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Effects of Dietary Fiber Level in Weaning Pig Diets on Growth Performance, Nutrient Digestibility and Intestinal Morphology

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Abstract: Insoluble dietary fiber is benefit on gut volume and morphology of the pigs. Rice hull is the by-product from rice processing that rich of dietary fiber content. The objectives of our study were to evaluate the effects of dietary fiber level from grounded rice hull on growth performance, nutrient digestibility, intestinal morphology and bacterial cell count in hindgut of weaning pigs. Thirty weaning pigs (21±3 days of age) were fed randomly with three experimental diets consisting of three levels of total Dietary Fiber (DF); 130, 140 and 150 g/kg with equal ratios of insoluble per soluble dietary fiber. On the 29th day, four pigs per treatment were euthanized for the collection of small intestinal tissue samples for morphological determination and digesta samples were collected for microbial counts. For digestibility determination, 12 weaned pigs were used to determine nutrient digestibility. The Feed Conversion Ratio (FCR) pigs at Week 1 was improved, however, there was overall no significant difference for growth performance and diarrhea incidence among the groups. The nutrient digestibility of energy and protein did not differ among treatments, whereas the digestibility of crude fat and fiber tended to increase (P = 0.082 and 0.074). Increasing of dietary fiber level tended to increase villus height and enhance villus height per crypt depth ratio (VH:CD) of ileum (VH:CD ratio were 1.94, 2.10 and 2.35 in pigs fed 130, 140 and 150 g/kg dietary fiber diets respectively; P = 0.062). The bacterial count in the gut content was not affected by dietary fiber level. In conclusion, the dietary fiber level between 130 to150 g/kg was not altering overall growth performance nutrient digestibility, intestinal morphology intestinal bacteria population. However, the dietary fiber 140-150 g/ kg in diet could improve FCR in the first week after weaning and tended to improve the ileal morphology.

Keywords: Dietary Fiber, Weaning Pig, Growth Performance, Morphology, Bacterial Population

Introduction

Newly weaned pigs represent a critical period in pig production due to the stressful environment and nutrition change. Villus atrophy leading to low feed intake has been observed within 24 to 48 h after weaning (Kitt *et al*., 2001; Moeser *et al*., 2017). This might affect the digestion and absorption of nutrients and also the growth performance of pigs. Low feed intake can lead to high proliferate pathogenic bacteria in the lower part of the digestive system by decreasing the rate of passage (Lallès *et al*., 2007; Superchi *et al*., 2017). Moreover, low feed intake causes villus atrophy which has been within the first week of weaning and which took 7 to 14 days for pig to recover. Previous studies have demonstrated the positive effect of dietary fiber in term of enhancing intestinal morphology in newly weaned pigs. Many ingredients have been used as dietary fiber sources such as a combination of oat hull and wheat straw (Gerritsen *et al*., 2012), barley hull (Hedemann *et al*., 2006) and grass meal (Skiba *et al*., 2005). Moreover, dietary fiber increases the activity of certain enzymes such as amylase and brush border enzymes in weaned pigs (Gerritsen *et al*., 2012). However, some researchers have observed decreasing nutrient digestibility, especially for energy and protein, for diets with high dietary fiber levels (Yu *et al*., 2016). Dietary fiber is divided into soluble Dietary Fiber (sDF) and insoluble Dietary Fiber (iDF). Many studies have indicated that including iDF in diet had benefits for gut physiology function, for example, increasing stomach weight (Gerritsen *et al*., 2012), increasing large intestine weight (Hermes *et al*., 2009), increasing mucous secretion and amylase activity and stimulating gut mucosal development (Gerritsen *et al*., 2012). Increasing iDF:sDF ratio by increasing iDF levels in diets demonstrated some beneficial effects on the gastrointestinal tract and its functions at 2 weeks after weaning and reduced incidence of post weaning diarrhea (Pluske *et al*., 2014). Taksinanan *et al*. (2019) reported the optimum ratio of insoluble to soluble dietary fiber at 4.0 could stimulate gut development in weaning pigs.

