The Role of Probiotics and Prebiotics in Preventing Salmonellosis

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Abstract

The host becomes increasingly susceptible to infectious agents when the variety and composition of gut microbes are altered by repeated antibiotic exposure, dietary modifications, and environmental changes. The development and continuous dissemination of antimicrobial resistance pathogens is a difficult public health concern. Probiotics and prebiotics may help decolonize drug-resistant bacteria by strengthening the gut's resistance to colonization, according to recent research. Salmonella causes infections that vary in type and severity based on several variables, such as the type of animal the host is, age, immunological condition, the virulence of the strain, and the infectious dose. Salmonellosis is treated with supportive and antibiotic therapy, but the effectiveness of these therapies is limited since the bacterium develops resistance to the most widely used antimicrobials. Antibiotic treatments include additional drawbacks, such as the potential for toxicity and severe diarrhea. This book chapter aimed to determine the use of probiotics and prebiotics in the prevention and treatment of salmonellosis. Probiotics and prebiotics may decolonize infections by altering gut diversity, according to moderately solid findings. Nevertheless, additional clinical results on specific strains are needed to validate the pathogens' eradication. Finally, for instance, the advantages of using probiotics, also have some disadvantages for the host, therefore, should be analyzed before it used, while the prebiotic has no side effects.

Keywords: Salmonellosis, Probiotic, Prebiotic, Prevention, Infection

Cite this Article as: Ismael SS, Abdullah BH and Abdulla BI, 2025. The role of probiotics and prebiotics in preventing salmonellosis. In: Aadil RM, Salman M, Mehmood K and Saeed Z (eds), Gut Microbiota and Holistic Health: The Role of Prebiotics and Probiotics. Unique Scientific Publishers, Faisalabad, Pakistan, pp: 155-160. https://doi.org/10.47278/book.HH/2025.288

A Publication of Unique Scientific Publishers

Chapter No: 25-021

Received: 07-Feb-2025
Revised: 16-Apr-2025
Accepted: 05-May-2025

Introduction

Salmonella is the bacteria that causes salmonellosis, can cause a variety of illnesses, from moderate gastroenteritis to enteric fever, bacteremia, and septicemia. It is thought to be the most commonly isolated food-borne microbe. With 150,000 fatalities and 94 million food-borne illnesses annually, it is a significant global public health concern (Rahman et al., 2020). The majority of Salmonellosis results in diarrhea, fever, and cramping in the abdomen 12 to 72 hours after infection. Even though it takes several months for bowel patterns to return to normal, most people recover without therapy during the four to seven days that the disease typically lasts. But when people get an enteric fever, their diarrhea can get so bad that they have to go to the hospital. If antibiotics are not administered to these people right away, *Salmonella* can move from the gut to the bloodstream and subsequently to other parts of the body, where it can be fatal (Castillo et al., 2012). *Salmonella* is a rod-shaped, facultative anaerobe that is Gram-negative and a member of the Enterobacteriaceae family (Barlow & Hall, 2002). Using the standard Kauffman-White method, over 2600 serotypes of the genus *Salmonella* have been found; the majority of these serotypes may adapt to a range of animal hosts, including humans (Allerberger et al., 2003). Other chronic sequelae of salmonellosis include Reiter's syndrome, which is characterized by joint discomfort, eye irritation, and painful urination in a tiny percentage of Salmonella-infected individuals. It may persist for months or years and result in chronic arthritis, which is challenging to cure. There is no correlation between the use of antibiotics and the development of arthritis. Additional side effects include appendicitis and endocarditis (Doorduyn et al., 2008).

The most commonly isolated foodborne pathogen is *Salmonella*, which is mostly found in dairy products, eggs, and poultry (Silva et al., 2011). Fresh fruits and vegetables are among the additional food sources that contribute to the spread of *Salmonella* (Pui et al., 2011). The main origin of Salmonellosis is typically animals including pigs, poultry, and cattle. Raw animal products and the commerce of animals are the main ways that the diseases spread. Abattoirs are thought to be one of the major sources of *Salmonella* infection in organs and carcasses during the slaughter of food animals (Gillespie et al., 2005). Due to their increased virulence and increased mortality rate among infected patients, the public is becoming more concerned about the advent of foodborne bacteria that are resistant to antibiotics (Travers & Barza, 2002).

The human host's health and the serotype of *Salmonella* that is present determine how severe an infection is. Immunocompromised patients, the elderly, and children under five are more vulnerable to *Salmonella* infection than healthy persons. Since Salmonella strains can infiltrate, multiply, and persist in human host cells, they are all considered dangerous and can cause potentially fatal illnesses (Eng et al., 2015). *Salmonella* strains can be classified as either typhoid or non-typhoid (NTS) based on the clinical characteristics of human salmonellosis. Enteric fever, gastroenteritis, bacteremia, and associated extraintestinal consequences, and chronic carrier state are the four distinct clinical presentations of human infections (Darby & Sheorey, 2008). There are two forms of salmonellosis: typhoidal and non-typhoidal forms and the severity of each depends on the host's immune system and the bacterial serotype (Wei et al., 2023). Salmonellosis is characterized by high fever, abdominal pain, and diarrhea (Keestra-Gounder et al., 2015). It typically resolves on its own in one to seven days without therapy, depending on the host (Hoelzer et al., 2011). However, 5% of people may develop bacteremia or invasive infections such as septic arthritis, meningitis, osteomyelitis, and endovascular infections, especially those with compromised immune systems, neonates, and older persons (Bula-Rudas et al., 2015; Abdullah & Ismael, 2025).

