Differential effect of fiber type and fermentability on the intestinal immune response of pigs fed high-fiber diets

Milena Saqui-Salces[1], Zhimin Huang[1], Pedro E. Urriola[1], Gerald C. Shurson[1]

[1]*Department of Animal Science, University of Minnesota*

Background

Dietary fiber is one of the most significant nutrients that affects gut physiology and health in humans and livestock species. High-fiber diets are prescribed as therapies for patients to reduce the incidence or severity of gastrointestinal inflammatory diseases. Diets rich in fiber and low in fermentable oligo-, di-, mono-saccharides and polyols (FODMAP) alter gut microbiota, local immune response, and intestinal endocrine function. In pigs, inclusion of corn dried distiller's grains with solubles (DDGS) in a commercial swine diet reduced severity and extension of ileitis.

The relative solubility or insolubility of fiber has been considered to be a determining factor of physiological responses. However, other factors such as viscosity, fermentability, and fiber interactions with lipids and protein are significant factors shown to affect gastrointestinal responses in animal models. Most studies on the effect of fiber on intestinal immune response have used purified fiber sources that may not model the effect of complex, real-life diets. In this study, we selected commercially available fiber sources with different solubility, fermentability, and associated lipid and protein concentrations that are currently used in swine production to evaluate their effect on gastrointestinal immune response.

Hypothesis and Objective

The hypothesis was that dietary fiber modulates the host immune response by changing the availability of nutrients for bacterial growth and subsequent microbiota composition.

The aim of this study was to characterize the immune response induced by diets formulated with fibers sources of different fiber composition and characteristics.

Materials and Methods

- **Experimental design**
  - Pigs (n = 36, 84 kg): individually fed experimental diets in metabolism cages for 14 days
  - Feed intake: 2.5% of each pig's body weight (BW) in two meals per day
  - Dietary treatments (**Table 1**): 3 diets ×12 replicates. Diets were formulated to similar total dietary fiber content.
    - 23% wheat straw diets (WS)
    - 30% soybean hulls diets (SBH)
    - 55% corn distillers dried grains with solubles (DDGS)
- **Analysis**
  - Pigs were fasted overnight and tissue samples were collected after euthanasia
  - Ileum mRNA was extracted, pooled, and analyzed for gene expression of inflammatory cytokines and receptors using a RT2 Profiler PCR array (Qiagen, PASS-011ZA)
- **Statistics**
  - RT2 Profiler PCR array data results were analyzed using the Qiagen data analysis excel worksheet following the instruction manual

Table 1. Diet composition

Item	WS	SBH	DDGS
Ingredient (%)			
WS	23.0	0.0	0.0
SBH	0.0	30.0	0.0
DDGS	0.0	0.0	55.0
Analyzed nutrient composition, DM basis			
Crude protein (%)	13.0	13.6	12.4
Ether extract (%)	2.9	2.6	3.1
Acid dietary Fiber (%)	12.4	12.5	13
Neutral detergent fiber (%)	22.2	23.5	26.9
Total dietary fiber (%)	23.0	23.4	21.4
Lignin (%)	2.2	2.3	2.2
Hemicellulose (%)	9.7	11.0	13.9
Cellulose (%)	10.3	10.2	10.8
Bulk density (g/100cm³)	13.0	13.6	12.4
Viscosity (cP)	2.9	2.6	3.1

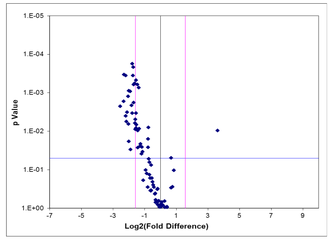
Wheat straw (WS)

Corn distillers dried grains with solubles (DDGS)

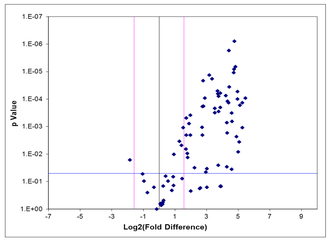
Soybean hulls (SBH)

Results

WS vs. DDGS



DDGS vs. SBH



WS vs. SBH

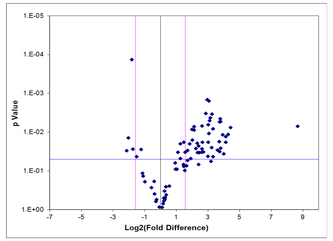


Fig. 1. Volcano plots showing the Log differences (X axis) to p Value (Y axis) of inflammatory-associated gene expression in pooled ileum samples (5 per group) of pigs in WS, SBH, and DDGS diets. WS: N = 10, SBH: N = 12, N = 11.

Table 2. Genes which expression was changed in the ileum by diet.

NS: Not statistically different. All the other data has P < 0.05.

Symbol	Gene Name	Fold Up- or Down-Regulation		
		WS vs. DDGS	DDGS vs. SBH	WS vs. SBH
CCL1	Chemokine (C-C motif) ligand 1	-2.9	38.8	13.5
CCL17	Chemokine ligand 17-like protein	-3.5	28.4	8.0
CCR2	Chemokine (C-C motif) receptor 2	-2.9	13.7	4.7
CCR3	Chemokine (C-C motif) receptor 3	-2.7	27.2	10.1
CCR4	Chemokine (C-C motif) receptor 4	-4.5	19.9	4.4
CCR7	Chemokine (C-C motif) receptor 7	-3.2	9.1	2.8
CD40LG	CD40 ligand	-1.7	7.5	4.4
CXCR2	Chemokine (C-X-C motif) receptor 2	-4.6	18.6	4.1
FASLG	Fas ligand (TNF superfamily, member 6)	-1.7	13.2	7.8
IL13	Interleukin 13	-3.0	11.6	3.8
IL15	Interleukin 15	-2.4	6.9	2.9^{NS}
IL17A	Interleukin 17A	-3.7	31.2	8.4
IL17F	Interleukin 17F	-2.7	26.3	9.7
IL23A	Interleukin 23, alpha subunit p19	12.2	33.9	413.2
IL27	Interleukin 27	-3.0	24.2	8.1
IL4	Interleukin 4	-4.3	38.3	9.0
IL-5	Interleukin 5	-3.3	26.8	8.1
IL6R	Interleukin 6 receptor	-1.7	14.8	8.6
IL9	Interleukin 9	-2.5	44.3	17.6
OSM	Oncostatin-M-like	-4.0	29.8	7.4
IL33	Interleukin-33-like	-3.2	13.0	4.0
LOC100519468	Tumor necrosis factor ligand superfamily member 14-like	-2.6	21.9	8.5
TNF	Tumor necrosis factor	-3.2	11.6	3.6
TNFRSF11B	Tumor necrosis factor receptor superfamily, member 11b	-3.4	21.4	6.3

Summary and Conclusion

Summary

- Feeding the DDGS diet accounted for higher expression levels of cytokines and receptors, particularly of IL17A, IL17F, IL-4, IL-9, CCL1, CCL17, CCR3, IL27 and IL5, most of which are associated to Th2 and T regulatory cells
- Feeding the SBH diet resulted in induction of the Th1 response mediators IL2RB, LTB,TNFSF4, IL1A and INFG
- The inflammatory profile of pigs fed the WS diet was closer to those fed DDGS than those fed SBH diets

Conclusion

- Highly fermentable fiber sources (SBH) induce Th1 related cytokines, while low fermentability fiber sources (WS) induce Th17 responses
- When feeding a high-fiber diet, the biochemical characteristics of the fiber source may significantly affect the host intestinal immune response

Financial support was provided by National Pork Board.