles/PMC86943/pdf/jm002465.pdf

Brichta-Harhay, D. M., Arthur, T. M., Bosilevac, J. M., Kalchayanand, N., Shackelford, S. D., Wheeler, T. L., & Koohmaraie, M. (2011). Diversity of multidrug-resistant *Salmonella* enterica strains associated with cattle at harvest in the United States. *Applied and Environmental Microbiology,* 77, 1783-1796. *doi*:10.1128/AEM.01885-10

Burakoff, A., Brown, K., Knutsen, J., Hopewell, C., Shannon, R., & Bennett, C. (2018). Outbreak of fluoroquinolone-resistant *Campylobacter jejuni* infections associated with raw milk consumption from a herdshare dairy - Colorado, 2016. *Morbidity and Mortality Weekly Report,* 67, 146-148. *doi*:http://dx.doi.org/10.15585/mmwr.mm6705a2.

Callaway, T. R., Edrington, T. S., & Nisbet, D. J. (2014). Ecological and dietary impactors of foodborne pathogens and methods to reduce fecal shedding in cattle. *Journal of Animal Science,* 92, 1356-1365. *doi*:10.2527/jas.2013-7308

Carbonero, A., Paniagua, J., Torralbo, A., Arenas-Montes, A., Borge, C., & García-Bocanegra, I. (2014). *Campylobacter* infection in wild artiodactyl species from southern Spain: Occurrence, risk factors and antimicrobial susceptibility. *Comparative Immunology, Microbiology and Infectious Diseases,* 37, 115-121. *doi*: 10.1016/j.cimid.2014.01.001

Chouhan, S. (2015). Enumeration and identification of standard plate count bacteria in raw water supplies. *IOSR Journal of Environmental Science, Toxicology and Food Technology*, 9, 67-73. *doi:*10.9790/2402-09226773

Clark, C. G., Price, L., Ahmed, R., Woodward, D. L., Melito, P. L., Rodgers, F. G., Jamieson, F., Ciebin, B., Li, A., & Ellis, A. (2003). Characterization of waterborne outbreak–associated *Campylobacter jejuni*, Walkerton, Ontario. *Emerging Infectious Diseases,* 9, 1232-1241. *doi:*10.3201/eid0910.020584

Clayton, D. J., Bowen, A. J., Hulme, S. D., Buckley, A. M., Deacon, V. L., Thomson, N. R., Barrow, P. A., Morgan, E., Jones, M. A., Watson, M., & Stevens, M. P. (2008). Analysis of the role of 13 major fimbrial subunits in colonization of the chicken intestines by *Salmonella enterica* serovar Enteritidis reveals a role for a novel locus. *BMC Microbiology,* 8, 228. *doi*:10.1186/1471-2180-8-228.

Coker, A. O., Isokpehi, R. D., Thomas, B. N., Amisu, K. O., & Obi, C. L. (2002). Human campylobacteriosis in developing countries. *Emerging Infectious Diseases,* 8, 237-243. *doi*:10.3201/eid0803.010233

Colette, G., Danielle, R., Réjean, D., Marc, S., Céline, G., Éric, L., Karon, H., Maude, M. Mélanie, G., & Marc, F. (2018) Veal liver as food vehicle for human *Campylobacter* infections. *Emerging Infectious Disease Journal,* 24**,** 1130. *doi*:10.3201/eid2406.171900

Colles, F. M., McCarthy, N. D., Layton, R., & Maiden, M. C. (2011). The prevalence of *Campylobacter* amongst a free-range broiler breeder flock was primarily affected by flock age. *PLoS One,* 6, e22825. *doi*:10.1371/journal.pone.0022825

Corry, J. E. L. (2014). *Campylobacter* detection by cultural and modern techniques. In M. Tortorello, Batt, C. A. (Ed.), Encyclopedia of Food Microbiology (2nd ed., pp. 357-

362). Oxford: Academic Press. Retrieved from http://dx.doi.org/10.1016/B978-0-12-384730-0.00053-7

Cox, N. A., Bailey, J. S., Richardson, L. J., Buhr, R. J., Cosby, D. E., Wilson, J. L., Hiett, K. L., Siragusa, G. R., & Bourassa, D. V. (2005). Presence of naturally occurring *Campylobacter* and *Salmonella* in the mature and immature ovarian follicles of late-life broiler breeder hens. *Avian Diseases,* 49, 285-287. *doi*:10.1637/7324-011005.

Cox, N. A., Richardson, L. J., Buhr, R. J., Bailey, J. S., Wlson, J. L., & Hiett, K. L. (2006). Detection of *Campylobacter jejuni* in various lymphoid organs of broiler breed hens after oral or intravaginal inoculation. *Poultry Science,* 85, 1378-1382. Retrived at https://doi.org/10.1093/ps/85.8.1378

Cox, N. A., Richardson, L. J., Maurer, J. J., Berrang, M. E., Fedorka-Cray, P. J., Buhr, R. J., Byrd, J. A., Lee, M. D., Hofacre, C. L., O'Kane, P. M., Lammerding, A. M., Clark, A. G., Thayer, S. G., & Doyle, M. P. (2012). Evidence for horizontal and vertical transmission in *Campylobacter* passage from hen to her progeny. *Journal of Food Protection,* 75, 1896-1902. *doi*:10.4315/0362-028.JFP-11-322

Crushell, E., Harty, S., Sharif, F., & Bourke, B. (2004). Enteric *Campylobacter*: purging its secrets? *Pediatric Research,* 55, 3-12. *doi*:10.1203/01.PDR.0000099794.06260.71

Cummings, K. J., Rodriguez- Rivera, L. D., Grigar, M. K., Rankin, S. C., Mesenbrink, B. T., Leland, B. R., & Bodenchuk, M. J. (2016). Prevalence and characterization of *Salmonella* isolated from feral pigs throughout Texas. *Zoonoses and Public Health,* 63, 436-441. *doi*:10.1111/zph.12244

Cummings, K. J., Warnick, L. D., Alexander, K. A., Cripps, C. J., Gröhn, Y. T., James, K. L., McDonough, P. L., & Reed, K. E. (2009). The duration of faecal *Salmonella* shedding following clinical disease among dairy cattle in the northeastern USA. *Preventive Veterinary Medicine,* 92, 134-139. *doi*:10.1016/j.prevetmed.2009.07.002

Cummings, K. J., Warnick, L. D., Gröhn, Y. T., Hoelzer, K., Root, T. P., Siler, J. D., McGuire, S. M., Wright, E. M., Zansky, S. M., & Wiedmann, M. (2012). Clinical features of human salmonellosis caused by bovine-associated subtypes in New York. *Foodborne Pathogens and Disease,* 9, 796-802. *doi*:10.1089/fpd.2012.1158

Dallman, T., Loman, N., Inns, T., Simon, S., Kornschober, C., Jombart, T., de Pinna, E., Chatt, C., Bernard, H., Mossong, J.,Cleary, P., Grant, K., Messelhaeusser, U., Rabsch, W., Jourdan da-Silva, N., Ashton, P., le Hello, S., Hawkey, P., & Nikisins, S. (2016). Phylogenetic structure of European *Salmonella* Enteritidis outbreak correlates with national and international egg distribution network. *Microbial Genomics,* 2. *doi*:10.1099/mgen.0.000070

Daniels, E. K., Woollen, N. E., Dickson, J. S., & Littledike, E. T. (1993). Beef cattle salmonellosis: A study of oral *Salmonella typhimurium* and topical *Salmonella newport* inoculations, 174-175. Retrieved from http://digitalcommons.unl.edu/hruskareports/334

De Lucia, A., Rabie, A., Smith, R. P. Davies, R., Ostanello, F., Ajayi, D., Petrovska,L., & Martelli, F. (2018) Role of wild birds and environmental contamination in the epidemiology of Salmonella infection in an outdoor pig farm. *Veterinary Microbiology,* 227**,** 148-154. *doi*:https://doi.org/10.1016/j.vetmic.2018.11.003

de Massis, F., Calistri, P., Di Donato, G., Iannetti, S., Neri, D., Persiani, T., Di Giannatale, E., & Cammà, C. (2018) *Campylobacter* infection occurrence in canine population in Italy. *International Journal of Infectious Diseases,* 73**,** 146. *doi*:10.1016/j.ijid.2018.04.3744

