Consumption of guar gum and retrograded high-amylose corn resistant starch increases IL-10 abundance without affecting pro-inflammatory cytokines in the colon of pigs fed a high-fat diet

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ABSTRACT: Increases in dietary intake of viscous and nonviscous soluble fiber are reported to improve bowel health. However, related biological mechanisms are not very clear. This study was conducted to examine if colonic inflammation would occur in a typical Western diet model and determine if consumption of soluble fiber components would attenuate potential detrimental effects by differentially affecting colonic abundances of anti-inflammatory cytokine IL-10 and 2 pro-inflammatory cytokines tumor necrosis factor-alpha (TNF-α) and IL-6 in pigs fed a high-fat basal diet supplemented, respectively, with 15% viscous soluble fiber guar gum (GG) and 15% nonviscous soluble fiber, that is, retrograded high-amylose corn (Zea mays) resistant starch (RS). A total of 24 Yorkshire growing barrows were assigned into a standard corn and soybean (Glycine max) meal (SBM)-based grower diet as a positive control (PC), an animal protein-based high-fat basal diet as the negative control (NC), and 2 NC basal diets supplemented with 15% GG and 15% RS, respectively, according to a completely randomized block design for 4 wk. Abundance of these cytokines in homogenized and extracted colonic tissue supernatant samples was measured by ELISA. Although colonic IL-10 abundance was lower ($P < 0.05$) in the corn and SBM-based PC group than that in the high-fat basal NC group, there were no differences ($P > 0.05$) in colonic abundances of TNF-α and IL-6 between NC and PC groups and among all of the treatment groups. Compared with the NC group, consumption of GG and RS at 15% increased ($P < 0.05$) colonic IL-10 abundance. Moreover, there was no difference ($P > 0.05$) in colonic IL-10 abundance between the 15% GG and the 15% RS groups. Thus, consumption of a typical high-fat Western diet did not induce colonic inflammation. Diets supplemented with 15% GG or 15% RS may protect the colon from developing inflammation by enhancing IL-10 abundance.

Key words: bowel inflammation, cytokines, guar gum, pigs, resistant starch, soluble fiber

INTRODUCTION

Low dietary fiber and high dietary sugars and digestible starch in association with consumption of a typical Western diet induce bowel inflammation and are associated with the increased incidence of colorectal cancers (Bruce et al., 2000). An inappropriate balance between pro-inflammatory cytokines, including IL-1β, IL-6, and tumor necrosis factor-alpha (TNF-α), and the anti-inflammatory cytokines such as IL-10 would lead to inflammation in local tissues such as bowel (Schreiber et al., 1995). The gastrointestinal tract is the largest secondary immune organ of the body and a suitable level of soluble fiber consumption will help maintain healthy gut microbiota and reduce gut inflammation (Galvez et al., 2005). In our previous study, soluble fiber ingredients such as guar gum (GG) and retrograded high-amylose corn resistant starch (RS) were shown to be effective in enhancing microbial biosynthesis of butyrate in the large intestine (Rideout et al., 2008). As a signaling nutrient, butyrate is known to directly affect immune cell functions in the gut (Schley and Field, 2002). Related research activities have been supported by grants (to M.Z.F.) from Agriculture and Agri-Food Canada (AAFC)-the Agricultural Bioproducts Innovation Program (ABIP), and the Ontario Ministry of Agriculture, Food and Rural Affairs (OMAFRA)-the University of Guelph Partnership Research Program.

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279 Therefore, this study was conducted to examine if colonic inflammation would occur in a typical Western diet model and determine if consumption of soluble fiber components would attenuate potential detrimental effects by differentially influencing colonic abundance of the anti-inflammatory cytokine IL-10 and the pro-inflammatory cytokines TNF-α and IL-6 in growing pigs fed a high-fat basal diet supplemented with 15% viscous soluble fiber GG and 15% nonviscous soluble fiber RS.

