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Research Article
Dried Banana (*Musaparadisiaca.*) For Feeding Pigs: Nutrient Compositions, Growth Performance and Small Intestinal Morphology

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Abstract

Background and Objective: Banana can be used as a dietary energy due to carbohydrate and high contents of sugars. In addition, the fructo-oligosaccharide in banana may be useful as a prebiotic. Thus, this study was conducted to evaluate the effect of banana (*Musaparadisiaca.*) in diet, on growth performance and intestinal morphology of nursery pigs. **Materials and Methods:** The whole sliced dried and ground bananas were used in this study and the study was divided into 2 experiments. Experiment 1, study the energy and nutrient composition of whole dried banana. Experiment 2, study the effect of dried banana at 0, 2.5, 5.0 and 7.5% in diet on growth performance and intestinal morphology of nursery pigs. Sixty male crossbreed pigs (body weight 8.00±0.27 kg) were randomly divided into four groups with five replications of three pigs each. The pigs fed a control diet without dried banana or experimental diets using dried banana at 2.5, 5.0 and 7.5% for 6 weeks. The experimental design was completely randomized design. All data were statistically analyzed using analysis of variance. The differences between the means of groups were separated by Duncan's New Multiple Range Test. Trend analysis from the orthogonal polynomial to test the relationship. Using the Orthogonal Polynomial Coefficient of 4 groups and two levels of linear and quadratic correlation were tested. **Results:** The results showed that the average daily gain, feed intake and feed conversion ratio did not influence by dried banana ($p>0.05$). In addition, white blood cells count Neutrophils:Lymphocytes and intestinal pH were not influenced by the dietary treatments. Moreover, the dietary treatments did not influence villous height and crypt depth in the small intestine of pigs ($p>0.05$). **Conclusion:** It can be concluded that dried banana can be substitution in feed and be useful as a feedstuff. The incorporation of dried banana up to 7.5% in feed contributed without negative effect on growth performance and small intestinal morphology of nursery pigs.

Key words: Banana, nutrient, feed, growth performance, intestinal morphology, nursery pigs

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Competing Interest: The authors have declared that no competing interest exists.

Data Availability: All relevant data are within the paper and its supporting information files.

INTRODUCTION

The main cost of pig production industry is related to the provision of a sustainable energy source. Feed cost account for 60-80% of livestock production costs and the energy component of feed accounts for 40-60%[1], the high cost of imported feed is a major constraint to the development of the local pig production especially when local meat competes with cheap import meat. Within tropical countries, if properly utilized, several local feed resources could greatly contribute to reduce the amount of imported raw material for livestock and the energy source such as corn that are at risk of contaminated by aflatoxin[2,3]. Banana is an important agricultural commodity for many tropical and subtropical countries. In Thailand, banana (*Musaparadisiaca.*) production 747,802 t per year. Banana is an alternative feedstuff can be used as energy source for animal feed because bananas are rich source of carbohydrate and high contents of sugars, mainly sucrose, glucose and fructose[4,5]. Moreover, Renaudeau *et al.*[6] reported that grower pigs that were fed up to 60% banana in place of corn had no effect on final body weight, average daily gain and feed conversion ratio.

In addition, banana also contains certain amounts of fructooligosaccharide (FOS). FOS are oligosaccharide which are not hydrolysed by digestive enzyme and may act as growth substrate for the intestinal microflora[5,7,8]. They are considered as prebiotics. They have been shown to have beneficial effects on the intestinal microflora by stimulating the growth of beneficial bacteria such as *Bifidobacterium* and *Lactobacillus* and inhibit pathogenic bacteria such as *E. coli* and *Salmonella*[9,10]. For example, Xu *et al.*[11] reported that supplementation with FOS improved feed conversion ratio (FCR) and increasing the villi height in jejunum to cecum in piglets. Therefore, this study focused on the effect of banana in diet on growth performance and intestinal morphology of nursery pigs.

MATERIALS AND METHODS

Two trials were designed to study the effect of composition analysis of whole dried bananas to use the nutrient composition to calculate the feed (experiment 1) and to evaluate the effect of banana in diet on growth performance and intestinal morphology of nursery pigs (experiment 2, *in vitro* study). The experiments were conducted at Animal Research Farm, Department of Animal Science, Faculty of Agriculture, Kasetsart University, Bangkok, Thailand in August, 2016-January, 2017. The experimental animals were kept, maintained and treated in adherence to accepted standards for the humane treatment of animals.

