Yeast Mannan Oligosaccharides: A Front-line Defense Mechanism for Pathogen Control

Bacterial adherence to host tissue is an important initial step in enabling gastrointestinal tract colonisation and infection. Adherence typically involves the interaction of complementary molecules on the surface of a bacteria with those of the host epithelium.

Historically, the first adherence specificity recognised in intestinal bacteria involved binding via mannose-selective receptors. Almost all isolates of *E. coli,* as well as other members of the Enterobacteriaceae, such as Enterobacter, Klebsiella, Shigella and Salmonella, attach to mannose receptors by means of type 1 fimbriae.

Attachment of type 1 fimbriae to D-mannose receptors can be blocked by means of mannose-containing receptor analogs. From a nutritional standpoint, many feed supplements focus on pathogen adhesion and GI tract exclusion, with the most commonly used being yeast cell wall mannan oligosaccharides (MOS). These are complex mannose-containing preparations linked to a protein group.

The use of MOS to protect and enhance gastrointestinal health stemmed from research that focused on the ability of mannose, the pure single unit of the complex sugar in MOS, to control and prevent the risk of Salmonella colonisation in the intestinal tract. Subsequently, distinct forms of mannose-type sugars were found to interact differently with type 1 fimbriae, and it was noted that the α-1,3 and α-1,6 branched mannans present in the cell wall of Saccharomyces cerevisiae were particularly effective. Based on the *in vitro* findings, applied research trials determined that the inhibition and reduction of Salmonella colonisation resulted in improved *in vivo* performance.

Within the cell wall of Saccharomyces cerevisiae, there are two main locations where MOS is found; attached to cell wall proteins as part of –O and –N glycosyl groups or as components of larger α-D-mannose polysaccharides. These larger mannose-containing polysaccharides consist of α-(1,2)- and α-(1,3)-D-mannose branches, which are attached to extended α-(1,6)-D-mannose chains.

Yeast MOS are widely used in animal nutrition, given their well-documented ability to bind and limit the colonization of gut pathogens, thereby acting as a front-line defense mechanism for pathogen control (Figure 1).

They have proven to be an effective solution for antibiotic-free diets, as well as providing support for immunity and digestion, leading to notable improvements in performance and wellbeing.

As first-generation variants, most commercially available MOS products are derived from the cell wall of the yeast, Saccharomyces cerevisiae. Subsequent research fractionated the yeast cell wall and isolated a mannose-rich fraction (MRF), which, as a 'second generation' product, can best be described as an enhanced MOS-type product with capabilities beyond simple bacterial adherence and agglutination.

One of the more interesting capabilities of MRF is its ability to increase microbiome diversity and, in doing so, enhance the colonisation resistance of the GI tract. By enabling greater GI tract resilience, foodborne pathogens, such as Campylobacter, for instance, can be controlled more effectively.

A comparison of first- and second-generation MOS and MRF products is highlighted in table 1.

	MOS	MRF
Developed through nutrigenomic studies	x	✓
Branched mannan structure	✓ (low)	✓(high)
Enhances diversity of microbiome	x	✓
Agglutinates *E. coli* and Salmonella	✓	✓✓
Broad-spectrum Salmonella control	✓	✓✓
Reduces Campylobacter	x	✓
Increases weight gain	?	✓
Improves FCR	✓	✓✓
Decreases mortality	?	✓
Modulates immune response	✓	✓
Protects the gastrointestinal tract • Enhances protective mucin barrier • Improves gut structure Improves villus height to crypt depth ratio	✓	✓✓
Increases goblet cell size	x	✓
Protects against leaky gut (improves barrier function)	x	✓
Enhances digestive enzyme production	✓	✓✓
Enhances energy production	✓	✓✓
Reduces foot pad lesions	x	✓