Debruyned, L., Eversa, I., & Vandamme, P. (2008). Taxonomy of the Family Campylobacteraceae. In I. Nachamkin, C. M. Szymanski, & M. J. Blaser (Eds.), *Campylobacter* (3rd ed., pp. 3-25). Washington, DC: American Society for Microbiology (ASM) Press. *doi*:10.1128/9781555815554.ch1

Devane, M., Gilpin, B., Robson, B., Klena, J., Savill, M., & Hudson, J. (2013). Identification of multiple subtypes of *Campylobacter jejuni* in chicken meat and the impact on source attribution. *Agriculture,* 3, 579. *doi*:10.3390/agriculture3030579

Dhanani, A. S., Block, G., Dewar, K., Forgetta, V., Topp, E., Beiko, R. G., & Diarra, M. S. (2015). Genomic comparison of non-typhoidal *Salmonella enterica* serovars Typhimurium, Enteritidis, Heidelberg, Hadar and Kentucky isolates from broiler chickens. *PLoS One,* 10, e0128773. *doi*:10.1371/journal.pone.0128773

Dione, M. M., Ikumapayi, U. N., Saha, D., Mohammed, N. I., Geerts, S., Ieven, M., Adegbola,R. A., & Antonio, M. (2011). Clonal differences between non-typhoidal *Salmonella* (NTS) recovered from children and animals living in close contact in The Gambia. *PLoS Neglected Tropical Diseases,* 5, e1148. *doi*:10.1371/journal.pntd.0001148

Diouf, K., Tabatabai, P., Rudolph,, J., & Marx, M. (2014). Diarrhoea prevalence in children under five years of age in rural Burundi: an assessment of social and behavioural factors at the household level. *Glob Health Action,* 7: 24895. *doi*:http://dx.doi.org/10.3402/gha.v7.24895

Döhne, S., Merle, R., Altrock, A. V., Waldmann, K. H., Verspohl, J., Gruning, P., Hamedy, A, Kreienbrock, L. (2012). Antibiotic susceptibility of Salmonella, *Campylobacter coli*, and *Campylobacter jejuni* isolated from northern German fattening pigs. *Journal of Food Protection,* 75, 1839-1845. *doi*:10.4315/0362-028X.JFP-12-051

Dong, H. J., Cho, A. R., Hahn, T. W., & Cho, S. (2014). Development of a loop-mediated isothermal amplification assay for rapid, sensitive detection of *Campylobacter jejuni* in cattle farm samples. *Journal of Food Protection,* 77, 1593-1598. *doi*:10.4315/0362-028X.JFP-14-056

Donoghue, A. M., Farnell, M. B., Cole, K., & Donoghue, D. J. (2006). Mechanisms of pathogen control in the avian gastrointestinal tract. In G. C. Perry (Ed.), Avian Gut Function in Health and Disease (Vol. 20, pp. 138-155). US: CAB International. Retrieved from https://www.scribd.com/doc/75159325/Avian-Gut-Function-in-Health-and-Disease.

Doorduyn, Y., Van Den Brandhof, W. E., Van Duynhoven, Y. T., Breukink, B. J., Wagenaar, J. A., & Van Pelt, W. (2010). Risk factors for indigenous *Campylobacter jejuni* and *Campylobacter coli* infections in The Netherlands: a case-control study. *Epidemiology and Infections,* 138, 1391-1404. *doi*:10.1017/S095026881000052X

Edrington, T. S., Hume, M. E., Looper, M. L., Schultz, C. L., Fitzgerald, A. C., Callaway, T. R., Genovese, K. J., Bischoff, K. M., McReynolds, J. L., Anderson, R. C., & Nisbet, D. J. (2004). Variation in the faecal shedding of *Salmonella* and *E. coli* O157:H7 in lactating dairy cattle and examination of *Salmonella* genotypes using pulsed-field gel

electrophoresis. *Letters in Applied Microbiology,* 38, 366-372. *doi*:10.1111/j.1472-765X.2004.01495.x

EFSA. (2015). The European Union summary report on trends and sources of zoonoses, zoonotic agents and food-borne outbreaks in 2014. *EFSA Journal,* 13, 4329. *doi*:10.2903/j.efsa.2015.4329

EFSA, & ECDP. (2017). Multi-country outbreak of *Salmonella* Enteritidis phage type 8, MLVA profile 2-9-7-3-2 and 2-9-6-3-2 infections - European Food Safety Authority (EFSA) and European Centre for Disease, Prevention Control (ECDP). *EFSA Supporting Publications,* 14, 1188E. *doi*:10.2903/sp.efsa.2017.EN-1188

Eguale, T., Engidawork, E., Gebreyes, W. A., Asrat, D., Alemayehu, H., Medhin, G., Johnson, R. P., & Gunn, J. S. (2016). Fecal prevalence, serotype distribution and antimicrobial resistance of Salmonellae in dairy cattle in central Ethiopia. *BMC Microbiology,* 16, 1-11. *doi*:10.1186/s12866-016-0638-2

El-Tras, W. F., Holt, H. R., Tayel, A. A., & El-Kady, N. N. (2015). *Campylobacter* infections in children exposed to infected backyard poultry in Egypt. *Epidemiology and Infection,* 143, 308-315. *doi*:10.1017/S095026881400096X

Elgroud, R., Granier, S. A., Marault, M., Kerouanton, A., Lezzar, A., Bouzitouna-Bentchouala, C., Brisabois, A., & Millemann, Y. (2015). Contribution of avian *Salmonella enterica* isolates to human salmonellosis cases in Constantine (Algeria). *Biomedical Research International,* Article ID 352029. *doi*:10.1155/2015/352029

Evans, M. R., Ribeiro, C. D., & Salmon, R. L. (2003). Hazards of healthy living: bottled water and salad vegetables as risk factors for *Campylobacter* infection. *Emerging Infectious Diseases,* 9, 1219-1225. *doi*:10.3201/eid0910.020823

Fahrion, A., Jamir, L., Richa, K., Begum, S., Rutsa, V., Ao, S., Padmakumar, V., Deka, R. & Grace, D. (2014). Food-safety azards in the pork chain in Nagaland, North East India: Implications for human health. *International Journal of Environmental Research and Public Health,* 11**,** 403-417. *doi*:10.3390/ijerph110100403

Fernandez, F., Sharma, R., Hinton, M., & Bedford, M. R. (2000). Diet influences the colonization of *Campylobacter jejuni* and distribution of mucin carbohydrates in the

chick intestinal tract. *Cellular and Molecular Life Sciences CMLS,* 57, 1793-1801. *doi*:10.1007/pl00000659

Foti, M., Daidone, A., Aleo, A., Pizzimenti, A., Giacopello, C., & Mammina, C. (2009). Salmonella bongori 48:z(35):– in Migratory Birds, Italy. *Emerging Infectious Diseases,* 15, 502-503. *doi*:10.3201/eid1503.080039

Friesema, I., de Jong, A., Hofhuis, A., Heck, M., van den Kerkhof, H., de Jonge R., Hameryck, D., Nagel, K., van Vilsteren, G., van Beek, P., Notermans, D., & van Pelt, W. (2014). Large outbreak of *Salmonella* Thompson related to smoked salmon in the Netherlands, August to December 2012. *Eurosurveillance,* 19, 1-8. Retrived from http://dx.doi.org/10.2807/1560-7917.ES2014.19.39.20918

Gaffga, N. H., Behravesh, C. B., Ettestad, P. J., Smelser, C. B., Rhorer, A. R., Cronquist, A. B., Nicole A. Comstock, M.S.P.H., Bidol, S. A., Patel, N. J., Gerner-Smidt, P., Keene, W. E., Gomez, T. M., Hopkins, B. A., Sotir, M. J. & Angulo, F. J. (2012). Outbreak of salmonellosis linked to live poultry from a mail-order hatchery. *New England Journal of Medicine,* 366, 2065-2073. *doi:*10.1056/NEJMoa1111818

Gambino-Shirley, K., Stevenson, L., Concepción-Acevedo, J., Trees, E., Wagner, D., Whitlock, L., Roberts, J., Garrett, N., Van Duyne, S., McAllister, G., Schick, B., Schlater, L., Peralta, V., Reporter, R. Li, L., Waechter, H., Gomez, T., Fernández, O. J., Ulloa, S., Ragimbeau, C., Mossong, J., & Nichols, M. (2018). Flea market finds and global exports: Four multistate outbreaks of human Salmonella infections linked to small turtles, United States—2015. *Zoonoses and Public Health,* 65**,** 560-568. *doi*:10.1111/zph.12466

Gast, R. (2013). Paratyphoid infection. In J. R. Glisson, D. E. Swayne, L. R. McDougald, L. K. Nolan, D. L. Suarez, & V. L. Nair (Eds.), Diseases of Poultry (13th ed., pp. 693-706). U.S.A: Wiley-Blackwell. Retrieved from http://ezproxy.library.usyd.edu.au/login?url=http://search.ebscohost.com/login.aspx?direct=true&db=nlebk&AN=609465&site=ehost-live&scope=site.