Experiment 1: Bananas were analyzed for nutrient composition by means of proximate analysis, including moisture, crude protein, crude fiber and ash. Calcium and phosphorus of banana using a spectrophotometer (Spectrophotometer, UNICO 2100, UNICO, NJ, USA). The gross energy analysis of banana was carried out by bomb calorimeter[12]. The Reducing sugar composition was determined by High Performance Liquid Chromatography[13] and analyze the fructooligosaccharide (Inulin type fructan) with the Megazyme Fructan HK Assay Kit using the machine spectrophotometer[14]. The results of the nutrient composition analysis of whole dried banana will be used to calculate the experimental diet.

Experiment 2

Animals and management: Sixty male commercial crossbred pigs (Duroc×Large White×Landrace; 8.00±0.27 kg body weight) were used in this trial. The pigs were randomly divided into four treatments and each treatment consisted of five replications (three pigs/pens). The average body weight of each replication were homogenized and balanced. For six weeks experimental period, an evaporative cooling system was used to control air ventilation and temperature. Feed were offered as *ad libitum* and water were provided by water nipples. During the feeding trial, the house was cleaned weekly, while the feces of piglets were removed every day.

Experimental diets: The experimental diets were divided into 2 phases including Pre-Starter Pig (1-14 days) and Starter Pig (15-42 days). Four experimental diets were used as control diet with and without banana diets containing 2.5, 5.0 and 7.5% of dried banana (*Musa sapientum* L. in Thailand), respectively. The feed ingredients composition of experimental diets in the pre-starter and starter diets were shown in the Table 1 and 2; respectively. The experimental diets were formulated to provide the same amount of nutrients and met the requirement as Nutrient requirements of swine from National Research Council (NRC)[15] without an antimicrobial agent. The nutrient composition of experimental diets in the pre-starter and starter diets were shown in the Table 3 and 4, respectively.

Measurements

Growth performances: The body weight of each pig was recorded and at the end of feeding trial (6 weeks) the body weight, body weight gain and feed intake were measured weekly. The feed conversion ratio (FCR) was calculated from body weight gain and feed intake data.

Table 1: Feed ingredients composition of experimental diets (Pre-starter)

Ingredient (%)	Control	2.50%	5.00%	7.50%
Banana	0.00	2.50	5.00	7.50
Broken rice	40.00	40.00	40.00	40.00
Corn	16.14	13.41	10.69	7.96
Soybean oil	0.68	0.59	0.51	0.42
Soybean meal (CP 48%)	22.48	22.81	23.13	23.45
Full fat soybeans	10.00	10.00	10.00	10.00
Fish meal (CP 65%)	2.00	2.00	2.00	2.00
Whey (CP 9%)	5.00	5.00	5.00	5.00
L-Lysine HCL	0.22	0.21	0.21	0.20
L-Threonine	0.07	0.07	0.07	0.07
DL-Methionine	0.10	0.11	0.11	0.11
Calcium carbonate	0.71	0.70	0.68	0.67
Monodicalciumphosphate (P 21%)	1.24	1.25	1.26	1.27
Choline chloride 75%	0.08	0.08	0.08	0.08
Sodium bicarbonate	0.39	0.39	0.39	0.39
Salt	0.38	0.38	0.38	0.38
Premix[1]	0.50	0.50	0.50	0.50
Total	100.00	100.00	100.00	100.00

Premix[1] content; Composition per kg: Vitamin A 15,000 IU, Vitamin D3 3,000 IU, Vitamin E 40 IU, Vitamin K3 3 mg, Vitamin B1 2 mg, Vitamin B2 7 mg, Vitamin B6 5 mg, Vitamin B12 0.02 mg, Pantothenic acid 10 mg, Folic acid 2 mg, Biotin, 0.1 mg, Niacin 70.0 mg, Mn 120 mg, Zn 110 mg, Fe 70 mg, Cu, 8 mg, I 1.2 mg, Se 0.3 mg, Co 0.2 mg

Table 2: Feed ingredients composition of experimental diets (Starter)

Ingredient (%)	Control	2.50%	5.00%	7.50%
Banana	0.00	2.50	5.00	7.50
Broken rice	35.00	35.00	35.00	35.00
Corn	28.93	26.06	23.18	20.31
Soybean oil	0.40	0.41	0.42	0.42
Soybean meal (CP 48%)	19.29	19.66	20.04	20.41
Full fat soybeans	8.00	8.00	8.00	8.00
Fish meal (CP 65%)	2.00	2.00	2.00	2.00
Whey (CP 9%)	3.00	3.00	3.00	3.00
L-Lysine HCL	0.14	0.13	0.13	0.12
L-Threonine	0.04	0.04	0.04	0.05
DL-Methionine	0.03	0.03	0.03	0.03
Calcium carbonate	0.76	0.74	0.72	0.70
Monodicalciumphosphate (P 21%)	0.88	0.90	0.92	0.93
Choline chloride 75%	0.08	0.08	0.08	0.08
Sodium bicarbonate	0.60	0.60	0.60	0.60
Salt	0.35	0.35	0.35	0.35
Premix[1]	0.50	0.50	0.50	0.50
Total	100.00	100.00	100.00	100.00