Rice is the most important crop in Thailand. The average production of paddy rice was approximately 30 to 32 million ton per year with the production area at roughly 45% of total agricultural area (OAE, 2018). One of the by-products of the rice milling process is rice hull, which constitutes 20% of total rice production, and it is usually used in the agricultural, livestock and energy industry. Rice hull is composed of 74.0%, 72.0% and 2.0% of total, insoluble and soluble dietary fiber, respectively (Rezaei *et al*., 2014). Therefore, rice hull is used as an insoluble fiber source at a rate of 3% in growing-finishing pig diets, without affecting energy and protein utilization (Tartrakoon *et al*., 2017). There exists a need to evaluate the optimum level of dietary fiber required using rice hull as a source if insoluble fiber that could be formulated to have the optimum iDF:sDF ratio of 4.0 with dietary fiber level at 140 g/kg diet (Taksinanan *et al*., 2019). Therefore, this study aimed to evaluate the effects of dietary fiber levels more and less than 140 g/kg diet in corn-broken rice and soybean based diets on growth performance, diarrhea incidence, nutrient digestibility, intestinal morphology and intestinal bacterial populations of weaning pigs.

Materials and Methods

The protocol of this research was reviewed and approved by the Naresuan University Animal Care and Use Committee (certificate no. AG590507). This study was conducted from November 2018 to April 2019 at Naresuan University, Phisanulok province, Thailand.

Experimental Diets

Experimental diets contain three dietary fiber levels: 130, 140 and 150 g/kg diet (±5 g/kg). All diets were fixed with an insoluble to soluble dietary fiber ratio of 4.0 as recommended by the previous study of Taksinanan *et al*. (2019). Grounded rice hull and pectin were used as insoluble and soluble fiber sources, respectively, in diets. For rice hull preparation, rice hull (*Oryza sativa* L.) was brought from a local dealer in Phisanulok province, Thailand. It was washed, dried and grounded in a hammer mill (Retsch model SM100) and passed through a sieve with a 0.50 mm opening at the Laboratory of Animal Nutrition, Department of Animal Science, Rajamangala University of Technology Lanna. Pectin was commercial food grade and extracted from green apples. All diets were formulated to meet or exceed swine standards according to NRC recommendations (NRC, 2012) as shown in Table 1.

Table 1: Feed formulation and nutrient composition of experimental diets (as-fed basis, %)

	DF level, g/kg diet		
Item	130	140	150
Extruded soybean	22.0	22.0	22.0
Broken rice	17.7	15.3	14.0
Grounded corn	25.0	25.0	25.0
Soybean meal	18.0	18.0	18.0
Palm oil	2.0	3.0	3.0
Milk replacer	6.0	6.0	6.0
Rice bran	5.0	5.0	5.0
Rice hull	-	1.25	2.50
Pectin[1]	0.50	0.60	0.70
Lysine	0.40	0.40	0.40
DL-Methionine	0.20	0.20	0.20
Dicalcium phosphate	2.00	2.00	2.00
NaCl	0.50	0.50	0.50
$CaCO_3$	0.20	0.20	0.20
Vitamin-mineral premix[2]	0.50	0.50	0.50
Nutrient composition	-	-	-
CP, %	20.86	20.72	20.66
EE, %	4.00	4.55	5.03
Ash, %	6.14	6.48	8.41
CF, %	4.16	4.78	5.40
Total dietary fiber, %	13.10	14.05	15.00
Insoluble dietary fiber, %	10.50	11.24	11.99
Soluble dietary fiber, %	2.61	2.81	3.01
ME, kcal/kg	3,418	3,426	3,391

[1]commercial pectin extracted from green apples; [2]Vitamin-mineral premixes provided the following per kilogram of premixes: vitamin A, 10,000,000 IU; vitamin D3, 2,000,000 IU; vitamin E, 20,000 IU; vitamin K, 1.6 g; vitamin B1, 1.2 g; vitamin B2, 3.2 g; vitamin B6, 0.06 g; vitamin B12, 0.016 g; pantothenic acid, 10 g; niacin, 16 g; folic acid, 0.4 g; biotin, 0.06 g; vitamin C, 0.06 g; selenium, 0.1 g; iron, 72 g; manganese, 20 g; zinc, 60 g; copper, 64 g; cobalt, 0.32 g; iodine, 0.6 g

Performance and Intestinal Morphology

Complete randomized design was adopted in this study. Thirty weaning pigs (Duroc x Landrace x Yorkshire; initial weight 6.03±0.46 kg) were randomized and assigned to three groups, two pigs per pen (n = 5). The pens were 2×2 m with plastic slat floors. All pigs were reared in an evaporative cooling system. The temperature was controlled at 32°C in the first week and decreased by 2°C weekly. The diets and water were fed to the pigs *ad libitum* for 28 days. The body weight and feed intake were recorded weekly. Average Daily Gain (ADG), Average Daily Feed Intake (ADFI) and Feed Conversion Ratio (FCR) were calculated. Feces were scored daily in the morning with a 3-level score according to Montagne *et al*. (2012): 1 = dry and normal feces, 2 = soft and mist feces and 3 = liquid or diarrheic feces. Percentage of diarrhea incidence was calculated according to Chen *et al*. (2013).