A major global health concern is the development of antibiotic resistance in *Salmonella* strains (Chiu et al., 2002). The first instance of Salmonella resistance to a single antibiotic chloramphenicol was documented in the early 1960s (Montville et al., 2012). Since then, numerous nations, including the USA, the UK, and Saudi Arabia, have seen an upsurge in the isolation of *Salmonella* strains that are resistant to one or more antimicrobial treatments (Yoke-Kqueen et al., 2008). *Salmonella* infections are traditionally treated with antimicrobial drugs such as ampicillin, trimethoprim-sulfamethoxazole, and chloramphenicol. Multi-drug-resistant Salmonella species are resistant to certain drugs (Yoke-Kqueen et al., 2008; Eng et al., 2015). The use of antibiotics in veterinary medicine to treat bacterial illnesses in animals and in animal feed to aid in the growth of food animals is the primary cause of the formation of Salmonella with antimicrobial resistance (Hyeon et al., 2011). Because MDR *Salmonella* strains can spread from animals to people by direct contact, ingestion of contaminated food, or ingestion of diseased animals, there is a significant danger of contracting a zoonotic disease (Holmberg et al., 1984). Furthermore, multi-drug resistance *Salmonella* strains have been discovered in the water environments of some exotic pets, including turtles and tortoises, which may increase the risk of zoonotic infections in humans who come into close contact with these animals (Marin et al., 2021).

One of the most effective strategies for preventing, reducing, and reversing antibacterial resistance is the use of medicinal plant extracts that naturally possess antibacterial properties (Cheesman et al., 2017). Because they come from plants, plant-derived antimicrobials are one of the most beneficial and safest sources of antimicrobials when compared to synthetic compounds (Casciaro et al., 2019). Traditional medicinal herbal methods have been used for many years to treat bacterial infections (Tuasha et al., 2018; Guerrero-Encinas et al., 2024).

Another way to reduce the antibiotic resistance in salmonellosis is the use of probiotics and prebiotics. People have been consuming probiotics in the form of fermented foods, such as yogurts and milk, since the beginning of time. They have been widely utilized to treat a range of digestive issues (Doorduyn et al., 2008; Guarino et al., 2015).

2. Using of Probiotics and Prebiotics as Alternative Treatment for Salmonellosis

It is commonly known that the host physiology is impacted by the gut bacteria. Since antibiotics have long-term effects on human health and gut microbiota, (Fishbein et al., 2023) and may add to the growth of resistant pathogens and undesirable microbial communities, the growing prevalence of multiple drug-resistant pathogens necessitates the investigation of antibiotic substitutes (McFarland & Goh, 2019; Matzaras et al., 2023). Furthermore, germs that are resistant to many drugs are not always decolonized by antibiotics. It may lessen both beneficial bacteria and intestinal infections (Shah et al., 2021). Combining probiotics or prebiotics with antibiotics may enhance microbial diversity and long-term health effects (Karbalaei & Keikha, 2022). However, as treatments for getting rid of or decolonizing dangerous bacteria, probiotics and prebiotics haven't gotten much attention (Galina & Valdovska, 2017).

In recent years, probiotic and prebiotic usage has also attracted more attention. A probiotic method is the employment of microflora to lower the pathogen load in the gut (Callaway et al., 2003). In order to supply a limiting food (prebiotic) that permits the growth of a certain fraction of the gut microflora, probiotic procedures entail introducing a typical population of microbes into the gut. This strategy aims to occupy every accessible niche in the gut to prevent the growth of harmful bacteria (Doyle & Erickson, 2006; Gaggìa et al., 2010). Since the rise in antibiotic resistance has raised concerns, using probiotics offers a useful substitute for treating foodborne infections such as salmonellosis (Dobson et al., 2012).

The connection between nutrition and health is currently widely recognized. Traditionally, the purpose of diet has been to supply the nutrients needed for metabolism. However, this concept has changed during the past few decades. It is now known that in addition to providing for metabolic requirements, a person's food also contributes to their overall health and well-being. A new category of nutritional goods known as functional foods has emerged as a result of this shift in thinking about the role that foods play in the diet. In addition to its nutritional worth, food can be deemed functional if it positively impacts a target's bodily function (Figueroa-González et al., 2011).