Premix[1] content; Composition per kg: Vitamin A 15,000 IU, Vitamin D3 3,000 IU, Vitamin E 40 IU, Vitamin K3 3 mg., Vitamin B1 2 mg, Vitamin B2 7 mg, Vitamin B6 5 mg, Vitamin B12 0.02 mg, Pantothenic acid 10 mg, Folic acid 2 mg, Biotin, 0.1 mg, Niacin 70.0 mg, Mn 120 mg, Zn 110 mg, Fe 70 mg, Cu, 8 mg, I 1.2 mg, Se 0.3 mg, Co 0.2 mg

Blood collection and analysis: On the final day of experiment, one pig per treatment with medium body weight were selected from each group and a 3 mL blood sample was collected to plastic tubes with anticoagulants via the jugular vein (feeders were removed from pens 3 h before). For determination of White Blood Cell (WBC) count and differentials. Reported total WBC concentration (WBC μL^{-1}); are the concentration of neutrophils per lymphocytes and the percentage of neutrophils per lymphocytes and monocytes relative to total WBC concentration (Drew Scientific Inc., Oxford, CT).

Table 3: Nutrient composition of experimental diets (Pre-starter)

Calculated chemical composition (%)	Control	2.50%	5.00%	7.50%
Swine ME (Kcal kg^{-1})	3,400.00	3400.00	3400.00	3400.00
Crude protein	21.00	21.00	21.00	21.00
Ether extract	4.41	4.33	4.25	4.16
Calcium	0.80	0.80	0.80	0.80
Available phosphorus	0.40	0.40	0.40	0.40
Lysine	1.35	1.35	1.35	1.35
Methionine+cysteine	0.76	0.76	0.76	0.76
Methionine	0.45	0.45	0.45	0.45
Threonine	0.86	0.86	0.86	0.86
Reducing sugar	0.00	0.22	0.43	0.65
Total sugar	0.00	0.35	0.70	1.04
FOS (Inulintypefructan)	0.00	0.01	0.03	0.04

Table 4: Nutrient composition of experimental diets (Starter)

Calculated chemical composition (%)	Control	2.50%	5.00%	7.50%
Swine ME (Kcal kg^{-1})	3,350.00	3350.00	3350.00	3350.00
Crude protein	19.00	19.00	19.00	19.00
Ether extract	4.00	4.00	4.00	4.00
Calcium	0.70	0.70	0.70	0.70
Available phosphorus	0.33	0.33	0.33	0.34
Lysine	1.15	1.15	1.15	1.15
Methionine+cysteine	0.65	0.65	0.65	0.65
Methionine	0.36	0.36	0.36	0.36
Threonine	0.74	0.74	0.74	0.74
Reducing sugar	0.00	0.22	0.43	0.65
Total sugar	0.00	0.35	0.70	1.04
FOS (Inulintypefructan)	0.00	0.01	0.03	0.04

Morphology and gastrointestinal pH of small intestine: At the end of the trial, one pig from each replication was putdown. The pH in the stomach, duodenum, jejunum, ileum, caecum, colon and rectum were directly measured by a pH meter. (IQ Scientific Instruments, Carlsbad, CA, USA) and tissue samples were collected from the duodenum, jejunum and ileum and were immediately fixed in 10% neutral buffer formalin. Then, the tissues were carefully embedded in paraffin. For each specimen, at least 10 sections of 7 μm thickness were prepared. Tissues were then stained with haematoxylin-eosin for histological evaluation. Histology of the duodenum, jejunum and ileum tissue was assessed by light microscope in accordance with Nunez *et al.*[16]. The morphology of the small intestines in this study included villous height, crypt depth and the villous height to crypt depth ratio were conducted by a computer-assisted for image-analysis system (Biowizard, Thaitec, Thailand). Measurements of villous height from the tip of the villus to the villous-crypt junction and crypt depth from the villous-crypt junction to the lower limit of the crypt were recorded as the mean of 10 fields for each specimen.

