Exploring Alternatives to Antibiotics for Reducing Salmonella in Poultry

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Scientia

EXPLORING ALTERNATIVES TO ANTIBIOTICS FOR REDUCING SALMONELLA IN POULTRY

Salmonella remains the leading pathogen of food safety concern in the US, with poultry being the main vector. For many years, poultry producers have relied on antibiotics to curtail the prevalence of pathogens in their flocks. However, consumer concerns and the rise of antimicrobial resistance are leading to the withdrawal of antibiotics, leaving farmers in unchartered territory. **Dr Adelumola Oladeinde** at the US Department of Agriculture is collaborating with researchers from the University of Georgia and Colorado State University to develop novel techniques for reducing Salmonella in chickens. Their work focuses on preventing infection and predicting risk in antibiotic-free production.

Salmonella: A Long-standing Problem

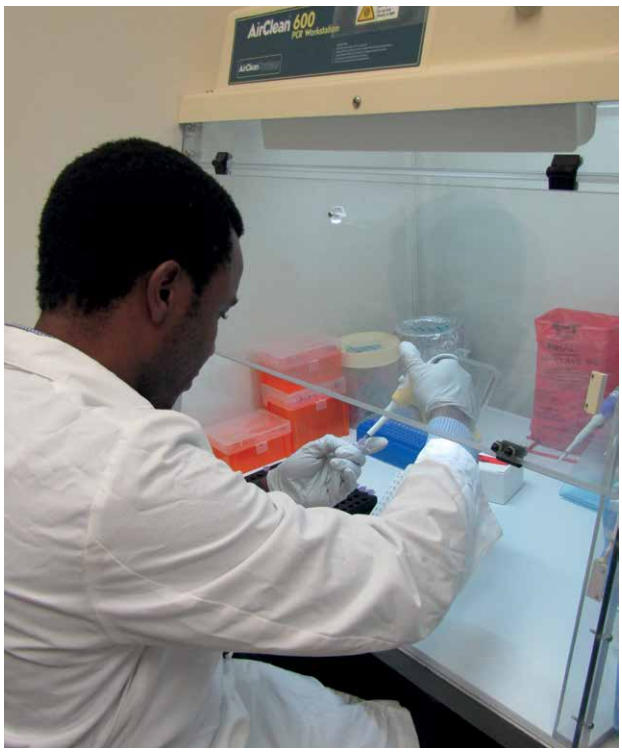
The US supports a multi-billion-dollar poultry industry and is currently the world's largest producer of broilers – chickens bred and raised specifically for meat production. However, broiler production in the US and worldwide is facing emerging challenges of animal health and food safety. Concerns over the human-health impacts of using antibiotics against bacteria such as Salmonella are leading to a push towards antibiotic-free broiler production. However, this could put birds at high risk of infection and increase the likelihood of food contamination.

Each year, Salmonella infects around 1.2 million people and results in economic losses of between 2.3 and 11.3 billion dollars in the US. Salmonella infection (salmonellosis) is a bacterial disease that affects the human intestinal tract and is usually characterised by the acute onset of fever, abdominal pain, diarrhoea, nausea and sometimes vomiting. Humans are most frequently infected through contaminated water or food, with poultry being the major cause of Salmonella infection.

In poultry production, the practice of using antibiotics to treat avian diseases can lead to the survival and subsequent proliferation of strains of bacteria that are resistant to the antibiotics used. These bacteria can then be transferred to consumers through meat and eggs.

Alongside the use of antibiotics, vaccination of broiler chickens is another common intervention adopted by producers to prevent diseases. However, there are currently no vaccines that can protect against all strains of Salmonella.

The prevalence of Salmonella in poultry has remained unchanged for many decades, leading Dr Adelumola Oladeinde at the US Department of Agriculture's Agricultural Research Service (USDA-ARS) to seek a novel



approach to reducing and identifying Salmonella infection in poultry production. Working with a multidisciplinary research team from the USDA-ARS, University of Georgia and Colorado State University, Dr Oladeinde has focused his research on Salmonella Heidelberg – one of the main strains of Salmonella that causes food-borne outbreaks.

'Infections caused by Salmonella Heidelberg are also more invasive than other strains, and Salmonella Heidelberg associated with poultry tends to carry antibiotic resistance and virulence genes,' says Dr Oladeinde. 'Therefore, Salmonella Heidelberg represents a model organism for testing the mechanisms that we have been developing.'

The team's research so far indicates that Salmonella is a hardy pathogen that is nearly impossible to get rid of after it successfully colonises a broiler farm. 'Our work therefore shows that it may be worthwhile directing resources towards prediction and prevention rather than decontamination or vaccination,' explains Dr Oladeinde. 'Consequently, we are focusing our efforts in two key areas – examining how the type of poultry litter used in broiler houses can prevent infection and development of antibiotic resistance, and devising a flock health monitoring system that can help us to predict infection risk sooner.'

Importance of the Litter Microbiome

Raising billions of broilers each year requires over 10 million metric tonnes of poultry litter annually in the US. This litter is composed of wood shavings, rice hulls, or sawdust, and becomes mixed with chicken faeces, uric acid, feathers and feed. Because of the increasing cost of bedding materials, and to reduce waste, it is common and well-accepted practice in the US to recycle these materials over multiple flocks for a year or longer.

Dr Oladeinde and his team wanted to study the impact of using fresh or recycled bedding material on the incidence of Salmonella within the flock and its impact on the development of antibiotic resistance – even in the absence of antibiotic use. The team inoculated fresh and reused broiler litter in the lab with different strains of Salmonella and monitored it for 14–21 days – collecting and characterising the Salmonella strains surviving and in the broiler litter.