2.1. Probiotics

Probiotics are live, nonpathogenic bacteria that are given to the gut to increase the diversity of microbes there. Prebiotics are substances that do not contain germs but improve health by promoting the development of good bacteria in the stomach (Galina & Valdovska, 2017; Roy & Dhaneshwar, 2023). Probiotics may be able to eradicate or lessen gut infections by a number of methods, such as immune regulation, intestinal colonization, competitive exclusion, and intestinal barrier function (Roberfroid, 2000). By encouraging the development of advantageous bacteria, prebiotics aid in the equilibrium of the gut flora. Prebiotic digestion results in the production of SCFAs and lowers the pH of the gut lumen, preventing pathogen colonization (Karbalaei & Keikh, 2022). Prebiotics' anti-adherence qualities can also aid in the reduction of harmful bacteria in the gut (Amorim et al., 2020). Probiotics and prebiotics can be taken together or separately (Galina & Valdovska, 2017; Janapatla et al., 2023)

Antibiotics are frequently used to eliminate colonized microorganisms all over the world. Antibiotics disrupt the gut and change the microbial composition, which affects normal gut homeostasis, according to recent research (Ramirez et al., 2020; Deep, 2023). In order to lessen the long-term effects of antibiotics on the gut flora, probiotics are taken in conjunction with antibiotics (*Kesavelu & Jog, 2023*). However, in the absence of antibiotics, probiotics demonstrated effective pathogen decolonization (Ljungquist et al.,2020; Rahman et al., 2024). Probiotics and prebiotics alter the gut microbiota to minimize and prevent gastrointestinal illnesses. Probiotics stop infections from adhering and invading the gut, whereas prebiotics increase the number of good gut flora. The mechanisms underlying these complex processes, which change the kinetics of Salmonella infection, are not well known. The hypothesis was that Salmonella uses glycosyl hydrolases to break down prebiotics and that it kills *Bifidobacterium infantis* by inhibiting inflammation signal transduction pathways and causing host cell death (Abdullah et al., 2024).

Here are some benefits of probiotics: First, give the host useful byproducts of the anaerobic fermentation of carbohydrates, like organic acids. After entering the bloodstream, these byproducts have the power to affect a person's mood, level of energy, and even cognitive function. Second, successfully prevent pathogen colonization from causing illness; third, boost the human immune system by generating certain polysaccharides (Fric, 2007). The most popular probiotics are bacilli, bifidobacter, lactobacilli, yeast, and a few nonpathogenic species from the *Enterococcus*, *Bacillus*, and *Escherichia* genera. Nonetheless, the most often used probiotics are members of the Bifidobacterium and Lactobacillus genera (Fric, 2007).

According to Metchnikoff, "good" lactic acid-producing bacteria promote homeostasis in the host by inhibiting the growth of other bacteria in the colon and, consequently, their hazardous byproducts (Podolsky, 1998). By isolating Bacillus bulgaricus and advocating for its application as a treatment to preserve equilibrium and fend off aging, he made yogurt (Podolsky, 1998), the basis for probiotics, widely known. Numerous investigations have demonstrated the critical functions that pattern recognition receptors. Toll-like receptors (TLRs), and Nod-like receptors play in preserving a stable and healthy interaction between the host gut and its microbiota (Kamada et al., 2013). When TLRs are activated, pro-inflammatory mediators are up-regulated, which helps the host's immunological defenses work. The commensal microbiota's activation of the cytoplasmic proteins known as NLRs, which control inflammatory responses, has been shown to support gut homeostasis (Yeretssian, 2012). Disturbances in PRR-microbiota interactions, in many cell types and gut mucosal compartments, are more likely to worsen inflammation-related illness conditions (Maynard et al., 2012).

Probiotics have been shown to help reduce a variety of gastrointestinal tract dysfunctions. Probiotics have been demonstrated in clinical trials to be effective in preventing diarrhea, particularly in newborns and young children (A*llen et al., 2010;* Guandalini, 2011). The primary symptom of acute gastroenteritis, which is most frequently caused by rotaviruses in children younger than one year, is acute diarrhea. The clinical benefits of treating Saccharomyces and Lactobacillus to shorten the length of diarrhea are well-established (*Szajewska et al., 2015*). Approximately thirty percent of newborns are also frequently affected by diarrhea linked to the use of antibiotics (*Szajewska & Mrukowicz, 2005*). *Streptococcus thermophilus* and *Bifidobacterium lactis* supplements have been demonstrated to lower the incidence of diarrhea caused by antibiotics in newborns. The main mechanisms by which probiotics lessen diarrheal symptoms have been suggested to be decreased permeability of the intestinal tract and invasion of pathogenic microorganisms, as well as higher production of short-chain fatty acids in the colon that promotes sodium absorption by the colonocytes (*Szajewska & Mrukowicz, 2005;* Morais & Jacob, 2006)

2.2. Prebiotics

Prebiotics are carbohydrates with brief chains that positively change the gut microbiota's metabolism or composition. Thus, it is anticipated that prebiotics will have a comparable health-improving effect to probiotics while also being less expensive, risk-free, and simpler to include in the diet (Macfarlane & Macfarlane, 2006). Prebiotics are made up of oligosaccharides that the host cannot digest and that, by selectively stimulating the growth and activity of particular gut microbiota members, improve host health. Prebiotics have several advantages, such as improving gut barrier function, lowering the number of harmful bacteria, producing short-chain fatty acids, and having an impact on the gastrointestinal tract (i.e., preventing pathogen damage or immune system regulation) (Slavin, 2013; Bindels et al., 2015).