Statistical analysis: All data were statistically analyzed using analysis of variance (ANOVA, Type I) of SAS[17]. The differences between the means of groups were separated by Duncan's New Multiple Range Test[18] according to the following model:

$$Y_{ij} = \mu + A_i + e_{ij}$$

Where:
Y_{ij} = Observed response
A_i = Effect of diet
e_{ij} = Experimental error
e_{ij} = ~NID (0, δ^2)

Statements of statistical significance were based on $p<0.05$. Trend analysis from the orthogonal polynomial (Trend Analysis) to test the relationship. Using the Orthogonal Polynomial Coefficient of 4 group and two levels of linear and quadratic correlation were tested. All statistical analyses were done in accordance with the method of Steel and Torrie[19].

RESULTS AND DISCUSSION

Chemical composition of dried banana (experiment 1): In this study, the effect of nutrient composition analysis of whole dried banana to use the nutrient composition to calculate the feed. It was found that the moisture content in bananas was 5.60%, protein 3.02%, fiber 1.35%, calcium 0.14% and phosphorus 0.06%. Reducing sugar content was 8.63%, total sugar 13.89% and fructooligosaccharide (inulin type fructan) 0.54%. The energy content in the banana was 3,638.52 Kcal kg^{-1} (Table 5).

Growth performance (experiment 2): The effects of banana in diet on growth performance were presented in Table 6. There was no significant effect of banana on final body weight, average daily gain (ADG), average daily feed intake (ADFI) and feed conversion ratio (FCR) throughout the experimental period ($p>0.05$). In the trend analysis of the effect of banana in diet, it was found that there was no significant effect of banana on performance production ($p>0.05$).

Banana was used as a substitute for corn to supply 2.5, 5.0 and 7.5% of the total diet for nursery pigs. Base on the chemical composition of banana in Table 5, the experimental diet was formulated to provide the same amount of nutrients and met the requirement as NRC[15]. Increasing the level of

Table 5: Chemical composition of dried banana (*Musaparadisiaca*)

Item	Amount
Gross energy (Kcal kg^{-1})	3,638.52
Moisture (%)	5.60
Crude protein (%)	3.02
Fiber (%)	1.35
Ash (%)	4.54
Calcium (%)	0.14
Total phosphorus (%)	0.06
Reducing sugar (%)	8.63
Total sugar (%)	13.89
FOS (Inulin type fructan) (%)	0.54

*FOS (Inulin type fructan)[14]

Table 6: Effect of banana (*Musaparadisiaca*.) in diet on growth performance of nursery pigs

	Level of banana (%)				p-value			
Item	Control	2.5	5.0	7.5	ANOVA	Linear	Quadratic	SEM
Initial body weight (kg)	8.00±0.27*	8.00±0.25	8.00±0.25	7.99±0.24	0.99	0.92	0.96	0.05
0 -14 days								
Body weight (kg)	13.30±0.95	13.28±0.73	13.35±0.48	13.04±0.66	0.90	0.62	0.66	0.15
Body weight gain (kg)	5.30±0.90	5.28±0.66	5.36±0.51	5.05±0.54	0.89	0.61	0.64	0.14
Feed intake (kg day^{-1})	0.44±0.06	0.45±0.06	0.44±0.04	0.42±0.05	0.83	0.47	0.57	0.01
Average daily gain (kg day^{-1})	0.38±0.06	0.38±0.05	0.38±0.04	0.36±0.04	0.89	0.62	0.65	0.01
Feed conversion ratio	1.17±0.07	1.19±0.06	1.15±0.06	1.17±0.05	0.75	0.65	0.97	0.01
14-42 days								
Body weight (kg)	32.31±2.47	31.82±1.99	31.91±1.60	31.99±1.02	0.98	0.82	0.74	0.38
Body weight gain (kg)	19.01±1.68	18.54±1.44	18.56±1.26	18.95±0.63	0.91	0.96	0.47	0.27
Feed intake (kg day^{-1})	1.12±0.14	1.05±0.10	1.07±0.11	1.10±0.05	0.75	0.96	0.32	0.02
Average daily gain (kg day^{-1})	0.68±0.06	0.66±0.05	0.66±0.04	0.68±0.02	0.91	0.95	0.47	0.01
Feed conversion ratio	1.64±0.10	1.58±0.04	1.62±0.07	1.63±0.05	0.56	0.95	0.26	0.02
0-42 days								
Body weight (kg)	32.31±2.47*	31.82±1.99	31.91±1.60	31.99±1.02	0.98	0.82	0.74	0.38
Body weight gain (kg)	24.31±2.45	23.82±1.89	23.91±1.57	24.00±0.85	0.97	0.82	0.72	0.37
Feed intake (kg day^{-1})	0.89±0.11	0.85±0.09	0.86±0.09	0.88±0.04	0.87	0.85	0.46	0.02
Average daily gain (kg day^{-1})	0.58±0.06	0.57±0.04	0.57±0.04	0.57±0.02	0.97	0.78	0.68	0.01
Feed conversion ratio	1.54±0.07	1.50±0.03	1.51±0.06	1.53±0.05	0.62	0.96	0.24	0.01

