DIET COMPOSITION AND ILEITIS IN PIGS

Effect of including distiller’s dried grains with solubles in the diet, with or without antimicrobial regimen, on the ability of growing pigs to resist a *Lawsonia intracellularis* challenge

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ABSTRACT: A disease challenge experiment was conducted to determine if including 10% DDGS in the diet, with or without antimicrobial supplementation, reduces the incidence and/or severity of intestinal lesions in growing pigs after a *L. intracellularis* challenge. One hundred 17-d old weaned pigs were blocked by sex and weight and randomly allotted to one of five treatment groups: negative control (NC) - unchallenged, corn-soy diet; positive control (PC) - challenged, corn-soy diet; 10% DDGS diet (D) – challenged; positive control with antimicrobial regimen (PC + A) – challenged; and 10% DDGS diet with antimicrobial regimen (D + A) - challenged. For antimicrobial-supplemented treatments, diets contained 30 g/ton

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BMD® continuously, with Aureomycin® pulsed at 500 g/ton from d 3 pre-challenge to d 11 post-challenge. Challenged pigs were orally inoculated with \(8.0 \times 10^8\) L. intracellularis after a 4-wk pre-challenge period. On d 21 post-challenge, pigs were euthanized, lesions of intestinal mucosa was evaluated, and ileal tissue samples were analyzed by immunohistochemistry to determine presence and proliferation of L. intracellularis. Compared to other dietary treatments, feeding a diet containing 10% DDGS reduced ileum and colon lesion length and prevalence (\(P < 0.05\)), and reduced severity of lesions in the ileum (\(P < 0.05\)) and colon (\(P < 0.10\)) in challenged pigs. Pigs fed the diet containing the antimicrobial regimen had a lower prevalence and severity of lesions in the jejunum (\(P < 0.05\)), and tended to have reduced total tract lesion length (\(P = 0.11\)) compared to other challenged pigs. No differences in length, severity, or prevalence of lesions were observed in D + A pigs (\(P > 0.15\)), but fecal shedding of L. intracellularis was reduced on d 14 post-challenge (\(P < 0.05\)) compared to other challenged pigs. No dietary effects on fecal shedding were observed by d 20 post-challenge (\(P < 0.10\)). The proportion of cells infected with L. intracellularis was reduced when DDGS (\(P = 0.05\)) or antimicrobial (\(P = 0.10\)) diets were fed. Dietary inclusion of 10% DDGS appears to provide some benefit to growing pigs subjected to a moderate ileitis challenge, similar to a currently approved antimicrobial regimen.

Key Words: Pig, Ileitis, Distiller’s dried grains with solubles, Antimicrobial
Introduction

Ileitis, also known as porcine proliferative enteropathy (PPE), is an enteric
disease in swine that can decrease feed intake, reduce growth rate, and increase
mortality. The disease is caused by *Lawsonia intracellularis*, an intracellular,
microaerophilic bacteria that infects the enterocytes of the intestine, causing cellular
proliferation and thickening of the infected intestine. It has been estimated that
PPE results in increased production costs ranging from $3 to $11 per pig, due to
increases in feed cost and time to reach market weight (McOrist et al., 1997).

Prevention and (or) control of PPE has largely been focused on the use of
antimicrobial agents. Tylosin phosphate (Tylan®), lincomycin (Lincomix®),
tiamulin (Denagard™), and chlortetracycline (CTC) + bacitracin methylene
disalicylate (BMD®) are the only FDA-approved antimicrobial regimens for
prevention of PPE. Sub-therapeutic levels of these antibiotics improve pig
performance but often fail to prevent the disease (Gebhart et al., 1998; Schwartz et
al., 1998; Winkelman, 1998). Providing CTC strategically at therapeutic levels can
positively affect growth performance and reduce the occurrence and severity of
intestinal lesions caused by PPE (McOrist, 1998; Winkleman et al., 1998). Schultz et
al. (1997) observed an additive and (or) synergistic effect when feeding the
combination of BMD® and CTC for the treatment of ileitis.

Feeding therapeutic levels of feed-grade antibiotics is very expensive and can
generally only be done for a limited period of time. Additionally, food safety
concerns over potential residue violations in meat and the risk of antibiotic-
resistance in human strains of pathogenic organisms precludes continued use of these drugs. Reports from informal field studies have suggested that including distiller’s dried grains with solubles (DDGS) in grow-finish diets in commercial herds that have historically had recurring problems with ileitis, may reduce dependence on antibiotics to combat this disease (Goihl, 2001). In several commercial grow-finish herds, dietary levels of 5 – 15% DDGS have resulted in a decrease or complete removal of antibiotics, while reducing the negative effects on growth performance as well as reducing mortality rates in herds with recurring problems with ileitis (Goihl, 2001). Distiller’s dried grains with solubles is a co-product of the dry mill fuel ethanol industry that contains approximately 10% crude fiber, and the fiber composition is primarily insoluble (42.2%) versus soluble (0.7%) in nature (Shurson et al., 2000). Feeding diets that are low in soluble non-starch polysaccharides can reduce the proliferation of pathogenic organisms in the gastrointestinal tract (Hampson et al, 1999). Smith and Halls (1968) suggested that fiber influences the secretory function of the epithelium, and this alteration may impair bacterial adhesion. Fiber also has a “cleansing” effect in the gut as a result of reducing the viscosity of digesta (Lawrence, 1972). The objective of this study was to evaluate the effect of dietary inclusion of DDGS, with or without use of a strategic antimicrobial regimen (CTC & BMD®), on the ability of growing pigs to resist a *L. intracellularis* challenge.
Materials and Methods

Animals and Allotment

Experimental protocols used in this study were reviewed and approved by the Institutional Animal Care and Use Committee of the University of Minnesota. One hundred crossbred pigs (50 gilts and 50 barrows, 1/4 Landrace x 1/4 Large White x 1/2 Duroc) were obtained and transported from a commercial farrowing unit to isolation barns located on the University of Minnesota (St. Paul) campus. The source herd had no history or recorded cases of proliferative enteropathy, and was serologically negative for *Lawsonia intracellularis*, porcine respiratory and reproductive syndrome (PRRS), and *Actinobacillus pleuropneumonia*. The source herd was also clinically negative for *Salmonella cholerasuis*, transmissible gastroenteritis (TGE), and pathogenic *Brachyspira* species. Pigs (approximately 17 d of age) were blocked by gender and weight, and blocks were randomly allotted to one of five treatment groups: negative control (NC) corn-soybean meal diet fed without disease challenge, positive control (PC) corn-soybean meal diet fed with disease challenge, 10% DDGS diet fed with disease challenge (D), control diet with antimicrobial regimen fed with disease challenge (PC + A), or 10% DDGS diet with antimicrobial regimen fed with disease challenge (D + A). The antimicrobial regimen consisted of continuous BMD® inclusion in the diet (33 g/tonne) along with
dietary pulsing of Aureomycin® (550 g/tonne) from d-3 pre-challenge to d-11 post-
challenge. The DDGS utilized for the study was obtained from Al-Corn Clean Fuel
(Claremont, MN). Animals were housed in isolation rooms, with 10 pigs per room
(7.25 m² per room, 10 rooms total) and 2 rooms per treatment group.