At the end of experiment, four pigs per treatment (n = 4) were randomized, weighted and euthanized. Digesta of the ileum, caecum and colon were collected in sterile tubes for microbiological tests. Two cm-length tissue samples of duodenum (approximately 10cm from the stomach), jejunum (5.5 m from stomach sphincter) and ileum (10 cm prior to the ileo-caecal junction) were collected and fixed instantly in 10% formalin buffer for morphological determination.

Nutrient Digestibility

Twelve weaned pigs (Duroc x Landrace x Yorkshire; initial weight 9.54±0.88 kg) were reared in metabolic cages and fed the experimental diets; each group was fed at 4% of body weight (Liu *et al*., 2016). The experiment lasted for 7 days. The pigs were weighted at the beginning and end of the experiment. After a 3-day adaptation period, 0.5% chromic oxide was added to the diets for 4 days. Feed and feces were sampled individually and kept at -20°C until analysis. Feces were pooled by being first replicated, then dried at 60°C for 72 h using hot air oven and grounded before being passed through a sieve with a 0.5 mm opening. The chemical composition of feed and feces were analyzed according to AOAC (1990) and chromic oxide was analyzed according to Bolin *et al*. (1952). The total tract digestibility was calculated through the following equation as described by Liu *et al*. (2016): digestibility (%) = $(1 - ((N_{feces}/N_{diet}) \times (Cr_2O_{3\,diet}/Cr_2O_{3\,feces})) \times 100$, where: N_{feces} represents the nutrient concentration in the feces, N_{diet} is the nutrient concentration in the diet, $Cr_2O_{3\,diet}$ is the chromium dioxide concentration in the diet and $Cr_2O_{3\,feces}$ is the chromium dioxide concentration in the feces.

Histology

The tissue samples from the duodenum, jejunum and ileum in 10% formalin buffer were sent to the histology laboratory of Faculty of Veterinary Medicine Kamphaengsaen Campus at Kasetsart University Kamphaeng Saen Campus (Nakhonpathom, Thailand) for dehydration, after which, they were embedded in paraffin and strained with haematoxylin and eosin. Twelve complete villi and crypt were selected and villus height and crypt depth were measured with 40X modification by light microscopy. All data were measured using an image analyzer (Nikkon Cosmozone IzS, Nikon Co., Ltd., Tokyo, Japan). Then, the ratio of villus height to crypt depth (VH:CD) was calculated.

Microbiological Test

The samples of digesta from the ileum, caecum and colon were used for bacterial quantification by plating technique. The samples of digesta were investigated for *E. coli*, Salmonella spp. and Lactic acid bacteria populations by being cultured in Eosin Methylene Blue agar (EMB), Bissmuth Sulfite Agar (BSA) and de man, rogosa and sharpe (MRS), respectively. The cultured agars were incubated and count as described by Berrocoso *et al*. (2015). The bacterial cell count was presented using log CFU/g.

Statistical Analysis

Performance, digestibility, intestinal morphology and bacterial population data were all analyzed with one-way Analysis of Variance (ANOVA), using SPSS statistical software (Ver. 15 for Windows, SPSS Inc., Chicago, IL, USA). The Duncan's multiple range test was used for measured difference between means of treatments. The statistical significance was based on $P < 0.05$ and tendencies between $0.05 < P < 0.10$ were also presented.

Results and Discussion

Growth Performance

As depicted in Table 2, dietary fiber level of 140 and 150 g/kg diet results in greater FCR in the first week after weaning than pig fed 130 g/kg dietary level diet (P = 0.023), however, ADG and ADFI were not significant. For other weeks and overall period performances (0 to 28 days of experiment), no statistically significant differences in terms of ADG, ADFI and FCR among treatments were detected. In the current study, we did not observe any significant reduction in the diarrhea incidence (P = 0.308).