*Values are Mean±SD

Table 7: Effect of banana (*Musaparadisiaca.*) in diet on white blood cell (WBC) and Neutrophils:Lymphocytes (N:L) of nursery pigs

		Level of banana (%)			p-value			
Item	Control	2.5	5.0	7.5	ANOVA	Linear	Quadratic	SEM
WBC	17.90±4.53*	18.57±2.25	20.24±6.51	18.12±4.48	0.86	0.81	0.52	0.99
Neutrophil (%)	24.76±5.01	26.70±7.68	22.54±5.30	27.22±8.36	0.69	0.81	0.66	1.45
Lymphocyte (%)	70.02±5.99	67.56±8.15	72.98±5.91	67.82±9.18	0.64	0.94	0.69	1.61
N:L	0.36±0.10	0.41±0.16	0.32±0.09	0.42±0.17	0.62	0.77	0.65	0.03

*Values are Mean±SD

Table 8: Effect of Banana (*Musaparadisiaca.*) in diet on intestinal morphology of nursery pigs

		Level of banana (%)			p-value			
Item	Control	2.5	5.0	7.5	ANOVA	Linear	Quadratic	SEM
Villus height (µm)								
Duodenum	629.00±86.75*	631.18±83.24	616.74±96.49	670.24±178.12	0.91	0.65	0.63	24.01
Jejunum	643.93±103.90	617.24±93.69	568.35±92.08	577.49±44.45	0.50	0.17	0.65	19.11
Ileum	490.62±26.91	539.10±97.67	501.65±70.95	572.01±131.03	0.49	0.27	0.79	19.90
Crypt depth (µm)								
Duodenum	302.72±34.93	306.13±55.61	294.63±39.99	312.02±32.05	0.93	0.85	0.71	8.67
Jejunum	296.15±39.67	275.53±42.53	276.78±37.91	302.38±7.14	0.53	0.78	0.16	7.65
Ileum	202.07±49.66	220.06±46.52	222.68±88.78	239.42±57.54	0.83	0.37	0.98	13.25
Villus height:Crypt depth								
Duodenum	2.09±0.30	2.11±0.44	2.10±0.20	2.12±0.74	0.99	0.93	0.99	0.09
Jejunum	2.21±0.42	2.25±0.27	2.08±0.41	1.91±0.14	0.38	0.13	0.47	0.07
Ileum	2.55±0.65	2.55±0.69	2.49±0.85	2.48±0.73	0.99	0.86	0.99	0.15

*Values are Mean±SD

incorporation of banana did not have negative effect on body weight gain, average daily gain (ADG), average daily feed intake (ADFI) and feed conversion ratio (FCR). Similarly, growth performance remained constant in post-weaning pigs fed by diet with 15 and 30% of green banana meal[20]. In a study of Renaudeau *et al.*[6] found that banana meal did not have negative effect on ADG and FCR in grower pigs fed by diet with 20, 40 and 60% of banana meal. However, some other works performed in Equator[21], in Colombia[22] and in Cameroon[23] in growing finishing pigs showed a gradual decrease in both ADG and FCR when level of BM increase.

In a present study, banana contains 0.54% of fructooligosaccharide (FOS). The experimental diet was calculated to contain an FOS (inulin type fructan) at 0.0, 0.01, 0.03 and 0.04%, respectively. There reported many improved ADG and FCR as a consequence of FOS inclusion in piglet diets[24-26]. According to Xu *et al.*[11], 0.4% FOS supplementation improved feed efficiency of piglets. As in the study of Xu *et al.*[27], supplementation of 0.4 and 0.6% FOS in growing pigs at the level of 0.4 and 0.4% resulted in the activation of protease, trypsin and amylase in the small intestine and improve ADG and FCR. However, some studies have reported that the effect of FOS supplementation has no effect on growth performance in pig[28,29].

Analysis of blood biochemical: Effect of banana on blood biochemical of piglets are presented in Table 7. There was no significant difference among the treatments concerning white blood cell count ratio and neutrophils:lymphocytes ratio ($p>0.05$). In the trend analysis of the effect of banana in diet to test the linear and quadratic relationship of the banana. It was found that, it had no significant effect of banana on white blood cell count ratio and neutrophils:lymphocytes ratio ($p>0.05$).