Experimental Diets

All pigs were fed a similar commercial pelleted Phase I nursery diet for the first
4-d of the experiment to encourage feed intake prior to initiation of dietary
treatments. After the initial 4-d acclimation period, animals were fed their
respective experimental diets for the remainder of the 53 d study. Representative
samples of each diet were obtained and analyzed for dry matter, gross energy, crude
protein, ash, ether extract, crude fiber, calcium, phosphorus, and individual amino
acid composition. Additionally, samples of the medicated feed were submitted to the
Alpharma Analytical Laboratory for analysis of BMD and CTC levels.

Experimental diets were formulated to contain equivalent energy (3390 kcal/kg
ME), calcium (0.80%), total phosphorus (0.70%), and apparent ileal digestible
lysine (1.15%). Diets were formulated based on recently determined DDGS nutrient
values for energy (Spihls et al., 1999), total amino acid and mineral levels (Spihls et
al., 2002), and apparent ileal amino acid digestibility coefficients (Whitney et al.,
2000). The ME value used for DDGS was 3350 kcal/kg on an as-fed basis. All other
nutrients were provided to meet or exceed NRC (1998) recommendations.
Digestible and metabolizable energy values were calculated based on proximate analysis values using the following formulas from Noblet and Perez (1993):

\[
\text{DE kcal/kg} = 4151 - (122 \times \% \text{ Ash}) + (23 \times \% \text{ CP}) + (38 \times \% \text{ EE}) - (64 \times \text{ Crude fiber})
\]

\[
\text{ME kcal/kg} = \text{DE} \times (1.003 - (0.0021 \times \% \text{ CP}))
\]

Disease Challenge

Four wks after experimental diets were initiated (d 32), pigs were manually restrained and provided 40 ml of either saline (NC) or an inoculation of \(L. intracellularis\) (PC, D, PC + A, and D + A treatments) via stomach tube. The inoculate was prepared as a mucosal homogenate collected from the small intestines of pigs previously infected with \(Lawsonia intracellularis\) and exhibiting lesions consistent with ileitis. Mucosal material was collected by scraping the lumen of the infected intestine, and was then diluted with a sucrose-phosphate-glutamate buffer with the goal of obtaining a dosage rate of \(1 \times 10^8\) \(L. intracellularis\) per pig. A representative sample of the harvested gut material was submitted to the University of Minnesota Veterinary Diagnostic Lab, and actual dosage rate of \(L. intracellularis\) provided per pig was determined to be \(8.0 \times 10^8\). Additionally, the material was screened and determined to be negative for other pathogens, including spirochetes, viruses, parasite ova, B-hemolytic \(E. coli\) and \(Salmonella\) sp. Care was taken to avoid cross-contaminating pigs from different rooms after the disease challenge. Biosecurity procedures included use of separate coveralls, boots, and gloves for each
room. In addition, cleaning and feeding schedules were developed and implemented
to ensure movement between rooms was conducted in order from non-infected (NC)
to infected groups.

Data Collection

Growth performance and feed intake data were collected for both the pre- and post-inoculation periods. Clinical observations for alertness, gauntness, and diarrhea were scored 3 times/week following challenge. Alertness was scored on animal behavior characteristics, with 1 = normal, 2 = slightly depressed and/or listless, and 3 = severely depressed or recumbent. Gauntness scores were based on visual body condition, with 1 = normal, 2 = slightly to moderately gaunt, and 3 = severely gaunt. Diarrhea was scored based on the following characteristics of feces: 1 = no diarrhea, 2 = semi-solid feces without blood, 3 = watery feces without blood, 4 = blood-tinged feces that was loose or formed, and 5 = profuse diarrhea with frank blood or dark tarry feces. Fecal samples were collected on d 14 and d 20 post-inoculation, and sent to the University of Minnesota Veterinary Diagnostic Laboratory for polymerase chain reaction (PCR) evaluation of *L. intracellularis* presence to determine shedding of the organism. Bacterial DNA was extracted from fecal samples using a Qiagen extraction kit (Qiagen, Valencia, CA) prior to PCR analysis using a Quanitect kit (Qiagen, Valencia, CA) and following the procedures of Jones et al. (1993).
On d 20 or d 21 post-challenge, all pigs were euthanized and necropsies were performed. Weights of the heart, empty stomach, liver, and empty small and large intestine were measured. Representative samples of digesta from the small and large intestines were collected and pH was measured. Length of the small and large intestine was also measured and visual evaluation of the length of observable lesions, and location and severity in the intestinal tract of lesions were made. Density of both the small and large intestines was calculated by dividing empty intestinal weight by intestinal length. Lesions were scored for severity based on the following characteristics: 0 = normal (no visual appearance of lesion), 1 = mild mesenteric and intestinal wall edema and hyperemia, 2 = mild to moderate edema and hyperemia of the mesentery and intestinal wall, and corrugated intestinal mucosa (PIA), 3 = severe mesenteric and intestinal wall edema and hyperemia, and necrosis of the mucosal surface with formation of pseudo-diphtheric membrane (necrotic enteritis), and 4 = moderate to severe edema and hyperemia of the mesentery and intestinal wall, thick and corrugated mucosa, and blood clots in the intestinal lumen (PHE). A 10 cm tissue section of the distal ileum proximal to the ileal-cecal junction was collected from each pig, along with adjacent lymph nodes, and were fixed by immersion in 10% neutral buffered formalin, embedded in paraffin, and analyzed by immunohistochemistry (IHC) using a monoclonal antibody specific for L. intracellularis (McOrist et al., 1987). The reaction to L. intracellularis antigen was graded from 0 (no L. intracellularis positive antigen labeled) to 4 (100% of epithelial cells in the crypts with positive antigen labeling) (Guedes et al., 2002).
Statistical Analysis

Growth performance data were statistically analyzed using the analysis of variance GLM procedures of SAS (1985), with room as the experimental unit (two replications per treatment). All other data were analyzed utilizing individual pig as the experimental unit, resulting in 20 replications per treatment. Least squares means were used to compare the negative and positive control groups, and thereby evaluate the effects of infecting pigs on response criteria. Data involving pigs on the disease challenge treatments were analyzed as a 2 x 2 factorial, with DDGS level (0 or 10%) and antimicrobial regimen (no antimicrobials or CTC/BMD) as the factors.

