Xylooligosaccharides: A Novel Prebiotic for Livestock Health

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Abstract

Xylooligosaccharides (XO) are emerging prebiotics obtained from crop residues or other lignocellulosic materials that are cheap and abundant in nature. XO improve gut health, nutrient digestibility, immune responses, and growth performance by selectively stimulating probiotic bacteria such as Bifidobacterium and Lactobacillus and thus promoting short chain fatty acid production in monogastrics such as swine, calves and chickens. In nursery piglets, XO supplementation reduced the occurrence of post-weaning diarrhoea. In laying hens, they improved egg yield, quality, and lipid metabolism; in broilers, they enhanced feed efficiency and reduction in mortality. In ruminants, XO supplementation increased fibre digestibility, milk yield, and utilization of metabolisable energy and lowering enteric methane emissions. In a nutshell, XO shown to support gut health, immunity, metabolism, and sustainability, highlighting their value as next-generation feed additives for animal production.

Key words: Diarrhoea, Gut health, Monogastrics, Nutrient utilisation, Prebiotics, Probiotics, Xylooligosaccharides

Introduction

Xylooligosaccharides (XO) are the newer generation candidate prebiotics having xylose repeating units of 2-10 degrees of polymers linked via β-(1→4) xylosidic bonds, making them resistant to digestion in the upper gastrointestinal tract and selectively fermented by beneficial gut microbes such as *Bifidobacterium* and *Lactobacillus* (Samanta et al., 2015). These are functional oligosaccharides with prebiotic activity, offering nutritional and therapeutic benefits in animals when supplied in adequate quantities. They demonstrate high specificity in modulating beneficial microbiota that could improve gut health and immune modulation.

XO production on an industrial scale is carried out from lignocellulosic material such as forestry, agricultural biomass, industry, or urban solid wastes. The important raw materials used for commercial production nowadays include corncobs, sugarcane bagasse (crop residues), and different plant woods. XO are particularly promising, being produced by the hydrolysis of xylan, a component of inexpensive and sustainable plant biomass such as sugarcane bagasse, corn cobs, and rice straw, which are cheaper and abundant in nature.

Mechanism of action of XO

XO exerts its benefits mainly through targeted modulation of gut microbiota, triggering a series of host physiological improvements. Being resistant to digestion in the upper gastrointestinal tract, XO reaches the cecum intact, where they are selectively fermented by Bifidobacterium and Lactobacillus spp., leading to suppression of pathogenic taxa such as Clostridium, *Escherichia-Shigella*, and *Terrisporobacter*. This shift enhances short chain fatty acids (SCFAs) production like acetate, propionate, and butyrate, which provide energy for colonocytes, lower intestinal pH to inhibit pathogens, and regulate genes linked to anti-inflammatory responses, epithelial barrier integrity, and fluid balance. SCFAs also improve mineral solubility and bioavailability, supporting nutrient absorption and bone health. In addition, XO reduces lipopolysaccharide levels, downregulates pro-inflammatory cytokines (TNF-α, IL-6, IL-1β), and stimulates goblet cell mucin secretion, thereby reinforcing gut defence. Studies in poultry and livestock further show that XO improves gut morphology (villus height, crypt depth), enhance tight junction protein expression, and promote immune stability, resulting in better growth performance and feed efficiency. Beyond gut health, XO influence systemic metabolism by lowering cholesterol and LDL, and improving glucose regulation, establishing them as promising next-generation prebiotics for livestock and poultry.

XO supplementation in livestock and poultry

Swine

XO supplementation generally modulates gut microbiota by increasing Lactobacillus while reducing Clostridium, Escherichia, Shigella, and Terrisporobacter populations in the ileum and cecum of piglets. Diets containing 200 mg/kg XO lowered fecal *E. coli* and elevated Lactobacillus counts, though some studies noted opposite trends with higher Streptococcus and Turicibacter in piglets. Both XO and galactooligosaccharides reduced intestinal *Listeria monocytogenes* and selectively promoted bifidobacteria and lactobacilli, which act antagonistically against pathogens. Similarly, the dietary XO supplementation (0.04% for 28 days) significantly increased the final body weight and average daily weight gain in piglets. In addition, XO increased serum glucose and decreased blood urea nitrogen and triglyceride content significantly. Compared with the control animals, dietary XO also increased the serum activity of superoxide dismutase and catalase and decreased malondialdehyde activity. In addition, serum IgG content was also significantly higher in XO-supplemented piglets (Hou et al., 2020).