Fructooligosaccharide (FOS) can be stimulated the growth of beneficial bacteria such as *Bifidobacterium* and *Lactobacillus* and inhibit pathogenic bacteria such as *E. coli* and *Salmonella*[9,10]. There are also research findings suggesting that bifidobacteria stimulate components of the immune system[30]. In this study, there were no significant difference among the treatments concerning white blood cell count ratio and neutrophils:lymphocytes ratio ($p>0.05$). Because few reports are available regarding this topic, more studies may be needed to verify the effects of FOS on leukocytes in pigs.

Intestinal morphology and gastrointestinal pH: Effects of banana in diet on intestinal morphology were shown in Table 8. There were no significant effect of banana on villus height and crypt depth of jejunum ileum ($p>0.05$) and significant on duodenum. In control treatment, the height of villi in duodenum is 629.0 µm. By incorporation of banana diet at 2.5% is 631.18 µm, somehow negligible difference but at banana concentration 5.0 and 7.5% the recorded villi height is 616.74 and 670.24 µm, respectively that was statistically

Table 9: Effect of Banana (*Musaparadisiaca.*) in diet on gastrointestinal pH of nursery pigs

		Level of banana (%)			p-value			
Item	Control	2.5	5.0	7.5	ANOVA	Linear	Quadratic	SEM
Stomach	3.57±0.81*	3.65±0.58	4.14±0.71	3.20±1.47	0.50	0.75	0.25	0.21
Duodenum	5.39±0.13	5.33±0.18	5.57±0.10	5.13±0.56	0.22	0.43	0.21	0.08
Jejunum	6.25±0.39	6.14±0.15	6.08±0.15	6.28±0.27	0.60	0.96	0.20	0.06
Ileum	6.45±0.21	6.50±0.34	6.30±0.53	6.45±0.55	0.90	0.82	0.81	0.09
Colon	5.76±0.50	5.49±0.09	5.78±0.42	5.74±0.62	0.71	0.80	0.57	0.10
Caecum	5.41±0.34	5.38±0.21	5.64±0.49	5.31±0.21	0.47	0.96	0.34	0.07
Rectum	6.51±0.21	6.08±0.33	6.37±0.36	6.40±0.44	0.28	0.97	0.16	0.08

*Values are Mean±SD

different among treatment groups. Consequently, there were not any significant effects of banana on the ration of crypt depth in each segment of small intestine. The effect of banana on pH of the gastrointestinal tract content are presented in Table 9. The pH each segment of the digestive tract was not significantly different among treatment groups ($p>0.05$) and in the trend analysis of the effect of banana in diet to test the linear and quadratic relationship of the banana. It was found that had no significant effect of banana on intestinal morphology and gastrointestinal pH.

Factors affecting small intestinal development of pigs includes, stress of weaning, adaptation to solid feed during weaning period and dietary factor[31]. For these reasons, villous atrophy after weaning is caused by an increased rate of cell loss[32,33]. Short chain fatty acids (SCFAs) production is related to the development of intestinal villous and crypts. Especially, the butyric acid has high potential to stimulate the growth of epithelial cells in the intestinal of pigs by providing energy to the cells[34,35].

Fructooligosaccharide(FOS) are oligosaccharide which are not hydrolysed by digestive enzymes, but FOS was fermented by *Bifidobacterium* and *Lactobacillus* induced SCFAs production in the large intestine[7]. SCFAs, butyrate in particular, support the major function of epithelial cells, such as water, mineral and nutrient absorption. SCFAs production is related to the development of intestinal villous and crypts[35]. The increase in the height of the villous increases the surface area for nutrient absorption[36].

In present study, there was significant effect of banana on the ration of villus height but no statistical difference observed in crypt depth and gastrointestinal pH in each segment of small intestine ($p>0.05$). This may be due to the FOS level is not enough in diet. However, Xu *et al.*[11] reported that supplementation with 0.4% FOS improved feed conversion ratio (FCR) and increase the villi height in jejunum to cecum in piglets. Because, feeding FOS to young piglets may have other effects. A number of complex sugars have been shown to alter the morphology of intestinal lining, presumably through increased production of SCFA[37-39].

CONCLUSION

Banana (*Musaparadisiaca.*) can be used as an energy source in diets. Since, banana did not have negative effect on growth performance, white blood cell and Neutrophils: Lymphocytes, gastrointestinal pH and small intestinal morphology. In conclusion, banana can be used incorporated up to 7.5% in nursery pig diets. In future studies, the effects of higher levels of banana on performance and mall intestinal morphology of growing pigs and fattening pigs.

SIGNIFICANCE STATEMENT

This study reports the energy and nutrient composition of banana for using as feed and evaluate the effect of banana in diets, on growth performance and intestinal morphology of nursery pigs. This study will help the researchers to uncover the critical areas of agricultural field and commercial areas for using banana as alternative feedstuffs for reducing feed cost, especially when the local feed materials are limited. Thus, this study represents an attempt to develop a procedure for using banana in feed.