Results and Discussion

Diet Composition

Experimental diet composition and nutrient analysis are provided in Table 1. Calculated metabolizable energy (ME) concentration based on proximate analysis tended to be lower in all diets compared to formulated levels (3145 vs. 3390 kcal/kg), but was similar among experimental diets (range = 3097 – 3162 kcal/kg ME). Calcium level tended to be higher in the corn-soybean meal diets (0.85% - 0.90%) compared to DDGS diets (0.75% - 0.81%) and the calculated level (0.80%), but was
within the permitted analytical range of 0.66% - 0.94% (AOAC, 1990). Total
dietary phosphorus concentration was similar among dietary treatments, but the
addition of DDGS to the diet increased crude protein level. The PC+A and D+A
diets contained 36 and 34.2 g/ton of BMD, respectively, which slightly exceeded the
target of 30 g/ton. Analyzed levels of CTC were 439 and 619 g/ton for the PC+A
and D+A diets, respectively, which were near the target of 500 g/ton.

Growth Performance

Two pigs were removed from the experiment prior to completion due to health
reasons unrelated to the ileitis challenge. Body weights, growth rate, feed intake,
and feed conversion results are shown in Table 2. Average initial pig weight was
6.35 kg. During the pre-challenge period, growth, feed intake and feed efficiency
were similar across all treatments ($P \geq 0.23$). However, a DDGS x antimicrobial
interaction was observed in the pre-challenge period, with pigs in the D + A
treatment group tending to exhibit reduced feed intake ($P = 0.09$) compared to
providing DDGS or antimicrobial regimen alone in the diet.

Infecting pigs with *L. intracellularis* did not affect growth performance in the 3-
wk post-challenge period ($P \geq 0.29$), although a numerical reduction in growth rate
(16%) and feed intake (9%) was observed between the negative and positive control
groups. No DDGS, antimicrobial, or DDGS x antimicrobial interactions were
observed for ADG, ADFI, or G/F in the post-challenge period ($P \geq 0.25$). Including
the antimicrobial regimen in the DDGS diet numerically improved growth rate and
feed intake (33% and 22%, respectively) compared to providing no antimicrobial regimen in the DDGS diet. Neither diet containing DDGS nor antibiotic regimen affected growth performance of challenged pigs ($P \geq 0.25$). Body weight at the time of necropsy was unaffected by *L. intracellularis* challenge and dietary treatment within challenged groups ($P \geq 0.47$).

Previous research results by Whitney and Shurson (2004) have indicated that dietary inclusion up to 25% DDGS provides similar growth performance of nursery pigs when high-quality DDGS is used, diets are formulated on a digestible amino acid basis, and pigs weigh at least 7 kg. Since only two replications per treatment were used in the analysis of growth performance data, more replication would be required to determine if the numerical trends observed for growth performance in this experiment are dietary responses that could be expected on a consistent basis under similar conditions. However, the main objective of this experiment was to evaluate length, severity, and prevalence of lesions and fecal shedding of *L. intracellularis* using PCR and immunohistochemistry techniques to determine dietary effects during a *Lawsonia* infection.

**Alertness, Gauntness, and Fecal Scores**

Weekly gauntness and fecal scores are presented in Table 3. Pig behavior appeared normal throughout the trial for all pigs, regardless of treatment. Unchallenged pigs remained healthy throughout the post-challenge period, as indicated by a lack of gauntness and normal fecal scores. Stools were of a looser
consistency (more watery) during wks 1, 2, and 3 post-challenge in PC pigs compared to NC pigs ($P < 0.01$). Additionally, PC pigs were more gaunt during wks 1 and 3 post-challenge compared to NC pigs ($P < 0.01$), although no difference in abdominal score was observed during wk 2 post-challenge.

Fecal looseness increased with increasing time post-challenge ($P = 0.001$). No time x DDGS inclusion or time x antimicrobial regimen interactions were observed. A time x DDGS inclusion x antimicrobial interaction was observed ($P = 0.02$, Fig. 2), indicating that as fecal looseness increased over time, the combination of D + A appeared to become more effective in reducing stool looseness compared to feeding either D or A individually. Dietary treatment did not affect fecal consistency prior to challenge ($P = 0.16$), although feeding the 10% DDGS diet tended to increase looseness of stools ($P = 0.10$). During the first wk post-challenge, a DDGS inclusion x antimicrobial regimen interaction was observed, with pigs fed the combination tending to have increased fecal scores ($P = 0.08$). During wks 2 and 3 post-challenge, however, no differences in fecal consistency due to dietary treatment were observed ($P > 0.10$).

Gauntness, as measured by abdominal scores, did not increase appreciably during the post-challenge period ($P > 0.10$), although time x DDGS inclusion ($P = 0.02$), time x antimicrobial regimen ($P = 0.04$), and time x DDGS inclusion x antimicrobial regimen ($P = 0.01$) effects were observed (Fig. 1). Abdominal scores tended to be affected by dietary treatment throughout the post-challenge period ($P < 0.10$). Effects of DDGS inclusion, antimicrobial regimen, and DDGS inclusion x antimicrobial regimen interaction were observed during wk 1 ($P = 0.06$) and wk 3 ($P
post-challenge, with pigs fed the control corn-soybean meal diet exhibiting more gauntness, although only 1 pig appeared gaunt each of the three wks post-challenge. During the second wk post-challenge, only an interactive effect was observed for abdominal score ($P = 0.05$), while no main effects were detected ($P = 0.27$).