A typical diet usually has a lot of prebiotic carbohydrates. Inulin-type fructans, for instance, are found in modest levels in grains like wheat but in higher concentrations in chicory root, and garlic (van Loo et al., 1995). A full diet could include other carbohydrates like soybean oligosaccharides, lactobionic acid, and galactomannan, all of which have been shown to have prebiotic effects (Macfarlane et al., 2006). Only inulin and galacto-oligosaccharides, which are found in some plants as storage carbohydrates and are natural food ingredients, now meet all of the requirements for prebiotic classification (Gibson et al., 2004). Because bacteria have varying preferences for different energy sources, diet alone has the most direct and powerful effects on gut microbial colonization. The species found in the gut microbiota are therefore directly linked to food (Scott et al., 2013). The dominant species profile in the human gut microbiota may be altered by dietary consumption, which could have negative health effects. Firmicutes and Bacteroidetes are the two most prevalent phyla present in the majority of healthy people (Arumugam et al., 2011). By significantly altering the composition of gut microbes and directly influencing the mucosal immune system, dietary fibers can function as efficient prebiotics, improving systemic immune response and enteric inflammatory diseases. Additionally, prebiotics may provide resistance to bacterial colonization by preventing pathogens from adhering to the intestinal epithelium. The intestinal microbiota's management indirectly mediates other health benefits of prebiotics, including preventing diarrhea or constipation, improving lipid metabolism, and promoting mineral adsorption (Gibson et al., 2004).

3. Side effects of using Probiotics and Prebiotics on host Health

There is little information available regarding the negative effects of probiotics on individuals who are immunocompromised (cancer, organ transplant), sick (diabetes mellitus and pancreatitis), or special healthy (baby, pregnant, elderly population). Numerous studies have shown that probiotics can change into opportunistic infections that cause a number of illnesses, including pneumonia and sepsis. Before the probiotic strain is released onto the consumer market, particular attention should be paid to a number of detrimental characteristics, including gene transfer, translocation, the formation of toxic metabolites, and immunomodulation, in order to ensure probiotic safety (Borase et al., 2022).

The majority of prebiotics have not yet been associated with any significant adverse effects. Intestinal bacteria ferment oligosaccharides and polysaccharides that are not degraded by intestinal enzymes. Thus, diarrhea, bloating, cramps, and gas are the only adverse effects of prebiotics, which are mostly associated with their osmotic impact. The development of adverse effects is significantly influenced by the length of prebiotic chains. When inulin is consumed as part of a liquid or solid meal, there are often no significant adverse effects (Niness, 1999; Ramirez-Farias et al., 2009).

Conclusion

Infection with *Salmonella* is a global health and economic burden, particularly in developing nations. Antibiotic-associated diarrhea, the effects of antibiotics on normal gut microbiota, and the startling increase in antibiotic-resistant *Salmonella* strains are all reasons why using antibiotic medications to treat infections is becoming less effective. As a result, there is an increasing need for alternative treatments, such as the use of probiotic microorganisms. Probiotics stop pathogens from attaching and invading the gut, whereas prebiotics increase the number of good gut flora. Nevertheless, little is known about the mechanisms underlying these complex processes that change *Salmonella* kinetics of infection. This book chapter found that the using of prebiotics and probiotics may aid in the removal of intestinal pathogens or improve the ability of traditional medicine to eradicate bacteria that are resistant to many drugs. The subgroup's probiotic intervention evidence had a moderate to high degree of certainty. Lastly, before using probiotics therapeutically, their risk-benefit ratio needs to be thoroughly examined.

References

Abdullah, B. H., Ismael, S. S., & Qasim, N. A. (2024). Antimicrobial Susceptibility of Proteus mirabilis Isolated from Urinary Tract Infections in Duhok City, Iraq, Using VITEK2 System. *European Journal of Medical and Health Research*, *2*(4), 75-79. https://doi.org/10.59324/ejmhr.2024.2(4).09

Abdullah, B. H. & Ismael, S. S. (2025). A Case Report on *Aeromonas veronii* Meningitis: Isolation from CSF in a Hospitalized Immunocompromised Girl, Duhok City, Iraq. *Sarcouncil Journal of Medical Sciences, 4*(1), 47-50. https://doi.org/10.5281/zenodo.14691763

Allerberger, F., Liesegang, A., Grif, K., Khaschabi, D., Prager, R., Danzl, J., Höck, F., Ottl, J., Dierich, M. P., Berghold, C., Neckstaller, I., Tschäpe, H., & Fisher, I. (2003). Occurrence of Salmonella enterica serovar Dublin in Austria. *Wiener medizinische Wochenschrift (1946), 153*(7-8), 148–152. https://doi.org/10.1046/j.1563-258x.2003.03015.x