According to previous research about iDF:sDF ratio, the recommendation of iDF:sDF was 4.0 with the dietary level at 140 g/kg diet. In the current study, increasing dietary fiber level from 140 to 150 g/kg of dietary fiber (or including 4.78% and 5.40% of crude fiber) demonstrated no effects on FCR but better than the pigs fed 130 g/kg of dietary fiber diet, however, there was no significantly differ on ADG and ADFI in the first week after weaning. Our study used dietary fiber levels lower than that reported in Pascoal *et al*. (2015), in which dietary fiber levels ranging from 217.3 to 234.0 g/kg did not affect ADG, ADFI and feed efficiency compared with a corn-soybean based diet. However, many studies have reported improved growth performances from the inclusion of high dietary fiber levels. Gerritsen *et al*. (2012) found significant increases in feed intake 7 days after weaning in pigs fed a diet containing 7.4% crude fiber, derived from a combination of oat hull and wheat straw. Montagne *et al*. (2012) observed that increasing dietary fiber level in diets from 120.9 to 169.1 g/kg tented to reduce ADG and ADFI 2 weeks after weaning. In addition, Molist *et al.* (2009) also discovered significantly higher feed intake 10 days after weaning after increasing Non-Starch Polysaccharide (NSP) levels (from 102 to 138 g/kg in diet by using 8% wheat bran). It should be considered that pigs can adapt to high fiber levels by increasing feed intake and increasing gastrointestinal capacity, for example, increases in stomach weight and large intestine (McDonald *et al*., 1999; Hermes *et al*., 2009; Gerritsen *et al*., 2012). The inconsistent results on growth performances in our current study might be related to the digestibility of energy and crude protein not being significant and could be explained by the fact that increasing ADFI does not improves ADG in pigs.

Nutrient Digestibility

As shown in Table 3, the dietary fiber level did not effect on the digestibility of gross energy and crude protein (P = 0.082 and 0.074). However, the increasing of dietary fiber level found that the digestibility of crude fiber tended to increase (P = 0.074). The digestibility of crude fat was highest in the pigs fed 140 g/kg diet following by the pigs fed 150 g/kg and 130 g/kg diets respectively (P = 0.082).

Table 2: Growth performance of pigs fed different levels of dietary fiber after weaning

	DF Level (g/kg diet)				
Items	130	140	150	SEM	*P*-value
Initial weight, kg	6.04	6.05	6.06	0.11	0.998
Final weight, kg	13.41	14.28	13.90	0.38	0.781
0 to 7d;					
Weight gain, g	774.00	1,286.00	1,168.00	75.69	0.123
ADG, g/d	110.00	183.57	166.43	10.83	0.121
ADFI, g/d	159.14	188.43	193.79	12.34	0.644
FCR	1.36^{a}	1.18^{b}	1.14^{b}	0.04	0.023
8 to14 d;					
Weight gain, kg	2.09	1.89	1.60	0.08	0.215
ADG, g/d	297.86	270.00	228.57	11.79	0.216
ADFI, g/d	334.50	316.93	341.21	3.29	0.823
FCR	1.14	1.31	1.58	0.02	0.206
15 to 21 d;					
Weight gain, kg	2.05	2.43	2.33	0.16	0.739
ADG, g/d	292.14	346.43	332.14	22.56	0.739
ADFI, g/d	469.29	442.71	466.43	22.19	0.918
FCR	1.82	1.44	1.51	0.10	0.463
22 to 28 d;					
Weight gain, kg	2.45	2.77	2.85	0.15	0.674
ADG, g/d	350.00	395.00	407.14	21.08	0.674
ADFI, g/d	640.00	628.57	657.14	16.55	0.861
FCR	1.94	1.60	1.41	0.07	0.170
0- to 28 d;					
Weight gain, kg	7.38	8.23	7.85	0.34	0.730
ADG, g/d	263.54	294.00	280.32	12.01	0.730
ADFI, g/d	400.73	394.16	414.64	12.61	0.873
FCR	1.57	1.34	1.51	0.05	0.317
Diarrhea incidence (%)[1]	0.28	0.11	0.06	0.04	0.308

[a,b] Means in the same raw with different superscript differ (*P*<0.05)

[1] calculation according to Chen *et al*. (2013); diarrhea incidence (%) = (total number of pigs per pen with diarrhea)/ (number of pigs per pen x 28d)/100

Table 3: The total tract nutrient digestibility (%) of pigs fed different dietary fiber levels in weaning pig diets

	DF Level (g/kg diet)				
	130	140	150	SEM	*P*-value
Gross energy	79.80	78.14	64.95	0.83	0.167
Crude protein	80.30	77.35	67.82	0.84	0.320
Ether extract	38.99	48.71	41.38	0.55	0.082
Crude fiber	44.92	48.93	56.26	0.58	0.074