Inclusion of some fiber sources in diets for growing pigs have increased the viscosity of digesta and increased water content of feces, resulting in looser stools. Feeding an 80% alfalfa meal diet decreased dry matter content of digesta in young pigs (Pond et al., 1988), while similar results have been observed when including 4% - 6% guar gum in the diet (Rainbird, 1986). Alfalfa contains 52.4% insoluble fiber and 4.3% soluble fiber (Shurson et al., 2000), while the dietary fiber in guar gum is soluble in nature (Grieshop et al., 2001). Including insoluble fiber in the form of 7.5% wheat bran or 30% oatmeal by-product also increased rate of passage of digesta in the large intestine (Potkins et al., 1991). Cereal bran contains approximately 28% insoluble fiber (Marlett, 1992), and therefore a 7.5% inclusion rate, at the expense of corn, would result in an additional 1.75% insoluble fiber in the complete diet. This is much less than the additional 3.1% insoluble fiber contributed to the diet when including 10% DDGS, which contains 42.2% insoluble fiber (Shurson et al., 2000), in the place of corn and soybean meal. Jorgensen et al. (1996) observed a 5 – 6 fold increase in passage rate through the terminal ileum when pigs were fed a high vs. low fiber diet (26.8% vs. 5.9% crude fiber), and attributed this response to an increase in peristaltic action and increased transit time.
Internal Organ Weights and Digesta Characteristics

Infecting pigs with L. intracellularis reduced stomach, liver, and small intestine weight relative to body weight ($P < 0.05$), but did not affect other organ weights at the time of necropsy (Table 4). No dietary effects were observed for heart or stomach weights ($P \geq 0.17$), but antimicrobial regimen reduced liver weight relative to body weight ($P < 0.001$). Feeding the DDGS diet increased weight of the large intestine ($P < 0.01$), while antimicrobial regimen tended to increase total intestinal tract weight ($P < 0.10$) relative to body weight. The combination of 10% DDGS and antimicrobials in the diet, however, resulted in reduced weights of both the small and large intestine, as a proportion of body weight, compared to intestine weights when each was fed alone ($P < 0.02$). Intestinal length and density were unaffected by disease challenge ($P \geq 0.22$) and diet ($P \geq 0.59$).

Challenging pigs with L. intracellularis resulted in more acidic digesta in the large intestine ($P < 0.01$), but did not affect pH of digesta collected from the small intestine ($P \geq 0.49$). Digesta dry matter was not affected by disease challenge ($P \geq 0.19$). Feeding DDGS increased the acidity of digesta collected from the large intestine ($P < 0.02$), but did not affect digesta pH in the small intestine ($P \geq 0.25$). Feeding the antimicrobial diets resulted in an increase in digesta pH collected from the small intestine ($P < 0.03$), but did not alter digesta pH in the large intestine ($P \geq 0.31$). Feeding the combination of DDGS and antimicrobials tended to increase the acidity of digesta collected from the small intestine ($P = 0.08$) compared to feeding
the antimicrobial diet alone. No dietary effects or interactions were observed on dry
matter content of digesta from the small intestine, but pigs receiving the
antimicrobial regimen had increased dry matter content of digesta collected from
the large intestine ($P = 0.04$).

Changes in the mass of the gastro-intestinal tract and other internal body organs
have been shown to occur as a result of feeding diets high in insoluble fiber to pigs.
Ma et al. (2002) reported increased intestinal tract weight, relative to bodyweight,
when including 5% wheat bran, a source high in insoluble fiber. No differences in
intestinal tract weight were observed, however, when including 5% sugar beet pulp
as a source high in soluble fiber. Liver weights were reduced when feeding diets
containing either fiber source, but pancreas weight was reduced only when wheat
bran was included in the diet.

Pond et al. (1988), however, observed an increase in liver and kidney weights,
relative to body weight, when an 80% alfalfa diet was fed to market-age pigs.
Alfalfa contains high levels of both insoluble (52.4%) and soluble (4.3%) fiber
(Shurson et al., 2000). Jorgensen et al. (1996) also observed increases in stomach,
cecum, and colon mass when growing pigs were fed diets containing high levels of
insoluble fiber.

Research by Jin et al. (1994) indicated that insoluble fiber addition in the diet
increases the rate of cellular turnover in the intestine. The rate of cellular
proliferation in both the jejunum and colon was increased when feeding a diet
containing 10% wheat straw. Wheat straw is somewhat similar in dietary fiber
composition to DDGS, containing 71.0% insoluble fiber, but only 0.5% soluble fiber
(Shurson et al., 2000). Because L. intracellularis is an enteric pathogen that must
invade mucosa cells intracellularly for infection, increasing cell turnover in the
distal portion of the small intestine may shorten the time and reduce the ability of
the organism to successfully colonize in mucosa cells. A trend toward increased
small intestine weight by feeding diets containing DDGS or antimicrobials was
observed in the current study ($P \leq 0.15$), which may indirectly indicate an increase
in cell turnover. Additionally, research results reported by Zebrowska et al. (1983)
suggested that providing fiber (barley) in the diet increases endogenous secretion of
saliva, gastric juice, pancreatic juice, and bile. Because bactericidal enzymes and
antibacterial peptides are contained in these endogenous fluids, increasing secretion
by these organs may provide additional protection against infection by enteric
pathogens.

Clinical Lesion Evaluation

Clinical lesion evaluation results for the jejunum, ileum, cecum, and colon are
presented in Table 5. Two pigs in the NC group had lesions that were suspect for
ileitis. Overall, 59% of the pigs that were challenged exhibited lesions consistent
with ileitis. Lesion length, severity, and prevalence were greater in PC pigs
compared to NC pigs in the jejunum ($P = 0.02$), ileum, colon, and overall ($P < 0.01$).
Only one pig in each of the PC, D, and P+A groups was observed to have lesions
indicative of ileitis in the cecum.
Adding 10% DDGS to the diet reduced the proportion of pigs exhibiting lesions in the gastro-intestinal tract on d 21 post-challenge ($P < 0.01$), with 40 and 50% of the pigs on the D and D+A treatments exhibited lesions compared to 68 and 80% of pigs receiving the PC and P+A treatments, respectively. Reductions in lesion prevalence were observed in the ileum and colon ($P \leq 0.03$), but not jejunum or cecum ($P > 0.60$) when pigs were fed DDGS in the diet. Lesion length and severity were also reduced in the ileum ($P = 0.02$) and colon ($P < 0.10$), but not in the jejunum or colon ($P > 0.10$) with dietary DDGS inclusion. Over the entire intestinal tract, feeding the 10% DDGS diet did not significantly affect lesion length ($P = 0.14$), although a numerical reduction of 42 and 68% was observed for the pigs on D and D+A treatments, respectively, compared to PC pigs.