Allen, S. J., Martinez, E. G., Gregorio, G. V., & Dans, L. F. (2010). Probiotics for treating acute infectious diarrhoea. *The Cochrane Database of Systematic Reviews*, *2010*(11), CD003048. https://doi.org/10.1002/14651858.CD003048.pub3

Amorim, C., Silvério, S. C., Cardoso, B. B., Alves, J. I., Pereira, M. A., & Rodrigues, L. R. (2020). In vitro assessment of prebiotic properties of xylooligosaccharides produced by Bacillus subtilis 3610. *Carbohydrate Polymer, 1*(229), 115460. https://doi.org/10.1016/j.carbpol.2019.115460

Arumugam, M., Raes, J., Pelletier, E., Le Paslier, D., Yamada, T., Mende, D. R., Fernandes, G. R., Tap, J., Bruls, T., Batto, J. M., Bertalan, M., Borruel, N., Casellas, F., Fernandez, L., Gautier, L., Hansen, T., Hattori, M., Hayashi, T., Kleerebezem, M., Kurokawa, K., ... Bork, P. (2011). Enterotypes of the human gut microbiome. *Nature*, *473*(7346), 174–180. https://doi.org/10.1038/nature09944

Barlow, M., & Hall, B. G. (2002). Origin and evolution of the AmpC beta-lactamases of Citrobacter freundii. *Antimicrobial Agents and Chemotherapy*, *46*(5), 1190–1198. https://doi.org/10.1128/AAC.46.5.1190-1198.2002

Bindels, L. B., Delzenne, N. M., Cani, P. D., & Walter, J. (2015). Towards a more comprehensive concept for prebiotics. Nature reviews. *Gastroenterology & Hepatology,* 12(5), 303–310. https://doi.org/10.1038/nrgastro.2015.47

Borase, H., Dwivedi, M.K., Krishnamurthy, R., Patil, S. (2022). Probiotics: health safety considerations, Editor(s): Mitesh Kumar Dwivedi, N. Amaresan, A. Sankaranarayanan, E. Helen Kemp, Probiotics in the Prevention and Management of Human Diseases, *Academic Press*, 449-463

Bula-Rudas, F. J., Rathore, M. H., & Maraqa, N. F. (2015). Salmonella Infections in Childhood. *Advances in Pediatrics*, *62*(1), 29–58. https://doi.org/10.1016/j.yapd.2015.04.005

Callaway, T.R., Anderson, R.C., Edrington, T.S., Elder, R.O., Genovese, K.J., Bischoff, K.M., Poole, T.L., Jung, Y.S., Harvey, R.B., Nisbet, D.J. (2003). Preslaughter intervention strategies to reduce food-borne pathogens in food animals. *Journal of Animal Science*, *81*(14_suppl_2), E17-23.

Casciaro, B., Calcaterra, A., Cappiello, F., Mori, M., Loffredo, M. R., Ghirga, F., Mangoni, M. L., Botta, B., & Quaglio, D. (2019). Nigritanine as a New Potential Antimicrobial Alkaloid for the Treatment of *Staphylococcus aureus*-Induced Infections. *Toxins*, *11*(9), 511. https://doi.org/10.3390/toxins11090511

Castillo, N.A., de LeBlanc, A.M., Galdeano, C.M., & Perdigón, G. (2012). Probiotics: An alternative strategy for combating salmonellosis: Immune mechanisms involved, *Food Research International*, *45*(2),831-841

Cheesman, M. J., Ilanko, A., Blonk, B., & Cock, I. E. (2017). Developing New Antimicrobial Therapies: Are Synergistic Combinations of Plant Extracts/Compounds with Conventional Antibiotics the Solution? *Pharmacognosy Reviews*, *11*(22), 57–72. https://doi.org/10.4103/phrev.phrev_21_17

Chiu, C. H., Wu, T. L., Su, L. H., Chu, C., Chia, J. H., Kuo, A. J., Chien, M. S., & Lin, T. Y. (2002). The emergence in Taiwan of fluoroquinolone resistance in Salmonella enterica serotype choleraesuis. *The New England Journal of Medicine*, *346*(6), 413–419. https://doi.org/10.1056/NEJMoa012261

Corrêa, N. B., Péret Filho, L. A., Penna, F. J., Lima, F. M., & Nicoli, J. R. (2005). A randomized formula controlled trial of Bifidobacterium lactis and Streptococcus thermophilus for prevention of antibiotic-associated diarrhea in infants. *Journal of Clinical Gastroenterology, 39*(5), 385–389. https://doi.org/10.1097/01.mcg.0000159217.47419.5b

Darby, J., & Sheorey, H. (2008). Searching for Salmonella. *Australian Family Physician*, *37*(10), 806–810.

Deep, S. (2023). *Probiotics may offset gut damage caused by antibiotics*. Med News Today.