Gast, R. K., Guraya, R., & Guard, J. (2013). *Salmonella* Enteritidis deposition in eggs after experimental infection of laying hens with different oral doses. *Journal of Food Protection,* 76, 108-113. *doi*:10.4315/0362-028X.JFP-12-268

Gast, R. K., Guraya, R., Jones, D. R., Anderson, K. E., & Karcher, D. M. (2016). Colonization of internal organs by *Salmonella* Enteritidis in experimentally infected laying hens housed in enriched colony cages at different stocking densities. *Poultry Science,* 95, 1363-1369. *doi:*10.3382/ps/pew037

Gast, R. K., Guraya, R., Jones, D. R., Guard, J., Anderson, K. E., & Karcher, D. M. (2017) Frequency and duration of fecal shedding of Salmonella serovars Heidelberg and Typhimurium by experimentally infected laying hens housed in enriched colony cages at different stocking densities, *Frontiers in Veterinary Science*, 47, 1-7. *doi*: 10.3389/fvets.2017.00047.

Gaydos, J. K. (2014). *Salmonella in wildlife.* Paper presented at the North American Veterinary Conference, Orlando, Florida.

Gharieb, R. M., Tartor, Y. H., & Khedr, M. H. (2015). Non-typhoidal *Salmonella* in poultry meat and diarrhoeic patients: prevalence, antibiogram, virulotyping, molecular detection and sequencing of class I integrons in multidrug resistant strains. *Gut Pathology,* 7, 1-11. *doi*:10.1186/s13099-015-0081-1

Glawischnig, W., Lazar, J., Wallner, A., & C. Kornschober, C. (2017). Cattle-derived *Salmonella* enterica serovar Dublin Infections in Red Foxes (*Vulpes vulpes*) in Tyrol, Austria. *Journal of Wildlife Diseases,* 53, 361-363. *doi:* 10.7589/2016-04-087

Gomes, F. R., Curcio, B. R., Ladeira, S. R. L,. Fernández, H., & Meireles, M. C. A. (2006). *Campylobacter jejuni* occurrence in chicken fecal samples from small properties in Pelotas, southern of Brazil. *Brazilian Journal of Microbiology,* 37, 375-378. Retrived from *http://www.scielo.br/scielo.php?script=sci_arttext&pid=S1517-83822006000300032*

Gopinath, S., Carden, S., & Monack, D. (2012). Shedding light on *Salmonella* carriers. *Trends in Microbiology,* 20, 320-327. *doi:*10.1016/j.tim.2012.04.004

Gras, L. M., Smid, J. H., Wagenaar, J. A., Koene, M. G. J., Havelaar, A. H., Friesema, I. H. M., French, N. P., Flemming, C., Galson, J. D., Graziani, C., Busani, L., & Van Pelt, W. (2013). Increased risk for *C. jejuni* and *C. coli* infection of pet origin in dog owners and evidence for genetic association between strains causing infection in

humans and their pets. *Epidemiology and Infection,* 141, 2526-2535. *doi:*10.1017/S0950268813000356

Griekspoor, P., Colles, F. M., McCarthy, N. D., Hansbro, P. M., Ashhurst-Smith, C., Olsen, B., Hasselquist, D., Maiden, M. C., & Waldenström, J. (2013). Marked host specificity and lack of phylogeographic population structure of *Campylobacter jejuni* in wild birds. *Molecular Ecology,* 22, 1463-1472. *doi*:10.1111/mec.12144

Grimont, P. A. D., & Weill, F.-X. (2007). *Antigenic formulae of the Salmonella serovars* (pp. 166). Retrieved from http://www.pasteur.fr/sante/clre/cadrecnr/salmoms/WKLM_

Grove-White, D. H., Leatherbarrow, A. J., Cripps, P. J., Diggle, P. J., & French, N. P. (2011). Molecular epidemiology and genetic diversity of *Campylobacter jejuni* in ruminants. *Epidemiology and Infection,* 139, 1661-1671. *doi*:10.1017/S0950268810002736

Grove-White, D. H., Leatherbarrow, A. J. H., Cripps, P. J., Diggle, P. J., & French, N. P. (2010). Temporal and farm-management-associated variation in the faecal-pat prevalence of *Campylobacter jejuni* in ruminants. *Epidemiology and Infection,* 138, 549-558. *doi*:10.1017/S0950268809991051

Hald, B., Marianne N., S. Eva, M., N., Rahbek, C., Madsen, J. J.,Waino, M., Chriel, M., Nordentoft, S., Dorte,L., B. & Madsen, M. (2016). *Campylobacter jejuni* and *Campylobacter coli* in wild birds on Danish livestock farms. *Acta Veterinaria Scandinavica,* 58, 1-10. *doi*: 10.1186/s13028-016-0192-9

Han, Z., Willer, T., Li, L., Pielsticker, C., Rychlik, I., Velge, P. Kaspers, B., & Rautenschlein, S. (2017). Influence of the Gut Microbiota Composition on Campylobacter jejuni Colonization in Chickens. *Infection and immunity,* 85, e00380-00317. *doi*: 10.1128/IAI.00380-17

Hanning, I., & Diaz-Sanchez, S. (2015) The functionality of the gastrointestinal microbiome in non-human animals. *Microbiome,* 3, 1-11. *doi:* 10.1186/s40168-015-0113-6

Hanson, D. L. (2015). *Salmonella in cattle populations in the Southern High Plains.* (Doctor of Philosophy), Texas Technical University, US.

Helm, R. A., Porwollik, S., Stanley, A. E., Maloy, S., McClelland, M., Rabsch, W. & Eisenstark, A. (2004) Pigeon-associated strains of *Salmonella enterica* serovar Typhimurium phage type DT2 have genomic rearrangements at rRNA operons. *Infection and Immunity,* 72, 7338-7341. *doi*: 10.1128/iai.72.12.7338-7341.2004

Holmberg, M., Rosendal, T., Engvall, E. O., Ohlson, A., & Lindberg, A. (2015) Prevalence of thermophilic *Campylobacter* species in Swedish dogs and characterization of *C. jejuni* isolates. *Acta Veterinaria Scandinavica,* 57, 1-8. *doi:* 10.1186/s13028-015-0108-0

Holt, P. S., Lara, E. V., Moore, R. W., & Gast, R. K. (2006). Comparison of *Salmonella enterica* Serovar Enteritidis levels in crops of fed or fasted infected hens. *Avian Diseases,* 50, 425-429. *doi*:http://dx.doi.org/10.1637/7519-022706R2.1

Hughes, L. A., Bennett, M., Coffey, P., Elliott, J., Jones, T. R., Jones, R. C., Lahuerta-Marin, A., Leatherbarrow, A. H., McNiffe, K., Norman, D., Williams, N. J., & Chantrey, J. (2009). Molecular epidemiology and characterization of *Campylobacter* spp. isolated from wild bird populations in Northern England. *Applied and Environmental Microbiology,* 75, 3007-3015. *doi*:10.1128/aem.02458-08

Hughes, L. A., Wigley, P., Bennett, M., Chantrey, J., & Williams, N. (2010). Multi- locus sequence typing of *Salmonella enterica* serovar Typhimurium isolates from wild birds in northern England suggests host- adapted strain. *Letters in Applied Microbiology,* 51, 477-479. *doi*:10.1111/j.1472-765X.2010.02918.x

Humphrey, S., Chaloner, G., Kemmett, K., Davidson, N., Williams, N., Kipar, A., Humphrey, T., & Wigley, P. (2014). *Campylobacter jejuni* is not merely a commensal in commercial broiler chickens and affects bird welfare. *mBio,* 5, e01364-01314. *doi*:10.1128/mBio.01364-14

Humphrey, T. (2004). *Salmonella*, stress responses and food safety. *Nature Reviews Microbiology,* 2, 504-509. *doi*:10.1038/nrmicro907

Humphrey, T. J., & Williams, L. K. (2017). Zoonosis affecting poultry: the case of *Campylobacter*. In S. Ricke (Ed.), *Achieving sustainable production of poultry meat. safety, quality and sustainability* (Vol. 1). UK: Burleigh Dodds Science.