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REFERENCES

1. Ademosun, A.A., 1976. Livestock production in Nigeria: Our commissions and omissions. Inaugural Lecture Series 17. February 29, 1976. University of Ife Press, Ife.

2. Chaytor, A.C., M.T. See, J.A. Hansen, A.L.P. De Souza, T.F. Middleton and S.W. Kim, 2011. Effects of chronic exposure of diets with reduced concentrations of aflatoxin and deoxynivalenol on growth and immune status of pigs. J. Anim. Sci., 89: 124-135.
3. Robens, J.F. and J.L. Richard, 1992. Aflatoxins in animal and human health. Rev. Environ. Contam. Toxicol., 127: 69-94.
4. Imam, M.Z. and S. Akter, 2011. *Musa paradisiacal* L. and *Musa sapientum* L.: A phytochemical and pharmacological review. J. Applied Pharm. Sci., 1: 14-20.
5. Tsen, J.H., Y.P. Lin and V.A.E. King, 2004. Fermentation of banana media by using κ-carrageenan immobilized *Lactobacillus acidophilus*. Int. J. Food Microbiol., 91: 215-220.
6. Renaudeau, D., J. Brochain, M. Giorgi, B. Bocage and M. Hery *et al*., 2014. Banana meal for feeding pigs: Digestive utilization, growth performance and feeding behavior. Animal, 8: 565-571.
7. Hartemink, R., K.M.J. van Laere and F.M. Rombouts, 1997. Growth of enterobacteria on fructo-oligosaccharides. J. Applied Microbiol., 83: 367-374.
8. Monsan, P.F. and F. Paul, 1995. Oligosaccharide Feed Additives. In: Biotechnology in Animal Feeds and Feeding, Wallace, R.J. and A. Chesson (Eds.). VCH Verlagsgesellschaft, Weinheim, Germany, New York, pp: 233-245.
9. Bailey, J.S., L.C. Blankenship and N.A. Cox, 1991. Effect of fructooligosaccharide on *Salmonella* colonization of the chicken intestine. Poult. Sci., 70: 2433-2438.
10. Xu, Z.R., C.H. Hu, M.S. Xia, X.A. Zhan and M.Q. Wang, 2003. Effects of dietary fructooligosaccharide on digestive enzyme activities, intestinal microflora and morphology of male broilers. Poult. Sci., 82: 1030-1036.
11. Xu, C., X. Chen, C. Ji, Q. Ma and K. Hao, 2005. Study of the application of fructooligosaccharides in piglets. Asian Aust. J. Anim. Sci., 18: 1011-1016.
12. AOAC., 2000. Official Methods of Analysis of the Association of Official Analytical Chemists. 17th Edn., AOAC International, Washington, DC USA.
13. AOAC., 1977. Official method 977.20, separation of sugars in honey, liquid chromatographic method. J. AOAC., 60: 838-838.
14. McCleary, B.V., A. Murphy and D.C. Mugford, 2000. Measurement of total fructan in foods by enzymatic/spectrophotometric method: Collaborative study. J. AOAC Int., 83: 356-364.
15. NRC., 1998. Nutrient Requirements of Swine. 10th Edn., National Research Council, Washington, DC., USA.
16. Nunez, M.C., J.D. Bueno, M.V. Ayudarte, A. Almendros, A. Rios, M.D. Suarez and A. Gil, 1996. Dietary restriction induces biochemical and morphometric changes in the small intestine of nursing piglets. J. Nutr., 126: 933-944.
17. SAS., 2000. SAS User's Guide, Statistics. SAS Institute, Cary, North Carolina.
18. Duncan, D.B., 1955. Multiple range and multiple F tests. Biometrics, 11: 1-42.
19. Steel, R.G.D. and J.H. Torrie, 1980. Principles and Procedures of Statistics: A Biometrical Approach. 2nd Edn., McGraw Hill Book Co., New York, USA., ISBN-13: 9780070609266, Pages: 633.
20. Restrepo, L.G.A., 1973. Digestibilidad, valor nutritivo y energťicodelpltano, *Musa paradisiacal* L., encerdos. Ph.D. Thesis, Universidad Nacional de Colombia, Facultad de Agronoma', Colombia.
21. Oliva, S.F., 1970. Evaluacion de la harina de banano verde con cascara en crecimiento y acabado de cerdos en confinamiento. Tesis de Medico Veterinario. Universidad Central de Ecuador, Quito.
22. Celleri, H., F. Oliva and J.H. Maner, 1971. Green banana meal for feeding growing-finishing pigs. Memoria Assoc. Latinoamer. Prod. Anim., 6: 148-148.
23. Fomunyam, R., 1992. Economic Aspects of Banana and Plantain use in Animal Feeding: The Cameroon Experience. In: Roots, Tubers, Plantain and Bananas in Animal Feeding, Machin, D. and S. Nyvold (Eds.). FAO. Animal Production and Health Paper, 95. Food and Agriculture Organization of the United Nations, Rome, pp: 277-289.
24. Apper, E., C. Meymerit, J.C. Bodin, F. Respondek and A. Wagner, 2016. Effect of dietary supplementation with short-chain fructooligosaccharides in lactating sows and newly weaned piglets on reproductive performance of sows, immune response and growth performance of piglets from birth to slaughter. J. Anim. Res. Nutr., Vol. 1, No. 4. 10.21767/2572-5459.100019.
25. Fukuyasu, T., T. Oshida and K. Ashida, 1987. Effect of oligosaccharides on growth of piglets and on bacterial flora, putrefactive substances and volatile fatty acids in their feces. Bull. Anim. Hyg., 26: 15-22.
26. Hidaka, H., T. Eida and T. Hamaya, 1988. Livestock feed containing inulo-oligosaccharides and breeding of livestock by using the same. United States Patent 4778680.
27. Xu, Z.R., X.T. Zou, C.H. Hu, M.S. Xia, X.A. Zhan and M.Q. Wang, 2002. Effects of dietary fructooligosaccharide on digestive enzyme activities, intestinal microflora and morphology of growing pigs. Asian Aust. J. Anim. Sci., 15: 1784-1789.
28. Farnworth, E.R., H.W. Modler, J.D. Jones, N. Cave, H. Yamazaki and A.V. Rao, 1992. Feeding Jerusalem artichoke flour rich in fructooligosaccharides to weanling pigs. Can. J. Anim. Sci., 72: 977-980.
29. Kornegay, E.T., C.M. Wood and L.A. Eng, 1992. Effectiveness and safety of fructooligosaccharides for pigs. J. Anim. Sci., 70 (Suppl. 1): 19-19.

