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Effect of maternal dietary supplementation of laminarin and fucoidan, independently or in combination, on pig growth performance and aspects of intestinal health

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ABSTRACT

The study investigated the effects of maternal dietary supplementation (*n* 10 gilts/treatment) of laminarin (0 and 1.0 g/d) and fucoidan (0 and 0.8 g/d) from day 107 of gestation until weaning (day 24) on pig growth performance from birth to slaughter (*n* 10 pigs/treatment group), and aspects of intestinal health at weaning (*n* 7 pigs/treatment group) and day 8 post-weaning (PW) (*n* 7 pigs/treatment group). Pigs were individually penned during days 0–26 PW, and penned in groups of 10 (based on maternal dietary treatment) during days 26–117. There was an interaction between laminarin and fucoidan on sow faecal *Enterobacteriaceae* gene copy numbers (GCN) (P<0.05). Fucoidan-sows had increased faecal *Enterobacteriaceae* CGN compared with basal-sows (P<0.05). However, there was no effect on *Enterobacteriaceae* CGN when laminarin was combined with fucoidan. Piglets suckling the fucoidan-sows had shorter villus height (VH) and down-regulated *SGLT1* mRNA in the ileum at weaning compared with those suckling the non-fucoidan-sows (P<0.05). Pigs from the laminarin-sows had longer VH in the ileum on day 8 PW compared with those from the non-laminarin-sows (P<0.05). Pigs from the laminarin-sows had *IL-6* mRNA down-regulated in the colon at weaning and *IL-8* down-regulated in the ileum on day 8 PW compared with those from the non-laminarin-sows (P<0.05). Pigs from the fucoidan-sows had increased body weight (BW) on day 26 PW compared with those from the non-fucoidan-sows (P<0.05). Pigs from the laminarin-sows had increased BW on day 67 and gain:feed ratio during days 26–117 PW compared with those from the non-laminarin-sows (P<0.05). In conclusion, maternal laminarin supplementation resulted in positive response in aspects of intestinal health PW and pig growth performance during the grower-finisher period.

Abbreviations: ACTB, beta-actin; ADFI, average daily feed intake; ADG, average daily gain; AGP, antibiotic growth promoters; B2M, beta-two-microglobulin; BW, body weight; CD, crypt depth; cDNA, complementary DNA; CP, crude protein; C_t, cycle threshold; DE, digestible energy; DM, dry matter; FOXP, forkhead box P; FUC, fucoidan; GCN, gene copy number; GAPDH, glyceraldehyde-3-phosphate dehydrogenase; GE, gross energy; G:F, gain to feed; GLUT, glucose transporter; IFN-γ, interferon gamma; IL, interleukin; LAM, laminarin; NDF, neutral-detergent fibre; PEPT, peptide transporter; PPIA, peptidylprolyl isomerase A; PPR, pattern recognition receptors; PW, post-weaning; RT-qPCR, real time quantitative PCR; SID, standard ileal digestible; SDP, seaweed derived-polysaccharides; SGLT, sodium-glucose linked transporter; TGF-β, transforming growth factor-beta; TNF-α, tumour necrosis factor alpha; VH, villous height.

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1. Introduction

The first 2 weeks post-weaning (PW) is a challenging phase, characterised by intestinal dysfunction, decreased feed intake, and reduced growth performance (Lallès et al., 2004; Weary et al., 2008). These PW disorders were controlled using antibiotic growth promoters (AGP) in weaning diets. However, since the ban on animal in-feed AGPs (European Communities Regulation no. 1831/2003), studies have been attentive on finding substitutes to AGPs (Gallois et al., 2009). Dietary supplementation of seaweed derived-polysaccharides (SDP), containing laminarin (LAM) and fucoidan (FUC), to weaned pigs improved growth performance in the absence of AGP (Gahan et al., 2009; McDonnell et al., 2010). Laminarin is a low-molecular-weight polysaccharide containing β-glucans (Brown and Gordon, 2005; Read et al., 1996). Beta-glucan stimulates the immune response (Volman et al., 2008), and have prebiotic properties (Lynch et al., 2010). Fucoidan is a high-molecular-weight sulphated polysaccharide (Berteau and Mulloy, 2003) and has anti-inflammatory (Matsumoto et al., 2004), antiviral (Hayashi et al., 2008) and antitumor (Maruyama et al., 2003) properties.