In commercial pig farming, weaning is a major biological stressor that disturbs the gut microbiome, reduced intestinal barrier integrity, and thus increases the susceptibility of piglets to pathogens. This results in post-weaning diarrhoea. Stanley et al. (2025) reported that XO supplementation in piglets (500 mg XO/kg feed) from weaning to 54 days post weaning resulted in significantly improved body weight, but did not affect feed conversion ratio. Salmonella and Veillonellaceae were reduced and there were increased Lactobacillus and Clostridium. Along with that there was increased duodenal and jejunal goblet cells and reduced duodenal crypt depth. XO upregulated tight junction proteins claudin-2, claudin-3, intestinal alkaline phosphatase, and zonula occludens-1 genes, which are gut positive parameters, while downregulating the cytokine IL-8. These findings attribute XO potential to enhance growth and gut health in weaning piglets with naturally occurring post-weaning diarrhoea, to maintain productivity and enhance welfare.

Poultry

In poultry like chickens, XO is selectively fermented in the paired caeca. It has been reported that, XO enhances microbial diversity and SCFAs production, which lowers gut pH, suppresses pathogens, fuels enterocytes, and improves barrier integrity in chickens. These changes lead to superior gut morphology, notably greater villus height and villus-to-crypt ratios, enhancing nutrient absorption and performance. XO also upregulates tight junction proteins (claudin-1, claudin-5, ZO-1) and boosts mucosal IgA and systemic IgG, strengthening both local and systemic immunity. In broilers exposed to pathogens, XO reduced Salmonella colonization, suppressed inflammatory cytokines, and mitigated intestinal damage (Zhang et al., 2024). Sequencing studies further show XO reshapes the cecal microbiota by enriching SCFA producing genera such as *Ruminococcaceae*, *Faecalitalea*, and *Lachnospiraceae*, while reducing harmful groups like *Bacteroides* and *Erysipelatoclostridium* (Jianmin Zhou et al., 2021).

Dietary supplementation with XO at doses up to 400 mg/kg was found to enhance the egg production of laying hens over 12 weeks ($P < 0.05$). This improved performance was associated with significant enhancements in gut health, including improved jejunal morphology (increased villus height and villus to crypt ratio). Furthermore, XO stimulated beneficial microbial activity, evidenced by increased cecal concentrations of butyric and isovaleric acids ($P < 0.05$). Microbiota analysis revealed that XO increased bacterial richness and beneficially shifted the microbial composition, characterized by a higher abundance of *Firmicutes*, *Bifidobacteriaceae*, and *Lactobacillus*, and a decrease in *Bacteroidetes* (Xiong et al., 2024).

The SCFA-mediated mechanism improves intestinal barrier function, fuels enterocytes, lowers luminal pH to increase mineral solubility, thus increases calcium absorption, and supports a resilient, anti-inflammatory immune status, with early life *in ovo* administration programming a post-hatch cytokine profile characterized by elevated IL-10 and reduced IFN-γ (Das et al., 2024). In broilers, these effects translate to enhanced growth performance and feed conversion with an efficacy comparable to antibiotics, alongside a significant reduction in mortality. In laying hens, XO improves the feed-to-egg ratio, laying rate, egg mass, and eggshell quality, outcomes associated with favourable regulation of reproductive hormones and adipokines, suggesting enhanced fecundity (Wen et al., 2022). Furthermore, XO modulates systemic lipid metabolism, reducing serum cholesterol and triglycerides while attenuating abdominal and hepatic lipid accumulation. These findings emphasize XO as a next generation prebiotic that optimizes the gut ecosystem to improve nutrient utilization, reproductive capacity, and metabolic resilience in poultry.

Ruminants

Dietary XO (25 g/day/head) and exogenous enzymes supplementation significantly improved milk yield, true protein, fat concentration, energy corrected milk (ECM)/DM intake, and fiber digestibility (NDF and ADF). XO reduced enteric CH_4 emissions, CH_4 per milk yield, and CH_4 per ECM, yielding the greatest metabolizable energy intake, milk energy output, and lowest CH_4 energy losses ($P<0.05$) in lactating Jersey cows. This finding suggests that XO addition to the diet enhanced lactation performance, nutrient utilization, and energy efficiency while mitigating enteric methane, suggesting a promising strategy for sustainable dairy production (Dong et al., 2023).

In conclusion, XO has emerged as a promising nutritional strategy to enhance health and productivity in livestock and poultry. XO selectively enhance beneficial gut microbes, increase SCFAs production, immunity, nutrient utilization, growth performance, reproductive efficiency and metabolic health thereby improving both productivity and environmental sustainability. Thus, XO act as next-generation prebiotics with multifaceted benefits on gut ecology, immune modulation, nutrient metabolism, and systemic health, making them as valuable feed additive for livestock production.

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