Providing BMD continuously in the diet, while strategically pulsing chlortetracycline, resulted in a reduced prevalence of lesions observed in the jejunum ($P = 0.04$), with 20 and 15% of pigs in the P+A and D+A groups exhibiting lesions compared to 47 and 30% of pigs in the PC and D groups, respectively. Lesion prevalence in the ileum, cecum, colon, and overall was unaffected by antimicrobial regimen ($P > 0.20$). Lesion severity ($P = 0.03$), but not length ($P = 0.18$), was reduced in the jejunum of pigs on the antimicrobial regimen treatment, while neither lesion length nor severity were affected by antimicrobial regimen in the remaining portions of the gastro-intestinal tract ($P > 0.10$). A numerical, but non-significant reduction ($P = 0.11$) in overall lesion length was observed in pigs provided the antimicrobial regimen (45% and 68% for treatments P+A and D+A, respectively), which was similar to the reduction observed with DDGS inclusion. No
DDGS x antimicrobial regimen interactions were observed for any of the lesion parameters measured at the time of necropsy ($P > 0.15$), indicating no additive or synergistic effect of combining both dietary treatments.

Length of lesions at necropsy is a useful quantitative measure of the severity of ileitis in pigs and its impact on growth performance (Winkelman, 1999). In the current study, DDGS inclusion in the diet reduced lesion length, severity, and prevalence in both the ileum and colon. Fibrous diets have also been demonstrated to have beneficial effects on the health of young pigs in relation to bacterial activity and gastro-enteritis. Smith and Halls (1968) were unable to infect pigs with certain types of *Escherichia coli* when fed a diet containing barley fiber. They suggested the mode of action in preventing enteric disease was the ability of fiber to influence the secretory or absorptive function of the epithelium, both of which are implicated in bacterial adhesion. Drochner et al. (1978) also suggested that crude fiber in the diet, especially lignin, can decrease bacterial activity in the gut of young pigs. Lawrence (1970, 1972) suggested the suppression of certain bacteria in the intestine might be associated with a change in transit time, fecal dry matter, and variations in bile secretion and volatile fatty acid production.

The strategic use of chlortetracycline and BMD® resulted in reduced severity and prevalence of lesions observed in the jejunum at the time of necropsy. These results are similar to previous research results when evaluating the use of chlortetracycline and (or) BMD® for ileitis prevention or control (Winkelman et al., 1997). In that study, the authors observed improved growth performance, feed intake, and feed conversion, with a concomitant reduction in diarrhea and gross intestinal lesions in
pigs challenged with ileitis when chlortetracycline (CTC) from Aureomycin® was included in the diet from 4 d prior to the infection to 10 d after the disease challenge. Feeding 500 g/ton of Aureomycin® appeared to provide some additional benefit over the 100 g/ton level.

In comparative ileitis challenge studies, McOrist (1998) and Winkelman et al. (1998) observed similar improvements in growth performance and presence of gross intestinal lesions when pigs were fed CTC from Aureomycin® (300 – 600 g/ton fed from 4 d pre-challenge to 10 d post-challenge) compared to pigs fed tylosin (100 ppm) and lincomycin (200 g/ton), respectively. Additive and (or) synergistic effects have been observed when feeding the combination of BMD® and CTC for the treatment of ileitis. In a BMD/CTC titration study, Schultz et al. (1997) observed a 78% improvement in growth of pigs, 21 d post-weaning, when 33 ppm BMD was provided continuously in the diet, and CTC was provided at 110, 220, or 440 g/ton from 4 d pre-challenge to 10 d post-challenge, compared to pigs fed a similar, but non-medicated diet. All pigs in the positive control group developed proliferative enteritis and visible lesions, with marked thickening of the mucosa at the terminal ileum. However, there were no visible lesions observed in pigs fed the medicated diets. Additionally, 63% of the positive control pigs developed looser stools compared to 0% of the medicated pigs. The authors suggested that other pathogenic organisms, such as Clostridium, bacteroides, and E. coli may exacerbate the severity of ileitis, but BMD is effective in providing protection against these pathogens.
PCR and IHC Analysis

All pigs tested negative for presence of *L. intracellularis* via the fecal PCR test prior to being inoculated. Negative control pigs did not acquire ileitis, and remained free of the organism as indicated by negative tests for fecal PCR on d 14 and d 21 post-challenge, and IHC from ileum collected at necropsy (Table 6). In comparison, 60% of challenged pigs were shedding *L. intracellularis* by d 21 post-challenge, while 97.5% of challenged pigs tested positive for the organism using ileum tissue IHC.

Although the combination of feeding the DDGS diet and antimicrobial regimen appeared to increase fecal shedding on d 14 post-challenge (*P* = 0.02), there were no dietary effects on fecal shedding of *L. intracellularis* by d 21 post-challenge (*P* > 0.20). Only 25% of pigs in the D and P+A groups were shedding *L. intracellularis* on d 14 post-challenge, compared to 63% of PC pigs, but by d 21 post-challenge, 60% and 65% of D and P+A pigs were shedding the organism, respectively. These results may indicate an accelerated rate of progression of ileitis infection or recovery when feeding diets containing both antimicrobials and DDGS, although further research studies designed to examine fecal shedding at several different time periods post-challenge are necessary to determine if such a response occurs.

Lesion prevalence, as determined by IHC, was unaffected by dietary treatment (*P* = 0.59). With the exception of one pig in each of the D and D+A groups, all challenged pigs tested positive for *L. intracellularis* by d 21 post-challenge. Lesion
severity was reduced by feeding the 10% DDGS diet \( (P = 0.05) \), and tended to be reduced by feeding the antimicrobial regimen \( (P = 0.10) \). Pigs in the D, P+A, and D+A groups had IHC scores of 1.95, 2.00, and 1.90, respectively, indicating that 25 – 50% of the mucosa was infected with \( L. \) intracellularis, compared to an IHC score of 2.58 in PC pigs, indicating that greater than 50% of the mucosa in these pigs was infected with \( L. \) intracellularis.

Implications

Results from this study suggest that including 10% DDGS in growing pig diets may provide some protection and aid the pig in resisting an ileitis challenge under a moderate disease challenge situation. These results are consistent with field reports suggesting that dietary DDGS inclusion results in reduced severity of clinical signs caused during an ileitis outbreak. The beneficial effects (reduced severity and prevalence of lesions in some parts of the intestinal tract) from feeding a diet containing 10% DDGS in this study were similar to the results observed for an approved antibiotic regimen (BMD\(^\circledR\) with 14-day Aureomycin\(^\circledR\) pulse). Although no additive effects of feeding a diet containing DDGS and BMD/Aureomycin were observed in this study, further investigation is needed to better understand the interaction of diet and antimicrobials, and their application towards improving gastro-intestinal health. The inoculum dosage rate used in this disease challenge
study appeared to be an appropriate level for examining dietary effects on ileitis infection.
Literature Cited


Marlett, J. A. 1992. Content and composition of dietary fiber in 117 frequently


ileal amino acid digestibilities of corn distiller’s dried grains with solubles produced from new ethanol plants in Minnesota and South Dakota. J. Anim. Sci. 78:185 (Suppl. 1).