Inclusion of dietary fiber did not affect nutrient digestibility. This may be due to the experimental diets having a balanced nutrient composition, with the exception of dietary fiber levels. In this study, the digestibility of gross energy and protein numerically decreased with increases in dietary fiber levels. This corresponds to the previous study that found no significant difference (P = 0.42) in apparent protein digestibility for diets supplemented with various dietary fiber sources (142 to 152 g/kg of dietary neutral detergent fiber) in the weaning period (Yu *et al*., 2016). Lower of protein and energy digestibility was occurred when fiber was included that could be explained by a few mechanisms: fiber binding to the amino acids and inhibiting their absorption (Sauer *et al*., 1991), increasing the endogenous nitrogen loss (Souffrant, 2001) or synthesis of bacterial protein (Canh *et al*., 1997). Moreover, the difference of dietary fiber level between treatments was very low (about 1%) that could be lack of effect on the nutrient digestibility.

In this study, increasing dietary fiber diluted energy in the formula; therefore, the high dietary fiber formula was supplemented with palm oil (Table 1). Results tended to suggest increasing total tract digestibility of fat after increasing dietary fiber level in the experimental diet. This can be due to the synthesis of fat or fatty acid utilization by microbes occurring in the gastrointestinal tract. This hypothesis is supported by Dierick *et al*. (1990) and Le Goff and Noblet (2001), their results revealed that the total tract digestibility of fat were affected by high dietary fiber diets, however, the digestibility of fat in the ileal was not clearly changed. In addition, increasing dietary fiber level by adding 20% cellulose in rat diets stimulated bile acid secretion (Schneeman and Gallaher, 1980). Cellulose is the main component in rice hull, constituting approximately 32.67% (Ma'ruf *et al*., 2017). Moreover, increase in crude fiber digestibility was observed in this study. These increases were probably due to increases in the portion of pectin as the rapid fermentation substrate for microorganisms in the lower part of digestive system resulting in lower fiber excretion. Unfortunately, our study did not measure the digestibility of total dietary fiber, insoluble fiber and soluble fiber for clearly describe digestion of each component. However, the effect of iDF content on crude fiber digestibility was discussed by Pascoal *et al*. (2015), which showed that increasing iDF levels from 1.59% to 4.26% in weaning diets resulted in higher crude fiber digestibility by 33.19%.

Intestinal Morphology

Increasing dietary level did not alter intestinal morphology of the duodenum and jejunum significantly. The heightest of villus on the ileum was found in the pigs fed 140 g/kg dietary fiber diet (344.70 μm) followed by the pigs fed 150 g/kg and 130 g/kg of dietary fiber diet and (355.40 and 267.40 μm; P = 0.074). Result in the VH:CD ratio of ileum tended to increase when increasing dietary fiber level (P=0.062) as shown in Table 4.

Increasing of the villus height in the ileum occurred when dietary fiber was increased. This effect was probably caused by increasing sDF from 2.81% to 3.01% in the diet. Soluble dietary fiber, such as pectin, possibly promotes fermentation by microorganisms in the lower part of the intestine (Pascoal *et al*., 2015). The main product of fermentation is short chain fatty acids (SCFAs): acetate, propionate and butyrate, which do not pass in blood but instead are directly utilized by the colonocytes of the intestinal mucosa (Bindelle *et al*., 2008). As described in a previous study, dietary fiber stimulates intestinal crypt cell production in the colon of germ-free animals (McGullough *et al*., 1998). Importantly, increases in the villi height and the VH:CD ratio has been correlated with increases in epithelial cell turnover and stimulation of epithelial cell proliferation (Fan *et al*., 1997). However, the rate of fermentation depends on the type of dietary fiber. Soluble dietary fiber possesses the characteristic of being easily fermented and the fermentation process usually starts in the ileum, whereas iDF is slowly fermented in the distal part of the intestinal tract (Freire *et al*., 2000). Therefore, increased villus height and VH:CD ratio in the ileum of pigs fed diets that contained high levels of dietary fiber in this study could be explained by the tendency of fiber to increase fermentation.