30. Lee, J., A. Ametani, A. Enomoto, Y. Sato, H. Motoshima, F. Ike and S. Kaminogawa, 1993. Screening for the immunopotentiating activity of food microorganisms and enhancement of the immune response by *Bifidobacterium adolescentis* M101-4. Biosci. Biotechnol. Biochem., 57: 2127-2132.
31. Steven, J.K., P.S. Miller and A.J. Lewis, 2001. Factors affecting small intestine development in weanling pigs. Nebraska Swine Report, University of Nebraska, Nebraska, USA.
32. Pluske, J.R., D.J. Hampson and I.H. Williams, 1997. Factors influencing the structure and function of the small intestine in the weaned pig: A review. Livestock Prod. Sci., 51: 215-236.
33. Pluske, J.R., I.H. Williams and F.X. Aherne, 1995. Nutrition of the Neonatal Pig. In: The Neonatal Pig: Development and Survival, Varley, M.A. (Ed.). CAB International, Wallingford, UK., pp: 187-235.
34. Roediger, W.E., 1980. Role of anaerobic bacteria in the metabolic welfare of the colonic mucosa in man. Gut, 21: 793-798.
35. Scheppach, W., H.P. Bartram and F. Richter, 1995. Role of short-chain fatty acids in the prevention of colorectal cancer. Eur. J. Cancer, 31: 1077-1080.
36. Bakir, B. and E.K. Sari, 2015. Immunohistochemical distribution of platelet-derived growth factor-C and platelet-derived growth factor receptor-? in small intestine of rats treated with capsaicin. Turk. J. Vet. Anim. Sci., 39: 160-167.
37. Howard, M.D., D.T. Gordon, L.W. Pace, K.A. Garleb and M.S. Kerley, 1995. Effects of dietary supplementation with fructooligosaccharides on colonic microbiota populations and epithelial cell proliferation in neonatal pigs. J. Pediatr. Gastroenterol. Nutr., 21: 297-303.
38. Tellez, G., C.E. Dean, D.E. Corrier, J.R. Deloach, L. Laeger and B.M. Harris, 1993. Effect of dietary lactose on cecal morphology, pH, organic acids and *Salmonella enteritidis* organ invasion in leghorn chicks. Poult. Sci., 72: 636-642.
39. Yoshioka, M., Y. Shimomura and M. Suzuki, 1994. Dietary polydextrose affects the large intestine in rats. J. Nutr., 124: 539-547.