<table>
<thead>
<tr>
<th>Item</th>
<th>NC</th>
<th>PC</th>
<th>D</th>
<th>PC + A&lt;sup&gt;c&lt;/sup&gt;</th>
<th>D + A&lt;sup&gt;c&lt;/sup&gt;</th>
<th>PC + A&lt;sup&gt;d&lt;/sup&gt;</th>
<th>D + A&lt;sup&gt;d&lt;/sup&gt;</th>
</tr>
</thead>
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<tr>
<td>DDGS&lt;sup&gt;e&lt;/sup&gt;</td>
<td>0.00</td>
<td>0.00</td>
<td>10.00</td>
<td>0.00</td>
<td>10.00</td>
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<tr>
<td>Corn</td>
<td>61.91</td>
<td>61.91</td>
<td>52.77</td>
<td>61.86</td>
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<td>31.77</td>
<td>32.62</td>
<td>31.77</td>
<td>32.62</td>
<td>31.77</td>
</tr>
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<td>2.20</td>
<td>2.30</td>
<td>2.20</td>
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<td>0.56</td>
<td>0.77</td>
<td>0.56</td>
<td>0.77</td>
<td>0.56</td>
<td>0.77</td>
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<tr>
<td>Vitamin/trace mineral premix&lt;sup&gt;f&lt;/sup&gt;</td>
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<td>0.45</td>
<td>0.45</td>
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<td>Salt</td>
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<tr>
<td>L-Lysine</td>
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<tr>
<td>DL-Methionine</td>
<td>0.04</td>
<td>0.04</td>
<td>0.04</td>
<td>0.04</td>
<td>0.04</td>
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</tr>
<tr>
<td>BMD-30 (30 g/ton)</td>
<td>0.00</td>
<td>0.00</td>
<td>0.00</td>
<td>0.05</td>
<td>0.05</td>
<td>0.05</td>
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</tr>
<tr>
<td>Aureo-90 (90 mg/ton)</td>
<td>0.00</td>
<td>0.00</td>
<td>0.00</td>
<td>0.28</td>
<td>0.28</td>
<td>0.28</td>
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<tr>
<td>Nutrient analysis</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>Crude protein, %</td>
<td>21.00</td>
<td>21.00</td>
<td>22.66</td>
<td>21.39</td>
<td>22.88</td>
<td>21.66</td>
<td>22.69</td>
</tr>
<tr>
<td>Lysine, %&lt;sup&gt;g&lt;/sup&gt;</td>
<td>1.21</td>
<td>1.21</td>
<td>1.26</td>
<td>1.24</td>
<td>1.28</td>
<td>1.27</td>
<td>1.26</td>
</tr>
<tr>
<td>Methionine, %</td>
<td>0.35</td>
<td>0.35</td>
<td>0.35</td>
<td>0.35</td>
<td>0.37</td>
<td>0.37</td>
<td>0.35</td>
</tr>
<tr>
<td>Threonine, %</td>
<td>0.73</td>
<td>0.73</td>
<td>0.78</td>
<td>0.73</td>
<td>0.79</td>
<td>0.77</td>
<td>0.77</td>
</tr>
<tr>
<td>Tryptophan, %</td>
<td>0.26</td>
<td>0.26</td>
<td>0.26</td>
<td>0.26</td>
<td>0.25</td>
<td>0.26</td>
<td>0.26</td>
</tr>
<tr>
<td>ME, kcal/kg</td>
<td>3133</td>
<td>3133</td>
<td>3097</td>
<td>3132</td>
<td>3129</td>
<td>3140</td>
<td>3162</td>
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<tr>
<td>Calcium, %</td>
<td>0.89</td>
<td>0.89</td>
<td>0.81</td>
<td>0.85</td>
<td>0.78</td>
<td>0.90</td>
<td>0.75</td>
</tr>
<tr>
<td>Phosphorus, %</td>
<td>0.73</td>
<td>0.73</td>
<td>0.72</td>
<td>0.67</td>
<td>0.69</td>
<td>0.74</td>
<td>0.71</td>
</tr>
</tbody>
</table>

<sup>a</sup>Diet were formulated to contain 3390 kcal/kg of ME, 1.15% apparent digestible lysine, 0.65% apparent digestible methionine & cystine, 0.80% Ca, and 0.70% total P.

<sup>b</sup>NC = negative control, PC = positive control, D = distiller's dried grains with solubles, and A = antimicrobial regimen provided in feed.

<sup>c</sup>Fed from d 4 to d 29 and d 43 to d 54.

<sup>d</sup>Fed from d 3 pre-challenge to d 11 post-challenge.

<sup>e</sup>Distiller's dried grains with solubles (Al-Corn Clean Fuel, Claremont, MN).

<sup>f</sup>Amount supplied per kg of premix: 1,466,667 IU vitamin A as retinyl acetate, 246,400 IU vitamin D<sub>3</sub>, 6,138 IU vitamin E as dl-a-tocopherol acetate, 979 mg vitamin K as menadione dimethylpyrimidinol bisulfite, 1,467 mg riboflavin, 8,800 mg niacin, 5,867 mg pantothenic acid as d-calcium pantothenate, 6.6 mg vitamin B12, 141 mg iodine as EDDI, 99 mg selenium as sodium selenite, 59,840 mg zinc as zinc oxide, 59,840 mg iron as ferrous sulfate, 3,960 mg copper as copper sulfate, and 1,980 mg manganese as manganese oxide.

<sup>g</sup>Amino acids are expressed on a total analyzed basis.
Table 2. Effect of dietary distiller's dried grains with solubles and antimicrobial regimen on growth performance, feed intake, and feed efficiency in pigs challenged with *L. intracellularis*.