Bacterial Count

As shown in Table 5, inclusion of dietary fiber in experimental diets demonstrated no effect on Salmonella spp., *E. coli* and lactic acid bacteria population of ileum, caecum and colon. *E. coli* and Salmonella spp. are the main causes of post-weaning diarrheas whereas the lactic acid bacteria is utilized as probiotics in humans and animals. Dietary fiber could be fermented by intestinal microbes in the hind-gut. The fermentation of soluble fiber usually starts in the ileum whereas insoluble fiber ferments slowly in the distal part of the intestine (Freire *et al*., 2000). The main products from fiber fermentation are SCFAs, which consequently have a crucial role in controlling populations of harmful bacteria in the distal part of digestive system (Bach Knudsen *et al*., 2012). Dietary fiber has been reported as having the ability to decrease pathogenic bacteria. According to Molist *et al*. (2009), a combination of 4% wheat bran plus 3% sugar beet pulp in weaning pig diet decreased enterobacteria counts in caecum on the 15th day after weaning compared with the control diet and reduced the incidence of post-weaning diarrhea. Chen *et al*. (2013) also discovered that inclusion of 10% pea fiber (CF = 4.95%) decreased the number of pathogenic *E. coli* and incidence of post-weaning diarrhea by reducing adhesion and increasing excretion of pathogenic *E. coli*. For lactic acid bacteria, dietary fiber did not alter lactic acid count. Similar results were observed by Gerritsen *et al*. (2012) when evaluating 15% wheat straw combined oat hull (74 g/kg of CF) and Pascoal *et al*. (2015) when evaluation various sources of dietary fiber (DF ranging from 384 to 764 g/kg). However, the current study revealed that dietary fiber level did not alter the population of *E. coli*, Salmonella spp. and lactic acid bacteria in the lower part of the digestive system. The first reasonable factor was the difference of dietary fiber content between the experimental diets was very low (about 1%) that could be lack of effect on bacterial count. The second factor was housing sanitation may be affect to the results. A similar effect was reported by Montagne *et al*. (2012). They suggested that good sanitation had positive effect on intestinal microflora in the early post weaning period, which resulted in balance of beneficial-pathogenic bacterial populations being altered in favor of beneficial bacteria. This condition possibly explains why we were unable to detect changes in bacteria populations at the end of experiment (28 days after weaning).

Table 4: The intestinal morphological alterations of weaning pigs fed different dietary fiber level in experimental diets at d 29 after weaning

	DF Level (g/kg diet)				
Items	130	140	150	SEM	*P*-value
Duodenum					
Villous height, μm	296.94	306.98	325.22	10.93	0.693
Crypt depth, μm	171.22	165.88	185.56	6.91	0.627
VH:CD ratio	1.73	1.85	1.75	0.17	0.881
Jejunum					
Villous height, μm	293.26	355.22	298.64	13.26	0.195
Crypt depth, μm	159.84	179.14	161.68	6.51	0.557
VH:CD ratio	1.83	1.98	1.85	0.12	0.422
Ileum					
Villous height, μm	267.40	344.70	355.04	13.55	0.074
Crypt depth, μm	137.94	164.08	142.52	6.09	0.293
VH:CD ratio	1.94	2.10	2.35	0.14	0.062

Table 5: Intestinal bacterial population (log CFU/g) of pigs fed different dietary fiber levels at 29th day of experiment

	DF level (g/kg diet)				
Items	130	140	150	SEM	*P*-value
Ileum					
Salmonella spp	7.90	7.62	7.72	0.04	0.235
E. coli	7.40	7.48	7.72	0.13	0.466
Lactic acid bacteria	7.55	7.30	7.16	0.21	0.495
Caecum					
Salmonella spp	7.66	7.36	7.18	0.12	0.208
E. coli	7.65	7.43	7.22	0.08	0.161
Lactic acid bacteria	6.92	7.06	7.06	0.19	0.869
Colon					
Salmonella spp	7.60	7.51	7.43	0.15	0.830
E. coli	7.55	7.34	7.63	0.09	0.403
Lactic acid bacteria	7.08	7.08	6.75	0.39	0.697

Conclusion

The dietary fiber level between 130 to150 g/kg was not altering overall growth performance, nutrient digestibility, intestinal morphology and intestinal bacteria population. However, the dietary fiber 140-150 g/kg in diet was improve FCR in the first week after weaning and tended to improve the morphology of ileum.

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Author's Contributions

Nujira Taksinanan: Conceptualized and designed the experiments, performed the experiment, carried out of laboratory and statistic analysis, drafted and revised the manuscript.

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Conflict of Interest

The authors declare no conflict of interest.

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