Table 1: Comparison of MOS and MRF capabilities

Salmonellosis, as a disease, requires an efficient control system, including dietary measures, and is critical to producing safe food for human consumers. The variable nature of Salmonella serotype prevalence is well documented, and in the highly regulated environment of food production, information on the occurrence of individual Salmonella spp. is readily available. One such source for serotype occurrence in US domestic chicken samples, for instance, is the USDA's food safety and inspection service (FSIS). Figure 2, in the form of a heat map, presents accumulated data with respect to Salmonella isolated from domestic chicken samples, with green representing low prevalence and red indicating high prevalence. These heat maps highlight some interesting features associated with Salmonella occurrence in the preceding number of years. Firstly, one can appreciate the highly variable nature of serotype recovery in chicken samples from 2016–2021. Of more interest, however, are the quite striking temporal changes in Salmonella serotype prevalence. While Salmonella Kentucky was the predominant serotype isolated in 2016, by 2021, Salmonella Infantis had become the dominant serovar. In the intervening period, Salmonella Enteritidis was isolated less frequently. From a pathogen control viewpoint, this presents a challenge for poultry producers in that any Salmonella control mechanism needs to be 'broad-spectrum' to account for not only the variable nature but also the temporal changes in Salmonella abundance.

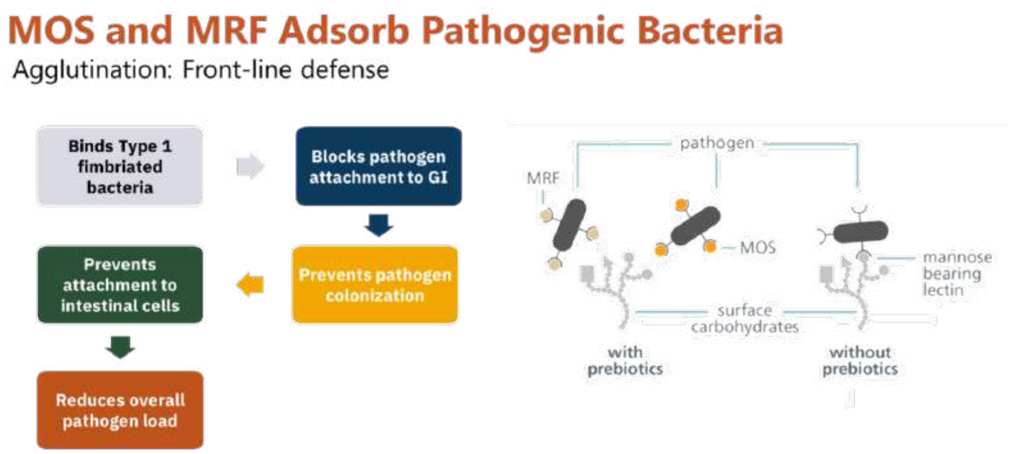


Figure 1: Yeast mannan oligosaccharides adsorb pathogenic bacteria

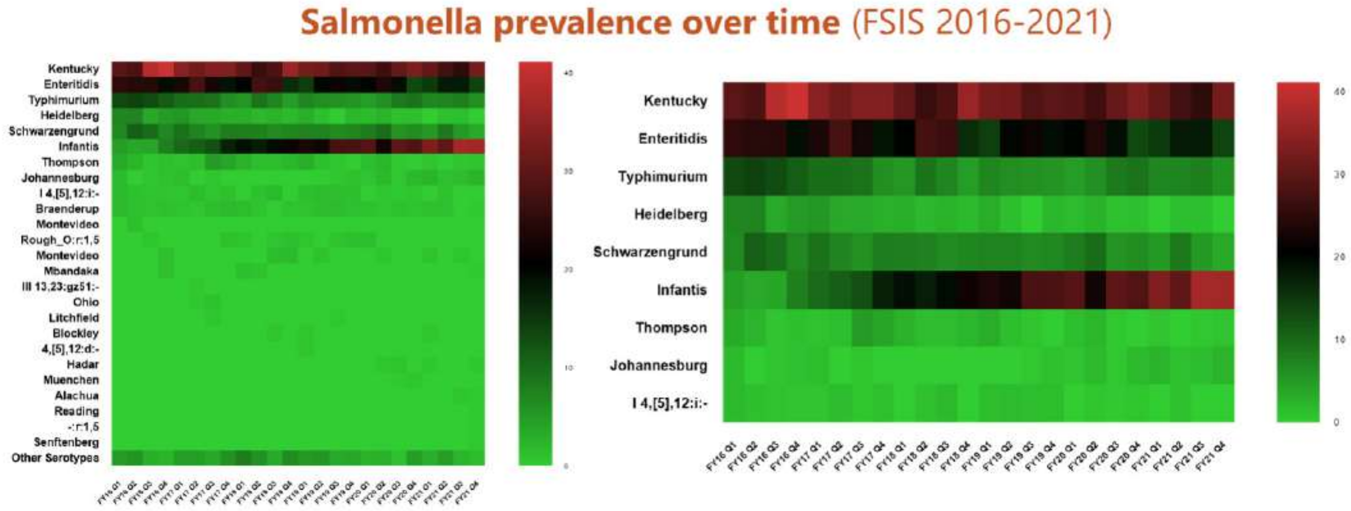
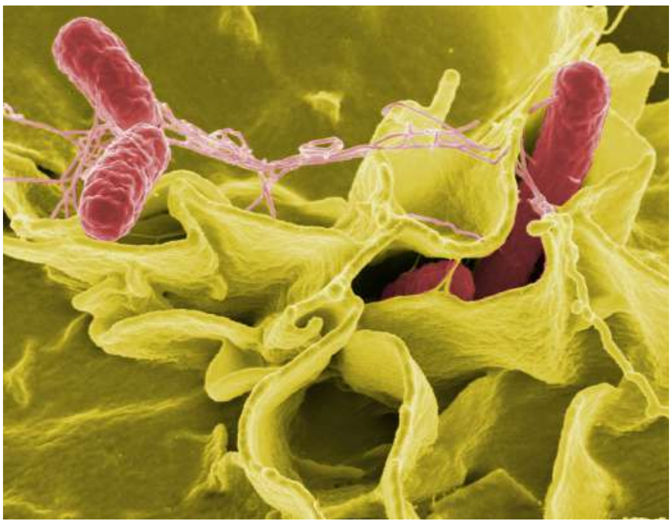


Figure 2: Salmonella prevalence over time (FSIS 2016–2021)