Dobson, A., Cotter, P. D., Ross, R. P., & Hill, C. (2012). Bacteriocin production: a probiotic trait?. *Applied and Environmental Microbiology*, *78*(1), 1–6. https://doi.org/10.1128/AEM.05576-11

Doorduyn, Y., Van Pelt, W., Siezen, C. L., Van Der Horst, F., Van Duynhoven, Y. T., Hoebee, B., & Janssen, R. (2008). Novel insight in the association between salmonellosis or campylobacteriosis and chronic illness, and the role of host genetics in susceptibility to these diseases. *Epidemiology and Infection*, *136*(9), 1225–1234. https://doi.org/10.1017/S095026880700996X

Doyle, M. P., & Erickson, M. C. (2006). Reducing the carriage of foodborne pathogens in livestock and poultry. *Poultry Science*, *85*(6), 960–973. https://doi.org/10.1093/ps/85.6.960

Eng, S. K., Pusparajah, P., Ab Mutalib, N. S., Leng, S. H., Chan, K. G., & Learn Han, L. (2015). Salmonella: A review on pathogenesis, epidemiology and antibiotic resistance. *Frontiers in Life Science*, *8*(3), 284 - 293. https://doi.org/10.1080/21553769.2015.1051243

Figueroa-González, I., Quijano, G., Ramírez, G., & Cruz-Guerrero, A. (2011). Probiotics and prebiotics--perspectives and challenges. *Journal of the Science of Food and Agriculture*, *91*(8), 1341–1348. https://doi.org/10.1002/jsfa.4367

Fishbein, S. R. S., Mahmud, B., & Dantas, G. (2023). Antibiotic perturbations to the gut microbiome. *Nature reviews: Microbiology*, *21*(12), 772–788. https://doi.org/10.1038/s41579-023-00933-y

Fric P. (2007). Probiotics and prebiotics—renaissance of a therapeutic principle. *Open Medicine, 22*(3), 237-70.

Gaggìa, F., Mattarelli, P., & Biavati, B. (2010). Probiotics and prebiotics in animal feeding for safe food production. *International Journal of Food Microbiology*, *141*(1), S15–S28. https://doi.org/10.1016/j.ijfoodmicro.2010.02.031

Galina, D., & Valdovska, A. (2017). Effect of probiotics and herbals on health and shedding of resistant Escherichia coli in piglets. *Livestock Research for Rural Development, 1*, 51–258. http://dx.doi.org/10.22616/rrd.23.2017.037

Gibson, G. R., Probert, H. M., Loo, J. V., Rastall, R. A., & Roberfroid, M. B. (2004). Dietary modulation of the human colonic microbiota: updating the concept of prebiotics. *Nutrition Research Reviews*, *17*(2), 259–275. https://doi.org/10.1079/NRR200479

Gillespie, I. A., O'Brien, S. J., Adak, G. K., Ward, L. R., & Smith, H. R. (2005). Foodborne general outbreaks of Salmonella Enteritidis phage type 4 infection, England and Wales, 1992-2002: where are the risks?. *Epidemiology and Infection*, *133*(5), 795–801. https://doi.org/10.1017/S0950268805004474

Guandalini S. (2011). Probiotics for prevention and treatment of diarrhea. *Journal of Clinical Gastroenterology*, *45*, S149–S153. https://doi.org/10.1097/MCG.0b013e3182257e98

Guarino, A., Guandalini, S., & Lo Vecchio, A. (2015). Probiotics for Prevention and Treatment of Diarrhea. *Journal of Clinical Gastroenterology*, *49*(1), S37–S45. https://doi.org/10.1097/MCG.0000000000000349

Guerrero-Encinas, I., González-González, J.N., Ayala-Zavala, J.F. *et al.* (2024). Reviewing the Potential of Natural Antimicrobials for *Salmonella* spp. Gastrointestinal Infections: *In Vitro* and *In Vivo* Evaluations. *Revista Brasileira de Farmacognosia, 34*, 236–249 https://doi.org/10.1007/s43450-023-00481-9

Hoelzer, K., Moreno Switt, A. I., & Wiedmann, M. (2011). Animal contact as a source of human non-typhoidal salmonellosis. *Veterinary Research*, *42*(1), 34. https://doi.org/10.1186/1297-9716-42-34

Holmberg, S. D., Osterholm, M. T., Senger, K. A., & Cohen, M. L. (1984). Drug-resistant Salmonella from animals fed antimicrobials. *The New England Journal of Medicine*, *311*(10), 617–622. https://doi.org/10.1056/NEJM198409063111001

Hyeon, J. Y., Chon, J. W., Hwang, I. G., Kwak, H. S., Kim, M. S., Kim, S. K., Choi, I. S., Song, C. S., Park, C., & Seo, K. H. (2011). Prevalence, antibiotic resistance, and molecular characterization of Salmonella serovars in retail meat products. *Journal of Food Protection*, *74*(1), 161–166. https://doi.org/10.4315/0362-028X.JFP-10-327