MATERIALS AND METHODS

Four experimental diets included a positive control (PC) diet containing corn (51.0%), cornstarch (16.4%), soybean meal (SBM) (29.0%), canola oil (0.5%), and salt (0.5%) and the rest as macro- and trace-mineral–vitamin supplements (2.6%), a negative control (NC) Western high-fat basal diet containing poultry meal, casein, fructose, starch, and animal fat with dietary nutrient contents formulated according to Rideout et al. (2008), and 2 additional test diets of the NC basal diet supplemented with 15% GG or 15% RS at the expense of conventional cornstarch, respectively. Twenty-four Yorkshire barrows (30–50 kg BW) were individually housed in metabolic crates and allocated to the 4 test diets according to a randomized block design for 4 wk by following our established animal study protocols (Rideout et al., 2008). At the end of the study, colonic tissues were collected from the sacrificed pigs, immediately frozen in liquid N, and then pulverized for the analyses of the target cytokines in the tissue samples by using ELISA kits (R & D Systems, Inc., Minneapolis, MN) according to our established procedures (Kim et al., 2010). Data were analyzed with the mixed model of SAS (SAS Institute Inc., Cary, NC) according to a completely randomized block design (Rideout et al., 2008). Multiple comparisons between treatments were made using Tukey’s test. Differences between the PC and NC groups and between each of the treatment groups and the NC as well as between the GG and RS groups were further analyzed by using Dunnett’s test. Differences were considered significant at \( P < 0.05 \).

RESULTS AND DISCUSSIONS

The first objective of this study was to examine if colonic inflammation would occur in a typical Western diet model established with growing pigs. Our previous study showed that cecal content of carcinogenic compound indole was elevated after feeding a typical Western diet that was the NC diet adopted for this study and was high in animal fat, animal proteins, and rapidly digestible sugar and starch (Rideout et al., 2008). The PC diet in this study, a typical commercial swine diet containing plant protein sources, was the healthy control group. Evidence also suggests that some key potential pathogenic bacterial species are predominantly protein fermenters (Bauer et al., 2006). High protein feeding increases populations of undesirable bacterial species such as Clostridium perfringens and Escherichia coli and contents of their enterotoxins such as lipopolysaccharides (LPS) in the large intestine (Bauer et al., 2006). It is well known that LPS is a typical ligand to Toll-like receptor 4 for inducing innate pro-inflammatory immune responses in the gut. Although colonic IL-10 abundance was higher in the NC than in the PC group (Figure 1A), there were no differences \((P > 0.05)\) in colonic abundances of TNF-α and IL-6 between the NC and the PC groups and among

![Figure 1.](image-url)
all of the treatment groups (Figures 1B and 1C). Whereas increases in IL-10 level are reported in the literature under acute bowel inflammation, elevation in expression of the pro-inflammatory cytokines such as TNF-α and IL-6 are the hallmark of acute bowel inflammation (Kim et al., 2010). On the other hand, a decreased level of IL-10 has been recognized as a biomarker for chronic bowel inflammation (Gasche et al., 2000). Therefore, our cytokine profiling results suggest that neither acute nor chronic bowel inflammation had occurred under this Western diet model with growing pigs.

Another objective of this study was to examine if consumption of these soluble fiber components would attenuate potential detrimental effects by directly alternating the gut immunity under the typical Western diet model established with growing pigs. As shown in Figure 1A, consumption of GG and RS at 15% increased (P < 0.05) colonic IL-10 abundance compared with the NC group. It is well documented that IL-10 inhibits expression of the pro-inflammatory cytokines (Schreiber et al., 1995). However, consumption of GG and RS at 15% did not affect (P > 0.05) colonic abundances of TNF-α and IL-6 compared with the NC group (Figures 1B and 1C). This is likely due to the fact that neither acute nor chronic colonic inflammation had occurred and the 2 pro-inflammatory cytokines were in their basal levels under this Western diet model with the growing pigs. The enhanced expression of IL-10 in consumption of 15% GG and 15% RS is likely mediated via the regulatory effects of butyrate on the gut local innate immune cells as well as adaptive and regulatory immune systems (e.g., Schley and Field, 2002). Therefore, diets supplemented with 15% GG and 15% RS may protect the colon from developing inflammation by enhancing IL-10 abundance.

**LITERATURE CITED**


