DISCONTOOLS

Salmonella enterica
Summary

Introduction

1. This note provides a summary of an analysis undertaken by the DISCONTOOLS group of experts on salmonellosis. They reviewed the current knowledge on the infection caused by this bacterium, considered the existing ways of prevention and control tools, identified current gaps in the availability and quality of the control tools and finally determined the research necessary to develop new or improved tools to prevent and control the infection. The group included experts with diverse backgrounds from various geographical regions of the EU. Their contributions were primarily based on consultations with specialists involved in *Salmonella* surveillance and control across different animal species in the countries where they work, as well as bibliography consultancy. Full details of their analysis can be downloaded from the web site at http://www.discontools.eu/ while the full gap analyses matrices can be found on the website and downloaded here

Disease profile

2. *Salmonellae* are found worldwide in both warm- and cold-blooded animals as well as in the environment. There are more than 2500 serovars of *Salmonella*e although the most commonly encountered in cases of disease in humans are *S.* Enteritidis, *S.* Typhimurium and the monophasic variant of *S*. Typhimurium. Although *Salmonella* prevalence varies significantly across species and geographic areas, the infection is generally more common in intensively reared animals, in countries with less stringent control programmes and in warmer climates.
3. In animals, generally *Salmonella* is asymptomatic. In the relatively rare cases of clinical infections, typical signs include diarrhoea, septicaemia, abortion and pneumonia. Acute infections primarily affect young animals and may lead to death with case-fatality rates that can be high.
4. In humans, the infection may cause diarrhoea, abdominal pain, fever, headache, nausea and vomiting. In severe cases, septicaemia and further complications may develop, and death might occur. The most serious cases are generally seen in infants, small children, the elderly and immunocompromised individuals. Infection is usually via ingestion of contaminated food. In rare situations can occur through direct contact with infected animals and contaminated environments.
5. Asymptomatic carriers may excrete *Salmonella* for several weeks and, in a minority of cases, become persistent carriers excreting the bacterium throughout the entire lifetime. Others may harbour a latent infection and shed the bacterium only during periods of stress. Most animal infections result from transmission by carrier animals or contaminated feed, with the faecal-oral route being the normal mode of transmission. Infections generally begin in young animals when maternal antibodies are wearing off. In intensive poultry in particular, vertical transmission via the egg is a recognised route of transmission.

Risk

6. Following a positive trend in the EU, which shows a reduction in reported human cases of salmonellosis, largely due to improved control of *S.* Enteritidis in poultry, the situation has recently stabilized in terms of human cases. However, some countries have seen an increase in human cases caused by *S.* Typhimurium and its monophasic variant. This is thought to be largely associated with increased pig meat consumption-related cases. Human cases reach a peak in summer, likely due to challenges in maintaining the cool-chain of food, to the consumption of undercooked meat during outdoor cooking and, in general, food habits related to the consumption of fresh-raw food.

7. Spread of infection between holdings can be rapid if carrier animals are distributed widely. *Salmonella* can survive for months in indoor environments. Rodents, wild birds and insects may act as vectors. Some emergent serovars have effectively colonized specific epidemiological niches, for example *S*. Infantis in broilers, leading to increased epidemiological success also associated with the persistence of such serovar at farm levels and along the production chain (from the primary production, through slaughterhouse and meat processing plans).
8. A number of on-farm measures—including strict biosecurity protocols, cleaning and disinfection routines, manure removal, dietary modulation of the intestinal microbiota, and monitoring the status of incoming animals—help prevent the introduction and within-herd spread of *Salmonella*. Surveillance at the slaughterhouse and slaughter techniques can significantly reduce the number of human infections originating from contaminated meat. In the EU, some Nordic countries have been able to eradicate the disease from some animal species (e.g. poultry), by implementing different control strategies.
9. Climate change, through rising temperatures and extreme weather events, is increasing the incidence and spread of *Salmonella* by accelerating bacterial growth and boosting vector activity. Effective disease control measures, such as systematic monitoring and improved hygiene, are essential but often demand higher water, energy, and chemical use, posing sustainability challenges. Non-climatic factors like urbanization and intensive farming interact with climate effects, reshaping *Salmonella* distribution and outbreak risks, especially in vulnerable areas. Without robust and adaptive prevention strategies, the frequency and severity of *Salmonella* outbreaks are likely to rise as climate change progresses.

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Diagnostics

10. A number of serological tests are available for the diagnosis of *Salmonella*. Historically, whole blood tests, serum agglutination and meat juice ELISAs have been used and in some contexts, they continue to be used. Depending on the antigen and tests used, serological cross-reactions can occur between different serovars and even with some non-*Salmonella* organisms, so bacterial isolation is required for confirmatory diagnosis. Indeed, *Salmonella* isolation remains the gold standard and is essential for carrying out further investigations such as serotyping, antimicrobial resistance profile and further typing of *Salmonella* isolates.
11. Identifying the *Salmonella* serovar is a crucial point in the epidemiological context of *Salmonella* surveillance. The availability of rapid and user-friendly diagnostic kits for the identification of *Salmonella* serovars would be highly beneficial. A molecular serotyping test targeting the main *Salmonella* serovars has been developed and WOAH validated. Other molecular typing methods could be beneficial for *Salmonella* diagnosis.
12. Development of new diagnostic tests, which also cover unconventional matrices such as aerosol, could be valuable.
13. Whole genome sequencing and genomic applications could be set up on a routine basis in diagnostic laboratories since these methodologies are superior to all existing methods for diagnosis, epidemiological studies, and surveillance of *Salmonella* isolates, although this analytical approach still remains relatively costly.