They also carried out experiments with live birds – rearing chickens carrying Salmonella Heidelberg on either fresh or recycled litter. They found that the microbiome (collection of microorganisms) present in the reused litter negatively correlated with the populations of antibiotic-resistant Salmonella Heidelberg in the chickens' guts, compared with broilers raised on fresh litter. 'This suggests that reused litter promotes an unfavourable microbiome for Salmonella carrying antibiotic resistance,' says Dr Oladeinde.

The team found that Bifidobacterium was the main type of bacteria that was in significantly higher concentrations in the gut of birds raised on reused litter versus fresh litter. They are now carrying out further work utilising the novel information gained from this study to identify the specific beneficial microbes found in the litter microbiome. These microbes could potentially be used as an alternative to antibiotics for Salmonella reduction.

'Reducing antibiotic use alone in poultry is likely insufficient to limit the development of antibiotic resistance,' says Dr Oladeinde. 'A beneficial microbe that can significantly reduce antibiotic-resistant Salmonella in live broiler chickens would provide a powerful new tool to improve food safety in chickens raised without antibiotics.'

Overall, the team's work shows that the litter material used for growing broilers has a significant impact on the developmental process of the chicken gut and its eventual microbiome. Therefore, interventions that can reduce the population of antibiotic-resistant Salmonella in litter have the potential to limit their transfer to the chicken gut.

Predicting Infection to Reduce Risk

As well as their research into preventing Salmonella infection and reducing the number of antibiotic-resistant strains of Salmonella in poultry, Dr Oladeinde and his team have also been investigating new ways to predict the Salmonella risk within a flock.

Previously, the asymptomatic nature of Salmonella infections has made it impossible for producers to determine whether a flock is infected. However, Dr Oladeinde's work in identifying the differences between the microbiomes of birds infected with Salmonella and those of uninfected birds could be key to recognising behavioural and physiological differences required for predicting infection.

Wider studies have shown that some 'beneficial' bacteria identified by the team in the microbiomes of birds raised on reused litter, including Bifidobacterium, can alleviate anxiety and depressive-like symptoms in mice and humans, indicating that the gut microbiome can have a positive impact on the brain.

Based on these studies, Dr Oladeinde hypothesises that even in the absence of obvious symptoms, chickens infected with Salmonella Heidelberg will exhibit social cues that are different from uninfected birds. 'The nature of broiler production – growing of more than 20,000 chickens for six to seven weeks in concentrated animal feeding operations makes it difficult for caretakers to manually detect these early cues that could be associated with the onset of an infection,' says Dr Oladeinde. 'That's what led us to embark on development of an automated vision-based Salmonella Predictor or vbSALP, which should be able to identify and locate individual birds with Salmonella infections within the first two weeks of life.'

The proposed vbSALP will use advanced imaging technologies to collect information on poultry health and social cues associated with Salmonella infection, including behaviour traits, bird weight and body temperature. Microbiology and molecular genetics will also be used to determine Salmonella prevalence, virulence and antimicrobial resistance status. The vbSALP will also employ machine learning to associate the image parameters with the flock's Salmonella status.

The vbSALP is currently in the early stage of development and the team has been training the system to identify social cues of Salmonella-free broiler chickens raised without antibiotics, using two on-site computers and twelve cameras in a small-scale broiler house.

So far, the team has generated 3528 hours of video footage, which they are analysing to develop prediction algorithms. Subsequent stages of development will include testing vbSALP on images of broiler chicks that have been inoculated with Salmonella Heidelberg strains and optimising vbSALP for a verification test in a commercial broiler house. Their goal is to make vbSALP available as a USB stick that can be used by farmers with little expertise in computer use – providing a practical and cost-effective tool for improving animal production and food safety.

Aside from Salmonella detection, the team plans to upgrade the technology for future use in animal welfare and other disease monitoring applications. It therefore has the potential to provide a solution for the early detection of animal disease and infection over a large geographic scale, and with significant economic gains.

'If our proposed early prediction tool is successfully developed and adopted by just 5% of US chicken producers, it could reduce the number of Salmonella-carrying chickens at slaughter by 90 million annually,' says Dr Oladeinde. 'This will significantly improve food safety and reduce the need to recall chickens because of Salmonella contamination.'

The combination of the team's research into the poultry microbiome, together with the development of the vbSALP to detect infection risk, has the potential to provide a novel approach to Salmonella prevention and prediction that does not rely on host immune response, antibiotic use or vaccine effectiveness.

'The poultry industry and the American consumer care deeply about food safety, animal health and welfare,' summarises Dr Oladeinde. 'This research could provide the practical means for producers to improve animal production and food safety by reducing the risk of Salmonella infection in antibiotic-free production.'

Meet the researcher

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Dr Ade Oladeinde gained his PhD in Environmental Health Science in 2017 from the University of Georgia, under the direction of Professor Erin Lipp and Dr Marirosa Molina (USEPA). Before joining USDA's Agricultural Research Service (USDA-ARS) as a Research Microbiologist, Dr Oladeinde was an ORISE Postdoctoral fellow under the mentorship of Dr Kimberly Cook (USDA-ARS). Dr Oladeinde's research within the Bacterial Epidemiology and Antimicrobial Resistance Unit of USDA-ARS focuses on food safety – specifically the microbial ecology of food-borne pathogens and the development of antimicrobial resistance in poultry production settings. Since joining USDA-ARS, Dr Oladeinde has conducted studies to evaluate the survival and evolutionary ecology of Salmonella in the chicken gut and litter, utilising Big Data to decipher the interplay between the poultry microbiome, mobile genetic elements and occurrence of multidrug resistant Salmonella.

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FURTHER READING

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