<table>
<thead>
<tr>
<th>Treatment a</th>
<th>Effects (within challenged treatments)</th>
</tr>
</thead>
<tbody>
<tr>
<td>NCb</td>
<td></td>
</tr>
<tr>
<td>PC</td>
<td></td>
</tr>
<tr>
<td>D</td>
<td></td>
</tr>
<tr>
<td>P+A</td>
<td></td>
</tr>
<tr>
<td>D+A</td>
<td></td>
</tr>
<tr>
<td>D</td>
<td>A</td>
</tr>
</tbody>
</table>

Pre-treatment (d 0 - 4)

| # of pens       | 2       | 2       | 2       | 2       | 2       | 4       | 4       | 2       |                          |
| Initial wt, kg  | 6.38    | 6.37    | 6.33    | 6.33    | 6.33    | 0.31    | 0.31    | 0.31    | 0.01 0.38                |

Pre-challenge (d 4 - 32)

| Initial wt, kg  | 8.16    | 8.66    | 8.35    | 8.22    | 8.34    | 0.37    | 0.51    | 0.33    | 0.04 0.44                |
| ADG, g          | 404     | 432     | 386     | 417     | 416     | 0.40    | 0.78    | 0.41    | 11.2 0.65                |
| ADFI, g         | 695     | 645     | 726     | 731     | 692     | 0.47    | 0.39    | 0.09    | 16.6 0.23                |
| G/F             | 0.58    | 0.67    | 0.53    | 0.57    | 0.60    | 0.34    | 0.80    | 0.17    | 0.03 0.38                |

Post-challenge (d 32 - 53)

| Initial wt, kg  | 19.47   | 20.76   | 19.16   | 19.90   | 19.99   | 0.40    | 0.98    | 0.35    | 0.37 0.61                |
| ADG, g          | 799     | 672     | 542     | 642     | 720     | 0.75    | 0.39    | 0.25    | 38.0 0.49                |
| ADFI, g         | 1262    | 1148    | 1046    | 1167    | 1276    | 0.98    | 0.38    | 0.45    | 57.0 0.67                |
| G/F             | 0.63    | 0.59    | 0.52    | 0.55    | 0.58    | 0.77    | 0.88    | 0.52    | 0.03 0.89                |
| Final wt, kg    | 36.25   | 34.87   | 30.54   | 33.39   | 35.11   | 0.57    | 0.50    | 0.22    | 1.04 0.47                |

Pre-CTC pulse (d 4 - 29)

| ADG, g          | 411     | 437     | 382     | 421     | 414     | 0.29    | 0.76    | 0.39    | 12.1 0.54                |
| ADFI, g         | 667     | 638     | 720     | 726     | 679     | 0.58    | 0.46    | 0.09    | 17.4 0.26                |
| G/F             | 0.62    | 0.69    | 0.53    | 0.58    | 0.61    | 0.32    | 0.85    | 0.16    | 0.03 0.36                |

CTC pulse period (d 29 - 43)

| ADG, g          | 604     | 496     | 419     | 489     | 552     | 0.91    | 0.34    | 0.30    | 28.4 0.52                |
| ADFI, g         | 1071    | 920     | 902     | 952     | 1036    | 0.73    | 0.41    | 0.60    | 39.2 0.74                |
| G/F             | 0.56    | 0.54    | 0.47    | 0.51    | 0.54    | 0.75    | 0.70    | 0.47    | 0.03 0.82                |

Post-CTC pulse (d 43 - 53)

| ADG, g          | 933     | 833     | 682     | 777     | 871     | 0.73    | 0.44    | 0.19    | 39.6 0.44                |
| ADFI, g         | 1454    | 1349    | 1209    | 1379    | 1488    | 0.92    | 0.33    | 0.42    | 64.5 0.61                |
| G/F             | 0.64    | 0.62    | 0.56    | 0.56    | 0.60    | 0.84    | 0.85    | 0.51    | 0.02 0.89                |

aNC = negative control, PC = positive control, D = distiller's dried grains with solubles, and A = antimicrobial regimen provided in feed.

bNo significant difference between NC and PC groups (P > 0.10).
Table 3. Effect of dietary distiller's dried grains with solubles and antimicrobial regimen on visual abdominal and fecal scores after challenge with *L. intracellularis*.  

<table>
<thead>
<tr>
<th>Treatment b</th>
<th>Effects (within challenged treatments)</th>
</tr>
</thead>
<tbody>
<tr>
<td>NC c</td>
<td>PC</td>
</tr>
<tr>
<td># of pigs</td>
<td>19</td>
</tr>
</tbody>
</table>

**Fecal score (1-5)** d

- Initial (d 32)
  - 1.00 1.24 1.25 1.15 1.43
  - 0.10 0.61 0.14 0.04 0.16
- Week 1 post-challenge
  - 1.00 1.39 1.14 1.20 1.48
  - 0.13 0.57 0.08 0.04 0.13
- Week 2 post-challenge
  - 1.14 1.93 1.68 1.48 1.48
  - 0.39 0.14 0.39 0.04 0.30
- Week 3 post-challenge
  - 1.13 1.52 1.90 1.66 1.64
  - 0.14 0.63 0.11 0.06 0.17

**Abdominal score (1-3)** e

- Initial (d 32)
  - 1.00 1.00 1.00 1.00 1.00
  - . . . . .
- Week 1 post-challenge
  - 1.00 1.08 1.00 1.00 1.00
  - 0.06 0.06 0.06 0.01 0.02
- Week 2 post-challenge
  - 1.00 1.00 1.03 1.10 1.00
  - 0.27 0.27 0.05 0.01 0.09
- Week 3 post-challenge
  - 1.00 1.08 1.00 1.00 1.00
  - 0.03 0.03 0.03 0.01 0.01

a Abdominal scores: 1 = normal, 2 = slightly to moderately gaunt, and 3 = severely gaunt.  
Fecal scores: 1 = no diarrhea, 2 = semi-solid feces, 3 = watery feces, 4 = blood-tinged feces that are loose or formed, and 5 = profuse diarrhea with frank blood or dark tarry feces.  
b NC = negative control, PC = positive control, D = distiller's dried grains with solubles, and A = antimicrobial regimen provided in feed.  
c Significant difference between NC and PC groups for abdominal score week 1 and 3 post-challenge and fecal score at the time of challenge and during weeks 1, 2, and 3 post-challenge (*P* < 0.01).  
d Significant effect of time (*P* = 0.001) and time x D x A (*P* = 0.02).  
e Significant effect of time x D (*P* = 0.02), time x A (*P* = 0.04), and time x D x A (*P* = 0.01).
Table 4. Effect of dietary distiller's dried grains with solubles and BMD/CTC inclusion after a *L. intracellularis* challenge on internal organ weight, intestinal length, and digesta dry matter and pH.