Hussain, M. A., & Gooneratne, R. (2017) Understanding the fresh produce safetychallenges. *Foods (Basel, Switzerland),* 6, 1-2. *doi*:10.3390/foods6030023

Ibrahim, M. A., Emeash, H. H., Ghoneim, N. H., & Abdel-Halim, M. A. (2013). Seroepidemiological studies on poultry salmonellosis and its public health importance. *Journal of World's Poultry Research,* 3, 18-23.Retrieved from http://jwpr.science-line.com/attachments/article/16/J.%20World's%20Poult.%20Res.%203(1)%2018-23,%202013.pdf

Ido, N., Iwabuchi, K., Sato'O, Y., Sato, Y., Sugawara, M., Yaegashi, G., Konno, M., Akiba, M., Tanaka, K., Omoe, K., & Uchida, I. (2015). Molecular typing of *Salmonella enterica* serovar 4,[5],12:i:- isolates from humans, animals and river water in Japan by multilocus variable-number tandem repeat analysis and pulsed-field gel electrophoresis. *The Journal of Veterinary Medical Science,* 77, 609-613. *doi*:10.1292/jvms.14-0465

Inns, T., Lane, C., Peters, T., Dallman, T., Chatt, C., McFarland, N., Crook, P., Bishop, T., Edge, J., Hawker, J., Elson, R., Neal, K., Adak, G. K., & Cleary, P. (2015). A multi-country *Salmonella* Enteritidis phage type 14b outbreak associated with eggs from a German producer: 'near real-time' application of whole genome sequencing and food chain investigations, United Kingdom, May to September 2014. *Eurosurveillance,* 20, 1-8. Retrived from http://dx.doi.org/10.2807/1560-7917.ES2015.20.16.21098

Ishola, O. O. (2009). Effects of challenge dose on faecal shedding of *Salmonella enteritidis* in experimental infected chickens. *African Journal of Biotechnology,* 8, 1343-1346. *doi*:10.5897/AJB09.159

Jacob, P., Mdegela, R. H., & Nonga, H. E. (2011). Comparison of Cape Town and Skirrow's *Campylobacter* isolation protocols in humans and broilers in Morogoro, Tanzania. *Tropical Animal Health and Production,* 43**,** 1007-1013. *doi:* 10.1007/s11250-011-9799-z

Jacobson, A., Lam, L., Rajendram, M., Tamburini, F., Honeycutt, J. , Pham, T., Van Treuren, W., Pruss, K., Stabler, S. R., Lugo, K., Bouley, D. M., Vilches-Moure, J. G., Smith,

M., Sonnenburg, J. L., Bhatt, A. S., Huang, K. C., & Monack, D. (2018) A gut commensal-produced metabolite mediates colonization resistance to *Salmonella* infection. *Cell Host & Microbe,* 24, 296-307.e297. *doi:* 10.1016/j.chom.2018.07.002

Jensen, A. N., Dalsgaard, A., Stockmarr, A., Nielsen, E. M., & Baggesen, D. L. (2006). Survival and transmission of *Salmonella enterica* Serovar Typhimurium in an outdoor organic pig farming environment. *Applied and Environmental Microbiology,* 72, 1833-1842. *doi*:10.1128/AEM.72.3.1833–1842.2006

Jorgensen, F., Ellis-Iversen, J., Rushton, S., Bull, S. A., Harris, S. A., Bryan, S. J., Gonzalez, A., & Humphrey, T. J. (2011). Influence of season and geography on *Campylobacter jejuni* and *C. coli* subtypes in housed broiler flocks reared in Great Britain. *Applied and Environmental Microbiology,* 77, 3741-3748. *doi*:10.1128/aem.02444-10

Jurado-Tarifa, E., Torralbo, A., Borge, C., Cerdà-Cuéllar, M., Ayats, T., Carbonero, A., & García-Bocanegra, I. (2016). Genetic diversity and antimicrobial resistance of *Campylobacter* and *Salmonella* strains isolated from decoys and raptors. *Comparative Immunology, Microbiology and Infectious Diseases,* 48, 14-21. Retrieved from https://doi.org/10.1016/j.cimid.2016.07.003

Kagambega, A., Lienemann, T., Aulu, L., Traore, A. S., Barro, N., Siitonen, A., & Haukka, K. (2013). Prevalence and characterization of *Salmonella enterica* from the feces of cattle, poultry, swine and hedgehogs in Burkina Faso and their comparison to human *Salmonella* isolates. *BMC Microbiology,* 13, 1-9. *doi*:10.1186/1471-2180-13-253

Kantsø, B., Andersen, A.-M. N., Mølbak, K., Krogfelt, K. A., Henriksen, T. B., & Nielsen, S. Y. (2014). *Campylobacter, Salmonella,* and *Yersinia* antibodies and pregnancy outcome in Danish women with occupational exposure to animals. *International Journal of Infectious Diseases,* 28, 74-79. Retrieved from http://dx.doi.org/10.1016/j.ijid.2014.06.021

Kapperud, G., Espeland, G., Wahl, E., Walde, A., Herikstad, H., Gustavsen, S., Tveit, I., Natås, O., Bevanger, L., & Digranes, A. (2003). Factors associated with increased and decreased risk of *Campylobacter* infection: A prospective case-control study in Norway. *American Journal of Epidemiology,* 158, 234-242. *doi*:10.1093/aje/kwg139

Khan, I. U. H., Hill, S., Nowak, E., & Edge, T. A. (2013). Effect of incubation temperature on the detection of thermophilic *Campylobacter* species from freshwater beaches, nearby wastewater effluents, and bird fecal droppings. *Applied and Environmental Microbiology,* 79, 7639-7645. *doi*:10.1128/AEM.02324-13

Kirk, M. D., Pires, S. M., Black, R. E., Caipo, M., Crump, J. A., Devleesschauwer, B., Döpfer, D., Fazil, A., Fischer-Walker, C. L., Hald, T., Hall, A. J., Keddy, K. H., Lake, R. J., Lanata, C. F., Torgerson, P. R., Havelaar, A. H., & Angulo, F. J. (2015). World Health Organization estimates of the global and regional disease burden of 22 foodborne bacterial, protozoal, and viral diseases, 2010: A data synthesis. *PLOS Medicine,* 12, e1001921. *doi*:10.1371/journal.pmed.1001921

Kommadath, A., Bao, H., Arantes, A. S., Plastow, G. S., Tuggle, C. K., Bearson, S. M., Guan, L. L., & Stothard, P. (2014). Gene co-expression network analysis identifies porcine genes associated with variation in *Salmonella* shedding. *BMC Genomics, 15*(452), 1-15. *doi*:10.1186/1471-2164-15-452

Koski, L.,., Stevenson, L., Huffman, J., Robbins, A., Latash, J., Omoregie, E., Kline.K., & Nichols, M. (2018). An Outbreak of Salmonella Agbeni Infections Linked to Turtle Exposure - United States, 2017. MMWR Morbidity and Mortality Weekly Report, 67, 1350. *doi*: http://dx.doi.org/10.15585/mmwr.mm6748a5.

Kunze, D. J., Loneragan, G. H., Platt, T. M., Miller, M. F., Besser, T. E., Koohmaraie, M., . Stephens, T., & Brashears, M. M. (2008). *Salmonella enterica* burden in harvest-ready cattle populations from the Southern High Plains of the United States. *Applied and Environmental Microbiology,* 74, 345-351. *doi*:10.1128/aem.02076-07

Kusiluka, L. J. M., Karimuribo, E. D., Mdegela, R. H., Luoga, E. J., Munishi, P. K. T., Mlozi, M. R. S., & Kambarage, D. M. (2005). Prevalence and impact of water-borne zoonotic pathogens in water, cattle and humans in selected villages in Dodoma Rural and Bagamoyo districts, Tanzania. *Physics and Chemistry of the Earth,* 30, 818-825. *doi*:10.1016/j.pce.2005.08.025

Lambrecht, B. N., & Hammad, H. (2017) The immunology of the allergy epidemic and the hygiene hypothesis. *Nature Immunology,* 18, 1076-1083. *doi:* http://dx.doi.org/10.1038/ni.3829

Lawes, J. R., Vidal, A., Clifton-Hadley, F. A., Sayers, R., Rodgers, J., Snow, L., Evans, S. J., & Powell, L. F. (2012). Investigation of prevalence and risk factors for *Campylobacter* in broiler flocks at slaughter: results from a UK survey. *Epidemiology and Infection,* 140, 1725-1737. *doi*:10.1017/S0950268812000982