Janapatla, R. P., Dudek, A., Chen, C. L., Chuang, C. H., Chien, K. Y., Feng, Y., Yeh, Y. M., Wang, Y. H., Chang, H. J., Lee, Y. C., & Chiu, C. H. (2023). Marine prebiotics mediate decolonization of Pseudomonas aeruginosa from gut by inhibiting secreted virulence factor interactions with mucins and enriching Bacteroides population. *Journal of Biomedical Science*, *30*(1), 9. https://doi.org/10.1186/s12929-023-00902-w

Kamada, N., Seo, S. U., Chen, G. Y., & Núñez, G. (2013). Role of the gut microbiota in immunity and inflammatory disease. *Nature Reviews: Immunology*, *13*(5), 321–335. https://doi.org/10.1038/nri3430

Karbalaei, M., & Keikha, M. (2022). Probiotics and intestinal decolonization of antibiotic-resistant microorganisms; A reality or fantasy?. *Annals of Medicine and Surgery 80*, 104269. https://doi.org/10.1016/j.amsu.2022.104269

Keestra-Gounder, A. M., Tsolis, R. M., & Bäumler, A. J. (2015). Now you see me, now you don't: the interaction of Salmonella with innate immune receptors. *Nature Reviews: Microbiology*, *13*(4), 206–216. https://doi.org/10.1038/nrmicro3428

Kesavelu, D., & Jog, P. (2023). Current understanding of antibiotic-associated dysbiosis and approaches for its management. *Therapeutic Advances in Infectious Disease*, *10*, 20499361231154443. https://doi.org/10.1177/20499361231154443

Ljungquist, O., Kampmann, C., Resman, F., Riesbeck, K., & Tham, J. (2020). Probiotics for intestinal decolonization of ESBL-producing Enterobacteriaceae: a randomized, placebo-controlled clinical trial. *Clinical microbiology and infection: the official publication of the European Society of Clinical Microbiology and Infectious Diseases*, *26*(4), 456–462. https://doi.org/10.1016/j.cmi.2019.08.019

Macfarlane, S., Macfarlane, G. T., & Cummings, J. H. (2006). Review article: prebiotics in the gastrointestinal tract. *Alimentary Pharmacology & Therapeutics*, *24*(5), 701–714. https://doi.org/10.1111/j.1365-2036.2006.03042.x

Marin, C., Lorenzo-Rebenaque, L., Laso, O., Villora-Gonzalez, J., & Vega, S. (2021). Pet Reptiles: A Potential Source of Transmission of Multidrug-Resistant *Salmonella*. *Frontiers in Veterinary Science*, *7*, 613718. https://doi.org/10.3389/fvets.2020.613718

Matzaras, R., Nikopoulou, A., Protonotariou, E., & Christaki, E. (2022). Gut Microbiota Modulation and Prevention of Dysbiosis as an Alternative Approach to Antimicrobial Resistance: A Narrative Review. *The Yale Journal of Biology and Medicine*, *95*(4), 479–494.

Maynard, C. L., Elson, C. O., Hatton, R. D., & Weaver, C. T. (2012). Reciprocal interactions of the intestinal microbiota and immune system. *Nature*, *489*(7415), 231–241. https://doi.org/10.1038/nature11551

McFarland, L. V., & Goh, S. (2019). Are probiotics and prebiotics effective in the prevention of travellers' diarrhea: A systematic review and meta-analysis. *Travel Medicine and Infectious Disease*, *27*, 11–19. https://doi.org/10.1016/j.tmaid.2018.09.007

Montville, T.J., Matthews, K.R., Kniel, K.E. (2012). *Food microbiology: an introduction*. ASM press.

Morais, M.B., & Jacob, C.M. (2006). The role of probiotics and prebiotics in pediatric practice. *Journal of Pediatrics, 82*, S189–97

Niness K. R. (1999). Inulin and oligofructose: what are they?. *The Journal of Nutrition*, *129*(7 Suppl), 1402S–6S. https://doi.org/10.1093/jn/129.7.1402S

Podolsky S. (1998). Cultural divergence: Elie Metchnikoff's Bacillus bulgaricus therapy and his underlying concept of health. *Bulletin of the History of Medicine*, *72*(1), 1–27. https://doi.org/10.1353/bhm.1998.0056

Pui, C.F., Wong, W.C., Chai, L.C., Nillian, E., Ghazali, F.M., Cheah, Y.K., Nakaguchi, Y., Nishibuchi, M., & Radu. S. (2011). Simultaneous detection of Salmonella spp., Salmonella Typhi and Salmonella Typhimurium in sliced fruits using multiplex PCR. *Food Control, 22*, 337–342. doi: https://doi.org/10.1016/j.foodcont.2010.05.021

Rahman, M. N., Barua, N., Tin, M. C. F., Dharmaratne, P., Wong, S. H., & Ip, M. (2024). The use of probiotics and prebiotics in decolonizing pathogenic bacteria from the gut; a systematic review and meta-analysis of clinical outcomes. *Gut Microbes*, *16*(1), 2356279. https://doi.org/10.1080/19490976.2024.2356279