Adherence and agglutination studies have demonstrated the ability of MRF to adhere to a wide range, or broad spectrum, of Salmonella isolates. In controlled studies with chickens, a reduction in the prevalence and concentration of different strains of Salmonella spp., as well as *E. coli* and Campylobacter, have also been reported with the use of MRF. As such, MRF represents an exceptional control mechanism for pathogens with food safety implications.

Given the increasing restrictions on the use of antibiotic gut microflora modifiers in animals, yeast mannans represent a technology that has become a critical part of the arsenal for veterinarians and animal producers.

MOS, due to cost of production, extraction technology and potential infinite supply, has been used widely in animal diets over the last 20 years, but is now being superseded by the next generation, MRF.



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Dr. Richard Murphy, research director at Alltech's European Bioscience Centre in Dunboyne, Ireland, received a bachelor's degree in biochemistry in 1994 and a doctorate from the Department of Biochemistry at National University of Ireland, Galway in 1999. Murphy maintains strong links with numerous academic institutions and is an adjunct professor on the faculty of science and health studies at Dublin City University. He also sits on the board of management of the National Institute for Cellular Biology at Dublin City University, where he is the external chairman. His research activities are diverse, including areas such as trace element and mineral bioavailability, gastrointestinal health, pathogen control, antimicrobial resistance, coordination chemistry and cellular redox reactions.

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