Leahy, A. M., Cummings, K. J., Rodriguez-Rivera, L. D., Rankin, S. C., & Hamer, S. A. (2016). Evaluation of faecal *Salmonella* shedding among dogs at seven animal shelters across Texas. *Zoonoses and Public Health,* 63, 515-521. *doi*:10.1111/zph.12257

Lebel, P., Letellier, A., Longpré, J., Laplante, B., Yergeau, E., & Fravalo, P. (2017). Feed presentation options in swine early fattening mitigates *Salmonella* shedding and specifically modulates the faecal microbiota. *Journal of Applied Microbiology,* 122, 30-39. *doi*:10.1111/jam.13305

Levantesi, C., Bonadonna, L., Briancesco, R., Grohmann, E., Toze, S., & Tandoi, V. (2012). *Salmonella* in surface and drinking water: Occurrence and water-mediated transmission. *Food Research International,* 45, 587-602. *doi*:10.1016/j.foodres.2011.06.037

Li, L., Pielsticker, C.. Han, Z., Kubasová, T., Rychlik, I., Kaspers B., & Rautenschlein, S. (2018) Infectious bursal disease virus inoculation infection modifies Campylobacter jejuni–host interaction in broilers. *Gut Pathogens,* 10, 13. *doi*:10.1186/s13099-018-0241-1

Li, X., Swaggerty, C. L., Kogut, M. H., Chiang, H. I., Wang, Y., Genovese, K. J., He, H., McCarthy, F. M., Burgess, S. C., Pevzner I. Y., & Zhou, H. (2012) Systemic response to *Campylobacter jejuni* infection by profiling gene transcription in the spleens of two genetic lines of chickens. *Immunogenetics,* **64,** 59-69. *doi*:10.1007/s00251-011-0557-1

Love, D., Madrigal, R., Cerveny, S., Raines, J., Rideout B., & Lung, N. P. (2017) Case series: Clinical salmonellosis in four black rhinoceros (Diceros bicornis) calves, *Journal of Zoo and Wildlife Medicine* 48, 466–475, Retrieved from https://doi.org/10.1638/2016-0081R.1

Lutful Kabir, S. M. (2010). Avian colibacillosis and salmonellosis: a closer look at epidemiology, pathogenesis, diagnosis, control and public health concerns. *International Journal of Environmental Research and Public Health,* 7, 89-114. *doi*:10.3390/ijerph7010089

Lyimo, B., Buza, J., Smith, W., Subbiah, M., & Call, D. R. (2016). Surface waters in northern Tanzania harbor fecal coliform and antibiotic resistant *Salmonella* spp. capable of horizontal gene transfer. *African Journal of Microbiology Research,* 10, 348-356. *doi*:10.5897/AJMR2015.7880

Macartney, L., Al-Mashat, R. R., Taylor, D. J., & McCandlish, I. A. (1988). Experimental infection of dogs with *Campylobacter jejuni*. *Veterinary Record,* 122, 245. *doi*:10.1136/vr.122.11.245

Mannering, S. A., West, D. M., Fenwick, S. G., Marchant, R. M., & O'Connell, K. (2006). Pulsed-field gel electrophoresis of *Campylobacter jejuni* sheep abortion isolates. *Veterinary Microbiology,* 115, 237-242. *doi*:10.1016/j.vetmic.2006.01.005

Manyi-Loh, C. E., Mamphweli, S. N., Meyer, E. L., Makaka, G., Simon, M., & Okoh, A. I. (2016). An overview of the control of bacterial pathogens in cattle manure. *International Journal of Environmental Reserch and Public Health* 13, 1-27. *doi*:10.3390/ijerph13090843

Maponga, B. A., Chirundu, D., Gombe, N. T., Tshimanga, M., Shambira, G. & Takundwa, L. (2013) Risk factors for contracting watery diarrhoea in Kadoma City, Zimbabwe, 2011: a case control study. *BMC Infectious Diseases,* 13, 567-567. *doi*:10.1186/1471-2334-13-567

Marotta, F., Garofolo, G., Di Donato, G., Aprea, G., Platone, I., Cianciavicchia, S., Alessiani, A., & Di Giannatale, E. (2015). Population diversity of *Campylobacter jejuni* in poultry and its dynamic of contamination in chicken meat. *BioMed Research International, 2015*, 1-10. Retrived from http://dx.doi.org/10.1155/2015/859845

Marshall, K. E. H., Tewell, M., Tecle, S., Leeper, M., Sinatra, J., Kissler, B., Fung, A., Brown, K., Wagner, D., Trees, E., Hise, K. B., Chaturvedi, V., Schlater, L. K., Morningstar-Shaw, B. R., Whitlock, L., Holt, K., Becker, K. Nichols, M., Williams,

I. T., Jhung, M., Wise, M. E., & Gieraltowski, L. (2018) Protracted Outbreak of Salmonella Newport Infections Linked to Ground Beef: Possible Role of Dairy Cows - 21 States, 2016-2017. *Morbidity and Mortality Weekly Report,* 67, 443-446. doi:10.15585/mmwr.mm6715a2

McCarthy, N. D., Gillespie, I. A., Lawson, A. J., Richardson, J., Neal, K. R., Hawtin, P. R., Maiden, M. C. J., & O'Brien, S. J. (2012). Molecular epidemiology of human *Campylobacter jejuni* shows association between seasonal and international patterns of disease. *Epidemiology and Infection,* 140, 2247-2255. *doi*:10.1017/S0950268812000192

Mdegela, R. H., Laurence, K., Jacob, P., & Nonga, H. E. (2011). Occurrences of thermophilic *Campylobacter* in pigs slaughtered at Morogoro slaughter slabs, Tanzania. *Tropical Animal Health and Production,* 43, 83-87. *doi:*10.1007/s11250-010-9657-4

Mead, G. C. (2002). Factors affecting intestinal colonization of poultry by *Campylobacter* and role of microflora in control. *World's Poultry Science Journal,* 58, 169-178. *doi*:10.1079/WPS20020016

Meerburg, B. G., & Kijlstra, A. (2007). Role of rodents in transmission of *Salmonella* and *Campylobacter*. *Journal of the Science of Food and Agriculture,* 87, 2774–2781. *doi*:10.1002/jsfa.3004

Mengistie, B., Y. Berhane & Worku, A., (2013) Household water chlorination reduces incidence of diarrhea among under-five children in rural Ethiopia: A cluster randomized controlled trial. *PLOS ONE,* 8, e77887. *doi*:10.1371/journal.pone.0077887

Merialdi, G., Giacometti, F., Bardasi, L., Stancampiano, L., Taddei, R., Serratore, P., & Serraino, A. (2015). Fecal shedding of thermophilic *Campylobacter* in a dairy herd producing raw milk for direct human consumption. *Journal of Food Protection,* 78, 579-584. *doi*:10.4315/0362-028X.JFP-14-224

Mhongole, O. J., Mdegela, R. H., Kusiluka, L. J. M., Forslund, A., & Dalsgaard, A. (2017). Characterization of *Salmonella* spp. from wastewater used for food production in

Morogoro, Tanzania. *World Journal of Microbiology and Biotechnology,*33, 1-7. *doi*:10.1007/s11274-017-2209-6

Mikkelsen, L. L., Naughton, P. J., Hedemann, M. S., & Jensen, B. B. (2004). Effects of physical properties of feed on microbial ecology and survival of *Salmonella enterica* serovar Typhimurium in the pig gastrointestinal tract. *Applied and Environmental Microbiology,* 70, 3485-3492. *doi*:10.1128/AEM.70.6.3485-3492.2004

Monack, D. M. (2012). *Salmonella* persistence and transmission strategies. *Current Opinion in Microbiology,* 15, 100-107. *doi*:10.1016/j.mib.2011.10.013

Moore, R. W., & Holt, P. S. (2006). The effect of feed deprivation on tissue invasion by *Salmonella enteritidis*. *Poultry Science,* 85, 1333-1337. Retrived from https://doi.org/10.1093/ps/85.8.1333

Msami, 2008: Poultry sector country review - Tanzania. In: J. Schwarz (Ed.). FAO Animal Production and Health Division. Retrieved from ftp://ftp.fao.org/docrep/fao/011/ai349e/ai349e00.pdf