Recent studies demonstrated that maternal dietary supplementation of SDP influenced aspects of intestinal health and immune status of piglets at weaning and immediately PW (Heim et al., 2014a; Leonard et al., 2011, 2012). The effects included: reduced colonic *Escherichia coli* (Leonard et al., 2010); down-regulation of pro-inflammatory cytokines (Heim et al., 2014a); and increased villous height (VH) (Heim et al., 2014a). Supplementation of SDP to weaned pigs has resulted in increased gene expression of glucose transporters (Heim et al., 2014b).

Thus, the objective of this study was to evaluate the effects of maternal dietary supplementation of LAM and FUC, independently or in combination, from day 107 of gestation until weaning, on sow and piglet *Enterobacteriaceae* and *Lactobacillus* spp. numbers, pig growth performance from birth to slaughter, and aspects of intestinal health, such as the gene expression of cytokines and nutrient transporters. It was hypothesised that maternal supplementation of LAM and/or FUC would modulate the inflammatory responses and improve aspects of gut health of suckling and weaned pigs, enhancing their growth performance PW, due to the biological properties of LAM and FUC.

2. Materials and methods

All procedures described in the present experiment were conducted under experimental license from the Irish Department of Health in accordance with the Cruelty to Animals Act 1876 and the European Communities (Amendments of the Cruelty to Animals Act, 1876) Regulations.

2.1. Experimental design and dam diets management

Forty crossbred pregnant gilts (Large White × Landrace genetic lines) were randomly assigned to one of the four dietary treatments (*n* 10 gilts/treatment): (T1) basal lactation diet (control); (T2) basal lactation diet supplemented with 1.0 g laminarin/d (LAM); (T3) basal lactation diet supplemented with 0.8 g fucoidan/d (FUC); and (T4) basal lactation diet supplemented with both 1.0 g LAM and 0.8 g FUC/d (LAM + FUC). The concentrations of LAM and FUC were based on previous work carried out by Leonard et al. (2012). The LAM (990 g LAM/kg) and FUC (720 g FUC/kg, 180 g/kg CP and 100 g/kg ash) were derived from *Laminaria* spp. and sourced from BioAtlantis Limited (Tralee, Co., Kerry, Ireland).

Introduction to experimental dietary treatment groups commenced on day 107 of gestation until weaning (piglet age 24 d). The lactation diet was formulated to contain 190 g/kg of crude protein (CP), 14.5 MJ/kg of digestible energy (DE) and 8.5 g/kg of standardised ileal digestible (SID) lysine. All amino acids requirements were met relative to lysine (NRC, 1998). The ingredient composition and chemical analysis of the lactation diet are given in Table 1.

The pregnant gilts were housed individually in farrowing pens (2.2 m × 2.4 m). The farrowing room was maintained at 20°C throughout the experiment. The experimental supplements were top-dressed on the lactation diet each morning (09.00 h) to ensure consumption. The dams received specific amounts of feed in the following quantities: 2 kg/d of the lactation diet from day 107 of gestation until the day of parturition and then the feed supply was increased by 1.0 kg/d until day 3 post-farrowing and by 0.5 kg/d until day 6 post-farrowing. Afterwards, the sows were allowed semi-*ad libitum* consumption of the lactation diet, which was adjusted for each sow depending on daily intake. The sows were fed in three equal meals provided at 09.00, 13.00 and 17.00 h. The sows had *ad libitum* access to drinking-water throughout the experimental period. No creep feed was offered to the piglets throughout the lactation period, and piglets had no access to the sow's feed. The piglets received an intramuscular injection of Fe-dextran (Ferdex – 100, Medion Farma Jaya, Bandung, Indonesia) on day 7 after birth.

2.2. Pigs management

2.2.1. Lactation period

All farrowings were supervised. At parturition, each piglet (meat-line boars × Large White × Landrace genetic lines) was individually weighed and tagged. Between 6 and 12 h after the birth of the last piglet, litter size was adjusted by cross-fostering piglets within dietary treatment groups to ensure that sows nursed a similar number of piglets (*n* 12 piglets/sow), and this was maintained throughout the lactation period. The individual piglet BW was recorded at birth and at weaning and the ADG calculated from these data.