<table>
<thead>
<tr>
<th>Treatment</th>
<th>Effects (within challenged treatments)</th>
</tr>
</thead>
<tbody>
<tr>
<td>NC b</td>
<td>PC D P+A D+A</td>
</tr>
<tr>
<td># of pigs</td>
<td>19 19 20 20 20</td>
</tr>
<tr>
<td>Internal organ weights, % of body weight</td>
<td>40 40 20</td>
</tr>
<tr>
<td>Heart</td>
<td>0.468 0.449 0.461 0.456 0.449</td>
</tr>
<tr>
<td>Stomach</td>
<td>0.753 0.803 0.842 0.841 0.810</td>
</tr>
<tr>
<td>Liver</td>
<td>2.604 2.591 2.664 2.349 2.397</td>
</tr>
<tr>
<td>Small intestine</td>
<td>3.363 3.806 4.266 3.921 3.809</td>
</tr>
<tr>
<td>Large intestine</td>
<td>1.611 1.602 1.987 1.697 1.680</td>
</tr>
<tr>
<td>Total intestine</td>
<td>4.974 5.408 6.252 5.618 5.489</td>
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<tr>
<td>Intestinal lengths, cm</td>
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</tr>
<tr>
<td>Small intestine</td>
<td>1517.0 1583.4 1530.7 1549.2 1576.0</td>
</tr>
<tr>
<td>Large intestine</td>
<td>393.2 373.9 378.8 371.2 375.0</td>
</tr>
<tr>
<td>Total intestine</td>
<td>1910.2 1957.3 1909.4 1920.4 1951.0</td>
</tr>
<tr>
<td>Intestinal density, g/cm</td>
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</tr>
<tr>
<td>Small intestine</td>
<td>0.82 0.83 0.84 0.84 0.84</td>
</tr>
<tr>
<td>Large intestine</td>
<td>1.48 1.48 1.57 1.54 1.56</td>
</tr>
<tr>
<td>Digesta dry matter, %</td>
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</tr>
<tr>
<td>Small intestine</td>
<td>10.49 9.46 8.85 8.11 9.66</td>
</tr>
<tr>
<td>Large intestine</td>
<td>19.89 19.00 18.34 21.26 19.84</td>
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<td>Digesta pH</td>
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<tr>
<td>Small intestine</td>
<td>6.40 6.30 6.37 6.72 6.41</td>
</tr>
<tr>
<td>Large intestine</td>
<td>6.23 5.82 5.72 5.94 5.74</td>
</tr>
</tbody>
</table>

a NC = negative control, PC = positive control, D = distiller's dried grains with solubles, and A = antimicrobial regimen provided in feed.

b Significant difference between NC and PC groups for weight of the stomach, liver, small intestine, total intestine, and pH of large intestine pH (*P < 0.05*).
Table 5. Effect of dietary distiller's dried grains with solubles and antimicrobial inclusion after a *L. intracellularis* challenge on lesion length, severity, and prevalence in the gastrointestinal tract.

<table>
<thead>
<tr>
<th>Treatment a</th>
<th>Effects (within challenged treatments)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>NC b</td>
</tr>
<tr>
<td># of pigs</td>
<td>19</td>
</tr>
<tr>
<td>Jejunum</td>
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<tr>
<td>Length, cm</td>
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<tr>
<td>Score (0-4)</td>
<td>0.05</td>
</tr>
<tr>
<td>Prevalence, %</td>
<td>5.3</td>
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<tr>
<td>Ileum</td>
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<tr>
<td>Length, cm</td>
<td>0.37</td>
</tr>
<tr>
<td>Score (0-4)</td>
<td>0.05</td>
</tr>
<tr>
<td>Prevalence, %</td>
<td>5.3</td>
</tr>
<tr>
<td>Cecum</td>
<td></td>
</tr>
<tr>
<td>Length, cm</td>
<td>0.00</td>
</tr>
<tr>
<td>Score (0-4)</td>
<td>0.00</td>
</tr>
<tr>
<td>Prevalence, %</td>
<td>0.0</td>
</tr>
<tr>
<td>Colon</td>
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<tr>
<td>Length, cm</td>
<td>0.00</td>
</tr>
<tr>
<td>Score (0-4)</td>
<td>0.00</td>
</tr>
<tr>
<td>Prevalence, %</td>
<td>0.0</td>
</tr>
<tr>
<td>Total</td>
<td></td>
</tr>
<tr>
<td>Length, cm</td>
<td>1.63</td>
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<tr>
<td>Prevalence, %</td>
<td>10.5</td>
</tr>
</tbody>
</table>

a NC = negative control, PC = positive control, D = distiller's dried grains with solubles, and A = antimicrobial regimen provided in feed.

b Significant difference between NC and PC groups for lesion length, score, and prevalence in the jejunum, ileum, colon, and overall (P < 0.05).
<table>
<thead>
<tr>
<th>Treatment</th>
<th>Effects (within challenged treatments)</th>
</tr>
</thead>
<tbody>
<tr>
<td>NC&lt;sup&gt;b&lt;/sup&gt;</td>
<td>PC</td>
</tr>
<tr>
<td># of pigs</td>
<td>19</td>
</tr>
<tr>
<td>IHC&lt;sup&gt;b&lt;/sup&gt;</td>
<td></td>
</tr>
<tr>
<td>Score (0-4)</td>
<td>0.00</td>
</tr>
<tr>
<td>Prevalence, %</td>
<td>0.0</td>
</tr>
<tr>
<td>Fecal PCR&lt;sup&gt;d&lt;/sup&gt;, %</td>
<td></td>
</tr>
<tr>
<td>Initial (d 32)</td>
<td>0.0</td>
</tr>
<tr>
<td>d 14 post-challenge</td>
<td>0.0</td>
</tr>
<tr>
<td>d 21 post-challenge</td>
<td>0.0</td>
</tr>
</tbody>
</table>

<sup>a</sup>NC = negative control, PC = positive control, D = distiller's dried grains with solubles, and A = antimicrobial regimen provided in feed.

<sup>b</sup>Significant difference between NC and PC groups for all IHC and PCR values (P < 0.01).

<sup>c</sup>IHC = immunohistochemistry.

<sup>d</sup>PCR = polymerase chain reaction.

---

Table 6. Effect of dietary distiller's dried grains with solubles and antimicrobial regimen after a *L. intracellularis* challenge on fecal PCR and ileal tissue IHC scores.
Fig. 1. Interactive effect of time (phase) and treatment on abdominal scores during the post-challenge period.

Significant time x D (P = 0.02), time x A (P = 0.04), and time x D x A (P = 0.01)

Fig. 2. Interactive effect of time (phase) and treatment on fecal scores during the post-challenge period.

Significant time x D x A effect (P = 0.02)