Najwa, M. S., Rukayadi, Y., Ubong, A., Loo, Y. Y., Chang, W. S., Lye, Y. L., Thung, T. Y., Aimi, S, Malcolm, T. T. H, Goh, S. G., A., Kuan, C. H.,. Yoshitsugu, N., Nishibuchi, M., & Son, R. (2015). Quantification and antibiotic susceptibility of *Salmonella* spp., *Salmonella* Enteritidis and *Salmonella* Typhimurium in raw vegetables (ulam). *International Food Research Journal,* 22, 1761-1769. Retrived from http://www.ifrj.upm.edu.my/22%20(05)%202015/(4).pdf

Nguyen, V. T., Fegan, N., Turner, M. S., & Dykes, G. A. (2012). Role of attachment to surfaces on the prevalence and survival of *Campylobacter* through food systems. *Journal of Food Protection,* 75, 195-206. *doi*:10.4315/0362-028X.JFP-11-012

Nielsen, E. M., Fussing, V., Engberg, J., Nielsen, N. L., & Neimann, J. (2006). Most *Campylobacter* subtypes from sporadic infections can be found in retail poultry products and food animals. *Epidemiology and Infection,* 134, 758-767. *doi*:10.1017/S0950268805005509

Nollet, N., Houf, K., Dewulf, J., De Kruif, A., De Zutter, L., & MAES, D. (2005). *Salmonella* in sows: a longitudinal study in farrow-to-finish pig herds. *Veterinary Research,* 36, 645-656. *doi*:10.1051/vetres:2005022

Nonga, H. E., & Muhairwa, A. P. (2010). Prevalence and antibiotic susceptibility of thermophilic *Campylobacter* isolates from free range domestic duck (*Cairina moschata*) in Morogoro municipality, Tanzania. *Tropical Animal Health and Production,* 42, 165-172. *doi*:10.1007/s11250-009-9401-0

Nordentoft, S., Mølbak, L., Bjerrum, L., De Vylder, J., Van Immerseel, F., & Pedersen, K. (2011). The influence of the cage system and colonization of *Salmonella* Enteritidis on the microbial gut flora of laying hens studied by T-RFLP and 454 pyrosequencing. *BMC Microbiology,* 11, 187. *doi*:10.1186/1471-2180-11-187

O'Mahony, E., Buckley, J. F., Bolton, D., Whyte, P., & Fanning, S. (2011). Molecular epidemiology of *Campylobacter* isolates from poultry production units in Southern Ireland. *PLoS One,* 6, e28490. *doi*:10.1371/journal.pone.0028490

Oberhelman, R., A., Gilman, R., H., Sheen, P., Cordova, J., Zimic, M., Cabrera, L., Meza, R., & Perez, J. (2006). An intervention-control study of corralling of free-ranging chickens to control Campylobacter infections among children in a Peruvian periurban Shantytown. *American Journal of Tropical Medicine and Hygiene,* 74, 1054-1059. Retrived from http://www.ajtmh.org/cgi/pmidlookup?view=long&pmid=16760519

Ogden, I. D., Dallas, J. F., MacRae, M., Rotariu, O., Reay, K. W., Leitch, M., Thomson, A. P., Sheppard, S. K., Maiden, M., Forbes, K. J., & Strachan, N. J. C. (2009). *Campylobacter* excreted into the environment by animal sources: Prevalence, concentration shed, and host association. *Foodborne Pathogens and Disease,* 6, 1161-1170. *doi*:10.1089/fpd.2009.0327

Olobatoke, R. Y., & Mulugeta, S. D. (2015). Incidence of non-typhoidal *Salmonella* in poultry products in the North West Province, South Africa. *South African Journal of Science,* 111, 1-7. *doi*:10.17159/sajs.2015/20140233

Olson, P., & Sandstedt, K. (1987). *Campylobacter* in the dog: a clinical and experimental study. *Veterinary Record,* 121, 99. *doi*:10.1136/vr.121.5.99

Paião, F. G., Arisitides, L. G. A., Murate, L. S., Vilas-Bôas, G. T., Vilas-Boas, L. A., & Shimokomaki, M. (2013). Detection of *Salmonella* spp, *Salmonella* Enteritidis and Typhimurium in naturally infected broiler chickens by a multiplex PCR-based assay. *Brazilian Journal of Microbiology,* 44, 37-41 *doi*:10.1590/S1517-83822013005000002

Parada, J., Carranza, A., Alvarez, J., Pichel, M., Tamiozzo, P., Busso, J., & Ambrogi, A. (2017). Spatial distribution and risk factors associated with *Salmonella enterica* in pigs. *Epidemiology and Infection,* 145, 568-574. *doi*:10.1017/S0950268816002612

Pires, A. F. A., Funk, J. A., & Bolin, C. (2014). Risk factors associated with persistence of *Salmonella* shedding in finishing pigs. *Preventive Veterinary Medicine,* 116, 120-128. *doi*:10.1016/j.prevetmed.2014.06.009

Pornsukarom, S., & Thakur, S. (2016). Assessing the impact of manure application in commercial swine farms on the transmission of antimicrobial resistant *Salmonella* in the environment. *PLoS One,* 11, e0164621. *doi*:10.1371/journal.pone.0164621

Rabsch, W. (2007). *Salmonella* Typhimurium phage typing for pathogens. In H. Schatten & A. Eisenstark (Eds.), *Salmonella: Methods and Protocol* (Vol. 394, pp. 177-211). Totowa, New Jersey, USA: Humana Press. *doi*:10.1007/978-1-59745-512-1_10

Rabsch, W., Andrews, H. L., Kingsley, R. A., Prager, R., Tschäpe, H., Adams, L. G., & Bäumler, A. J. (2002). *Salmonella enterica* serotype Typhimurium and its host-adapted variants. *Infection and Immunity,* 70, 2249-2255. *doi*:10.1128/iai.70.5.2249-2255.2002

Ragione, R. L., Metcalfe, H. J., Villarreal- Ramos, B., & Werling, D. (2013). *Salmonella* Infections in Cattle. In P. A. Barrow, Methner, U. (Ed.), *Salmonella* in domestic animals (2nd ed., pp. 233-262). United Kingdom: CAB International. Retrieved from http://www.cabi.org.ezproxy1.library.usyd.edu.au/cabebooks/FullTextPDF/2013/20133229802.pdf. doi:10.1079/9781845939021.0000

Rahimi, E., Alipoor-Amroabadi, M., &Khamesipour, F. (2017) Investigation of prevalence of thermotolerant *Campylobacter* spp. in livestock feces. *Canadian Journal of Animal Science,* 97**,** 207-213. *doi:* 10.1139/cjas-2015-0166

Rasschaert, G., Michiels, J., Tagliabue, M., Missotten, J., Desmet, S., & Heyndrickx, M. (2016). Effect of organic acids on *Salmonella* shedding and colonization in pigs on a farm with high *Salmonella* prevalence. *Journal of Food Protection,* 79, 51-58. *doi*:10.4315/0362-028X.JFP-15-183

Ratert, C., Sander, S. J., Verspohl, J., Beyerbach, M., & Kamphues, J. (2014). Effects of the physical form of diet on the outcome of an artificial *Salmonella* infection in broilers. *Avian Diseases,* 59, 74-78. *doi*:10.1637/10890-062414-Reg

Rattanawut, J., Todsadee, A., & Yamauchi, K. (2017) Effect of dietary supplementation of silicic acid powder containing bamboo vinegar on production performance, egg quality, intestinal microflora, and morphology of laying hens. *Canadian Journal of Animal Science,* 98, 119-125.*doi*: 10.1139/cjas-2017-0041

Ravel, A., Smolina, E., Sargeant, J. M., Cook, A., Marshall, B., Fleury, M. D., & Pollari, F. (2010). Seasonality in human salmonellosis: Assessment of human activities and chicken contamination as driving factors. *Foodborne Pathogens and Disease,* 7, 785-794. *doi*:10.1089/fpd.2009.0460

Rebolledo, J., Garvey, P., Ryan, A., O'Donnell, J., Cormican, M., Jackson, S., Cloak, F., Cullen, L., Swaan, C. M., Schimmer, B., Appels, R. W., Nygard, K., Finley, R., Sreenivasan, N., Lenglet, A., Gossner, C., & McKeown, P. (2014). International outbreak investigation of *Salmonella* Heidelberg associated with in-flight catering. *Epidemiology and Infection,* 142, 833-842. *doi*:10.1017/S0950268813001714