Rahman, M. T., Sobur, M. A., Islam, M. S., Ievy, S., Hossain, M. J., El Zowalaty, M. E., Rahman, A. T., & Ashour, H. M. (2020). Zoonotic Diseases: Etiology, Impact, and Control. *Microorganisms, 8*(9), 1405. https://doi.org/10.3390/microorganisms8091405

Ramirez, J., Guarner, F., Bustos Fernandez, L., Maruy, A., Sdepanian, V. L., & Cohen, H. (2020). Antibiotics as Major Disruptors of Gut Microbiota. *Frontiers in Cellular and Infection Microbiology*, *10*, 572912. https://doi.org/10.3389/fcimb.2020.572912

Ramirez-Farias, C., Slezak, K., Fuller, Z., Duncan, A., Holtrop, G., & Louis, P. (2009). Effect of inulin on the human gut microbiota: stimulation of Bifidobacterium adolescentis and Faecalibacterium prausnitzii. *The British Journal of Nutrition*, *101*(4), 541–550. https://doi.org/10.1017/S0007114508019880

Roberfroid M. B. (2000). Prebiotics and probiotics: are they functional foods?. *The American Journal of Clinical Nutrition*, *71*(6 Suppl), 1682S–90S. https://doi.org/10.1093/ajcn/71.6.1682S

Roy, S., & Dhaneshwar, S. (2023). Role of prebiotics, probiotics, and synbiotics in management of inflammatory bowel disease: Current perspectives. *World Journal of Gastroenterology, 29*(14), 2078–2100. https://doi.org/10.3748/wjg.v29.i14.2078

Scott, K. P., Gratz, S. W., Sheridan, P. O., Flint, H. J., & Duncan, S. H. (2013). The influence of diet on the gut microbiota. *Pharmacological Research, 69*(1), 52-60.

Shah, T., Baloch, Z., Shah, Z., Cui, X., & Xia, X. (2021). The Intestinal Microbiota: Impacts of Antibiotics Therapy, Colonization Resistance, and Diseases. *International Journal of Molecular Sciences*, *22*(12), 6597. https://doi.org/10.3390/ijms22126597

Silva, J., Leite, D., Fernandes, M., Mena, C., Gibbs, P. A., & Teixeira, P. (2011). Campylobacter spp. as a Foodborne Pathogen: A Review. *Frontiers in Microbiology*, *2*, 200. https://doi.org/10.3389/fmicb.2011.00200

Slavin J. (2013). Fiber and prebiotics: mechanisms and health benefits. *Nutrients*, *5*(4), 1417–1435. https://doi.org/10.3390/nu5041417

Szajewska, H., & Kołodziej, M. (2015). Systematic review with meta-analysis: Lactobacillus rhamnosus GG in the prevention of antibiotic-associated diarrhoea in children and adults. *Alimentary Pharmacology & Therapeutics*, *42*(10), 1149–1157. https://doi.org/10.1111/apt.13404

Szajewska, H., & Mrukowicz, J. (2005). Meta-analysis: non-pathogenic yeast Saccharomyces boulardii in the prevention of antibiotic-associated diarrhoea. Alimentary Pharmacology & Therapeutics, 22, 365–72. https://doi.org/10.1111/j.1365-2036.2005.02624.x

Travers, K., & Barza, M. (2002). Morbidity of infections caused by antimicrobial-resistant bacteria. *Clinical Infectious Diseases: An Official Publication of the Infectious Diseases Society of America, 34*(3), S131–S134. https://doi.org/10.1086/340251

Tuasha, N., Petros, B. & Asfaw, Z. (2018). Medicinal plants used by traditional healers to treat malignancies and other human ailments in Dalle District, Sidama Zone, Ethiopia. *Journal of Ethnobiology and Ethnomedicine, 14*, 15. https://doi.org/10.1186/s13002-018-0213-z

van Loo, J., Coussement, P., de Leenheer, L., Hoebregs, H., & Smits, G. (1995). On the presence of inulin and oligofructose as natural ingredients in the western diet. *Critical Reviews in Food Science and Nutrition*, *35*(6), 525–552. https://doi.org/10.1080/10408399509527714

Wei, X., Long, L., You, L., Wang, M., Wang, D., Liu, C., Li, S., & Wang, J. (2023). Serotype distribution, trend of multidrug resistance and prevalence of β-lactamase resistance genes in human Salmonella isolates from clinical specimens in Guizhou, China. *PloS One*, *18*(4), e0282254. https://doi.org/10.1371/journal.pone.0282254

Yeretssian G. (2012). Effector functions of NLRs in the intestine: innate sensing, cell death, and disease. *Immunologic Research*, *54*(1-3), 25–36. https://doi.org/10.1007/s12026-012-8317-3

Yoke-Kqueen, C., Learn-Han, L., Noorzaleha, A. S., Son, R., Sabrina, S., Jiun-Horng, S., & Chai-Hoon, K. (2008). Characterization of multiple-antimicrobial-resistant Salmonella enterica Subsp. enterica isolated from indigenous vegetables and poultry in Malaysia. *Letters in Applied Microbiology*, *46*(3), 318–324. https://doi.org/10.1111/j.1472-765X.2007.02311.x