Vaccines

14. There are several inactivated and live vaccines available, primarily targeting *S*. Enteritidis and *S.* Typhimurium, in mono or bivalent formulations, and they are mainly used in poultry.
15. *Salmonella* vaccination programmes have been considered a successful measure for reducing *Salmonella* prevalence in several EU countries, particularly in relation to control programmes targeting poultry populations. Conversely, in areas where *Salmonella* prevalence is very low (e.g. North EU countries), vaccination is generally not considered an effective control measure. Whereas, in some other geographical areas, where *Salmonella* prevalence is non- negligible, vaccination remains one of the most used tools for the control of this pathogen, especially in poultry flocks.
16. The current vaccines are claimed to reduce the infection and mortality in affected animals but are not guaranteed to prevent infection.

17. The use of vaccines against Salmonella must be economically sustainable; therefore, they should be highly effective, reasonably priced, and evaluated in relation to the specific epidemiological context in which they are applied. It would be valuable to quantify the real benefits of vaccination across different animal species through cost-benefit analyses.

Pharmaceuticals

18. In most cases, *Salmonella* causes asymptomatic infections in livestock, so pharmaceutical treatments are rarely used. For instance, calves are treated when suffering from a severe clinical form of the infection. Antibiotic treatment of flocks of poultry is not permitted for control of *Salmonella,* unless there is a welfare implication or the potential loss of valuable genetic lines. For other animal species, antibiotics are not generally used to treat infected animals. Successful control of *Salmonella* relies fundamentally on Good Farming and Good Hygienic Practices from the stable to the table.
19. The approach for controlling *Salmonella* is characterized by applying several intervention strategies that work synergically to minimize contamination risks. Control starts at the farm and includes qualified management in connection with strict cleaning and disinfection, pest control and strict biosecurity protocols. Moreover, within-herd spreading of *Salmonella* may be reduced using certain kinds of feed, prebiotics, probiotics and competitive exclusion agents of organic acids added to feed or water.
20. Any new antibiotics will probably be restricted to use in human medicine for the foreseeable future. The potential for developing new antibiotics for agricultural use is thought to be limited.

Knowledge

21. More needs to be known about serovar variability between countries and within individual serovars. There are some gaps in knowledge about virulence factors and host- pathogen interactions in key target species. Research tackling the identification of virulent clones, investigating their ability to spread in different epidemiological niches and molecular drivers associated with their epidemiological success, would be highly valuable for improving *Salmonella* control.
22. Detailed longitudinal and quantitative data on herd infection, environmental spread, and slaughterhouse contamination dynamics are needed to better understand the epidemiology and to populate transmission models. Moreover, it would be valuable to know the relative risk of different vectors, different sources of infection and infectious doses. Details of bacterial shedding, including variability, time and numbers, in food animals and in humans are lacking. The reasons behind global spread of some strains compared to others and for the rise and fall of epidemic strains are poorly understood.
23. Validated procedures for minimising *Salmonella* populations on large farms, especially pig farms, are lacking. Cost benefit analyses of control measures may be valuable to provide convincing evidence of the value of investment in *Salmonella* prophylaxis.
24. There is a lack of multi-year, cross-regional studies and integrated frameworks that combine climate, genomic, and mobility data to understand and forecast *Salmonella* outbreaks, especially in low- and middle-income countries. Key knowledge gaps remain, particularly regarding the efficiency of transmission by various vectors, the role of microclimates and environmental reservoirs, the sustainability of control strategies, and how climate change will affect both the effectiveness and environmental impact of interventions.
25. Social science studies are needed to understand barriers and motivators for consistently implementing biosecurity measures along the food chain, as these currently represent a cornerstone of *Salmonella* control along the food chain.

Conclusions

26. *Salmonella*e are widespread in the environment and are most prevalent in areas of animal husbandry. Many animals may be infected without showing any clinical illness and are therefore important in the spread of the disease. The widespread nature of the bacteria, together with its longevity and diversity in the environment constitute the main obstacles to prevention and control.
27. Although diagnostic methods are available, further developments leading to faster, more reliable, and more affordable results and covering alternative matrices, would be valuable. Moreover, *Salmonella* typing is essential for many epidemiological investigations. However, it is currently performed by reference laboratories, especially when based on whole genome sequencing (WGS), which is the gold standard, partly due to the still high cost.
28. At the EU level, the situation is highly fragmented in terms of control and surveillance programmes implemented by different countries and covering different animal species.
29. In most cases, *Salmonella* infection in livestock is asymptomatic, and pharmaceutical treatments are not used. The control approach involves the synergistic application of multiple interventions aimed at minimizing the risk of contamination. Control begins at the farm level and includes proper management practices combined with strict cleaning and disinfection protocols, pest control, and rigorous biosecurity measures. Additionally, *Salmonella* prevention can be supported by the use of feed or water additives such as prebiotics, probiotics, competitive exclusion agents, and organic acids. Equally important is maintaining high standards of slaughter hygiene to prevent meat contamination.