Ribas, A., Saijuntha, W., Takeshi Agatsuma, Prantlova, V., & Poonlaphdecha, S. (2016). Rodents as a source of *Salmonella* contamination in wet markets in Thailand. *Vector-Borne and Zoonotic Diseases,* 16, 537-540. *doi*:10.1089/vbz.2015.1894

Ricke, S. C., & Gast, R. K. (2014). *Salmonella* Enteritidis. In M. Tortorello, Batt, C. A. (Ed.), Encyclopedia of Food Microbiology (2nd ed., pp. 343-348). Oxford: Academic Press. *doi*:10.1016/B978-0-12-384730-0.00295-0

Ritchie, H. & Roser, M. (2018). Meat and seafood production and consumption. Our World In Data. Retrieved from https://ourworldindata.org/meat-and-seafood-production-consumption

Robertson, S., Burakoff, A., Stevenson, L., Tompkins, B., Patel, K., Tolar, B., Whitlock, L., House, J., Schlater, L., Mackie, T., Morningstar-Shaw, B., Nichols, M. & Basler, C. (2018) Notes from the field. *Morbidity & Mortality Weekly Report,* 67**,** 1195-1196. *doi*:10.15585/mmwr.mm6742a6

Rosenquist, H., Sommer, H. M., Nielsen, N. L., & Christensen, B. B. (2006). The effect of slaughter operations on the contamination of chicken carcasses with thermotolerant *Campylobacter*. *International Journal of Food Microbiology,* 108, 226-232. *doi*:10.1016/j.ijfoodmicro.2005.12.007

Ruggeri, J.. Foresti, , F., Pavesi, R., Terrini, A., Giudici, F., Padoan, D., Corradi, A., Ossiprandi, M. C., Pasquali, P., & Alborali, G. L., (2018) The synergistic effect of organic acids, phytochemicals and a permeabilizing complex reduces *Salmonella* Typhimurium 1,4,[5],12:i-shedding in pigs. *Veterinary research communications,* 42, 209-217. *doi*:10.1007/s11259-018-9723-3

Saha, A. K., Sufian, M. A., Hossain, M. I., & Hossain, M. M. (2012). Salmonellosis in layer chickens: pathological features and isolation of bacteria from ovaries and inner content of laid eggs. *Journal of Bangladeshi Agriculture University,* 10, 61-67. Reftrived from http://dx.doi.org/10.3329/jbau.v10i1.12095

Santos, F. B. O., Sheldon, B. W., Santos Jr, A. A., & Ferket, P. R. (2008). Influence of housing system, grain type, and particle size on *Salmonella* colonization and shedding of broilers fed triticale or corn-soybean meal diets. *Poultry Science,* 87, 405-420. *doi*:10.3382/ps.2006-00417

Schildt, M., Savolainen, S., & Hanninen, M. L. (2006). Long-lasting *Campylobacter jejuni* contamination of milk associated with gastrointestinal illness in a farming family. *Epidemiology and Infection,* 134, 401-405. *doi*:10.1017/S0950268805005029

Schmid, M. W., Lehner, A., Stephan, R., Schleifer, K.-H., & Meier, H. (2005). Development and application of oligonucleotide probes for in situ detection of thermotolerant

Campylobacter in chicken faecal and liver samples. *International Journal of Food Microbiology,* 105, 245-255. *doi*:10.1016/j.ijfoodmicro.2005.04.012

Schulze, F., Bagon, A., Müller, W., & Hotzel, H. (2006). Identification of *Campylobacter fetus* subspecies by phenotypic differentiation and PCR. *Journal of Clinical Microbiology,* 44, 2019-2024. *doi*:10.1128/JCM.02566-05

Schwartz, K. J. (1999). Salmonellosis. In B. E. Straw, D'Allaire, S., Mengeling, W. L., Taylor, D. J. (Ed.), *Diseases of Swine* (8th ed., pp. 535-551). Ames, Iowa: Iowa State University Press.

Schweitzer, N., Dan, A., Kaszanyitzky, E., Samu, P., Toth, A. G., Varga, J., & Damjanova, I. (2011). Molecular epidemiology and antimicrobial susceptibility of *Campylobacter jejuni* and *Campylobacter coli* isolates of poultry, swine, and cattle origin collected from slaughterhouses in Hungary. *Journal Food Protection,* 74, 905-911. *doi*:10.4315/0362-028X.JFP-10-376

Shivarprasad, H. L., & Barrow, P. A. (2013). Pullorum Disease and Fowl Typhoid. In J. R. GLISSON, D. E. SWAYNE, L. R. MCDOUGALD, L. K. NOLAN, EDITOR., D. L. SUAREZ, & V. L. NAIR (Eds.), Diseases of Poultry (13th ed., pp. 678-693). U.S.A: Wiley-Blackwell. Retrieved from http://ezproxy.library.usyd.edu.au/login?url=http://search.ebscohost.com/login.aspx?direct=true&db=nlebk&AN=609465&site=ehost-live&scope=site.

Simaluiza, R. J., Toledo, Z., Ochoa, S., & Fernandez, H. (2015). The prevalence and antimicrobial resistance of *Campylobacter jejuni* and *Campylobacter coli* in chicken livers used for human consumption in Ecuador. *Journal of Animal and Veterinary Advances,* 14, 6-9. *doi*:10.3923/javaa.2015.6.9

Smith, S., Messam, L. L. M., Meade, J., Gibbons, J., McGill, K., Bolton, D., & Whyte, P. (2016). The impact of biosecurity and partial depopulation on *Campylobacter* prevalence in Irish broiler flocks with differing levels of hygiene and economic performance. *Infection Ecology and Epidemiology,* 6, 31454. *doi*:10.3402/iee.v6.31454

Sokolow, S. H., Rand, C., Marks, S. L., Drazenovich, N. L., Kather, E. J., & Foley, J. E. (2005). Epidemiologic evaluation of diarrhea in dogs in an animal shelter. *American Journal of Veterinary Research,* 66, 1018-1024. *doi*:10.2460/ajvr.2005.66.1018

Spector, M. P., & Kenyon, W. J. (2012). Resistance and survival strategies of *Salmonella enterica* to environmental stresses. *Food Research International,* 45, 455-481. Retrieved from http://doi.org/10.1016/j.foodres.2011.06.056

Sproston, E. L., Ogden, I. D., MacRae, M., Dallas, J. F., Sheppard, S. K., Cody, A. J., Colles, F. M., Wilson, M. J., Forbes, K. J., & Strachan, N. J. C. (2011). Temporal variation and host association in the *Campylobacter* population in a longitudinal ruminant farm study. *Applied and Environmental Microbiology,* 77, 6579-6586. *doi*:10.1128/aem.00428-11

Stanley, K., & Jones, K. (2003). Cattle and sheep farms as reservoirs of *Campylobacter*. *Journal of Applied Microbiology,* 94, 104-113. *doi*:10.1046/j.1365-2672.94.s1.12.x

Stanley, K. N., Wallace, J. S., Currie, J. E., Diggle, P. J., & Jones, K. (1998). The seasonal variation of thermophilic campylobacters in beef cattle, dairy cattle and calves. *Journal of Applied Microbiology,* 85, 472-480. *doi*:10.1046/j.1365-2672.1998.853511.x

Stein, M. M., Hrusch, C. L., Gozdz, J., Igartua, C., Pivniouk, V., Murray, S. E., Ledford, J. G., Marques dos Santos, M., Anderson, R. L., Metwali, N., Neilson, J. W. Maier, R. M., Gilbert, J. A., Holbreich, M., Thorne, P. S., Martinez, F. D., von Mutius, E., Vercelli, D., Ober, C. & Sperling, A. I. (2016) Innate immunity and asthma risk in Amish and Hutterite farm children. *New England Journal of Medicine,* 375**,** 411-421. *doi*:10.1056/NEJMoa1508749

Stevens, M. P., & Gray, J. T. (2013). *Salmonella* infections in pigs. In p. A. Barrow, Methner, U. (Ed.), Salmonella in domestic animals (2nd ed., pp. 263-293). United Kingdom: CAB International. Retrieved from http://www.cabi.org.ezproxy1.library.usyd.edu.au/cabebooks/ebook/20133229802.

Stone, D., Davis, M., Baker, K., Besser, T., Roopnarine, R., & Sharma, R. (2013). MLST genotypes and antibiotic resistance of *Campylobacter* spp. Isolated from poultry in

Grenada. *BioMed Research International*, Article ID 794643. *doi*:10.1155/2013/794643

Strauch, A. M., & Almedom, A. M. (2011). Traditional water resource management and water quality in rural Tanzania. *Human Ecology,* 39, 93-106. *doi*:10.1007/s10745-011-9376-0

Studahl, A., & Andersson, Y. (2000). Risk factors for indigenous *Campylobacter* infection: a Swedish case-control study. *Epidemiology and Infection,* 125, 269-275. Retrived from http://www.jstor.org/stable/3865174

Subler, K. A., Mickael, C. S., & Jackwood, D. J. (2006). Infectious bursal disease virus-induced immunosuppression exacerbates *Campylobacter jejuni* colonization and shedding in chickens. *Avian Diseases,* 50, 179-184. *doi*:10.1637/7434-090705R.1

Suzuki, H.& Yamamoto, S. (2009) *Campylobacter* contamination in retail poultry meats and by-products in the world: A literature survey. *Journal of Veterinary Medical Science,* 71, 255-261. *doi*: https://doi.org/10.1292/jvms.71.255

Taff, C. C. & Townsend, A. K. (2017) *Campylobacter jejuni* infection associated with relatively poor condition and low survival in a wild bird. *Journal of Avian Biology,* 48, 1071-1076. *doi*:10.1111/jav.01282

Takata, T., Liang, J., Nakano, H., & Yoshimura, Y. (2003). Invasion of *Salmonella* Enteritidis in the tissues of reproductive organs in laying Japanese quail: an immunocytochemical study. *Poultry Science, 82*(7), 1170-1173. Retrived from https://doi.org/10.1093/ps/82.7.1170

Taylor, E. V., Herman, K. M., Ailes, E. C., Fitzgerald, C., Yoder, J. S., Mahon, B. E., & Tauxe, R. V. (2013). Common source outbreaks of *Campylobacter* infection in the USA, 1997-2008. *Epidemiology and Infection,* 141, 987-996. *doi*:10.1017/S0950268812001744

Thomas, J. L., Slawson, R. M., & Taylor, W. D. (2013). *Salmonella* serotype diversity and seasonality in urban and rural streams. *Journal of Applied Microbiology,* 114, 907-922. *doi*:10.1111/jam.12079

Trongjit, S., Angkititrakul, S., Tuttle, R. E., Poungseree, J., Padungtod, P., & Chuanchuen, R. (2017). Prevalence and antimicrobial resistance in *Salmonella enterica* isolated from broiler chickens, pigs and meat products in Thailand–Cambodia border provinces. *Microbiology and Immunology,*61, 23-33. *doi*:10.1111/1348-0421.12462

Truyers, I., Luke, T., Wilson, D., & Sargison, N. (2014). Diagnosis and management of venereal campylobacteriosis in beef cattle. *BMC Veterinary Research,* 10, 280. *doi*:10.1186/s12917-014-0280-x

Uthe, J. J., Bearson, S. M. D., Qu, L., Dekkers, J. C., Nettleton, D., Rodriguez, T. Y., Connor, A. M. O., McKean, J. D., & Tuggle, C. K. (2011). Integrating comparative expression profiling data and association of SNPs with *Salmonella* shedding for improved food safety and porcine disease resistance. *Animal Genetics,* 42, 521-534. *doi*:10.1111/j.1365-2052.2010.02171.x

Uzzau, S. (2013). *Salmonella* infections in sheep. In P. A. Barrow, Methner, U. (Ed.), *Salmonella* in domestic animals (2nd ed., pp. 295-304). United Kingdom: CAB International. *doi*:10.1079/9781845939021.0000

Van Gerwe, T. J. W. M., Bouma, A., Jacobs-Reitsma, W. F., van den Broek, J., Klinkenberg, D., Stegeman, J. A., & Heesterbeek, J. A. P. (2005). Quantifying transmission of *Campylobacter* spp. among broilers. *Applied and Environmental Microbiology,* 71, 5765-5770. *doi*:10.1128/aem.71.10.5765-5770.2005

van Immerseel, F., De Buck, J., Pasmans, F., Bohez, L., Haesebrouck, F., & Ducatelle, R. (2004). Intermittent long-term shedding and induction of carrier birds after infection of chicken early posthatch with a low or high dose of *Salmonella* Enteritidis. *Poultry Science,* 83, 1911-1916. *doi*: https://doi.org/10.1093/ps/83.11.1911

Verbrugghe, E., Boyen, F., Van Parys, A., Van Deun, K., Croubels, S., Thompson, A., . Shearer, N., Leyman, B., Haesebrouck, F., & Pasmans, F. (2011). Stress induced *Salmonella* Typhimurium recrudescence in pigs coincides with cortisol induced increased intracellular proliferation in macrophages. *Veterinary Research,* 42, 118-118. *doi*:10.1186/1297-9716-42-118

Vinueza-Burgos, C., Cevallos, M., Ron-Garrido, L., Bertrand, S., & De Zutter, L. (2016). Prevalence and diversity of *Salmonella* serotypes in Ecuadorian broilers at slaughter age. *PLoS One,* 11, e0159567. *doi*:10.1371/journal.pone.0159567

Wang, L., Li, L., Lv, Y., Chen, Q., Feng , J., & Zhao, X. (2018) *Lactobacillus plantarum* restores intestinal permeability disrupted by *Salmonella* infection in newly-hatched chicks. *Scientific Reports,* 8,. *doi*:10.1038/s41598-018-20752-z

Whiley, H., van den Akker, B., Giglio, S., & Bentham, R. (2013). The role of environmental reservoirs in human campylobacteriosis. *International Journal of Environmental Research and Public Health,* 10, 5886-5907. *doi*:10.3390/ijerph10115886

WHO. (2012). *The global view of campylobacteriosis: report of an expert consultation*. Geneva, Switzerland. Retrieved from www.who.int/iris/bitstream/10665/80751/1/9789241564601_eng.pdf

Wilfred, R. S., K., N. P., & Naveen, K. G. S. (2012). Prevalence of food borne pathogens in market samples of chicken meat in Bangalore. *International Food Research Journal,* 19, 1763-1765. Retrived from http://www.ifrj.upm.edu.my/19%20(04)%202012/65%20IFRJ%2019%20(04)%202012%20Ruban%20(206).pdf .

Williams, P. G., 2007: Nutritional composition of red meat. *Nutrition and Dietetics,* 64**,** S113-S119. Retrieved from http://ro.uow.edu.au/hbspapers/48

Wright, J. G., Tengelsen, L. A., Smith, K. E., Bender, J. B., Frank, R. K., Grendon, J. H., Rice, D. H., Thiessen, A. M. B., Gilbertson, C. J., Sivapalasingam, S., Timothy, B. J. Besser, T. E., Hancock, D. D., & Angulo, F. J. (2005). Multidrug-resistant *Salmonella* Typhimurium in four animal facilities. *Emerging Infectious Disease journal,*11, 1235-1241. *doi:*10.3201/eid1108.050111

Yano, S., Amano, E., Katou, A., Taneda, I., Tsutsui, T., & Murase, T. (2014). Intestinal carriage and excretion of *Campylobacter jejuni* in chickens exposed at different ages. *Journal of Food Protection,* 77, 1184-1187. *doi*:10.4315/0362-028.JFP-14-061

You, Y., Rankin, S. C., Aceto, H. W., Benson, C. E., Toth, J. D., & Dou, Z. (2006). Survival of *Salmonella enterica* serovar Newport in manure and manure-amended soils.

Applied and Environmental Microbiology, 72, 5777-5783. *doi*:10.1128/AEM.00791-06

Zenner, D., Zoellner, J., Charlett, A., Marmairis, W., Lane, C., & Chow, J. Y. (2014). Till receipts - a new approach for investigating outbreaks? Evaluation during a large *Salmonella* Enteritidis phage type 14b outbreak in a north west London takeaway restaurant, September 2009. *Eurosurveillance,* 19, 1-8. Retrived from http://dx.doi.org/10.2807/1560-7917.ES2014.19.27.20848

Zhang, Y., Bi, P., & Hiller, J. E. (2009). Climate variations and *Salmonella* infection in Australian subtropical and tropical regions. *Science of the Total Environment,* 408, 524-530. *doi*:10.1016/j.scitotenv.2009.10.068

Zishiri, O. T., Mkhize, N., & Mukaratirwa, S. (2016). Prevalence of virulence and antimicrobial resistance genes in *Salmonella* spp. isolated from commercial chickens and human clinical isolates from South Africa and Brazil. *Onderstepoort Journal of Veterinary Research,* 83, 1-11. *doi*:http://dx.doi.org/10.4102/