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GROWTH PERFORMANCE, DIARRHOEA INCIDENCE, AND NUTRIENT DIGESTIBILITY IN WEANED PIGLETS FED AN ANTIBIOTIC-FREE DIET WITH DEHYDRATED PORCINE PLASMA OR POTATO PROTEIN CONCENTRATE*

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Abstract

Two experiments were conducted to test if dehydrated porcine plasma (DPP) and potato protein concentrate (PPC) could be used as an alternative to antibiotics in starter diets for piglets. Experiment one was conducted to test if DPP and PPC in an antibiotic-free diet affected pig performance, and faecal consistency. Eighty-four piglets weaned at 22 days and weighing 6.9 kg were used. Piglets were fed for two weeks with one of four diets: a positive control diet with antibiotics (C+); and three other diets without antibiotics added with DPP, PPC, or DPP and PPC (DPP+PPC) to measure the average daily feed intake (ADFI), average daily gain (ADG), feed efficiency (FE), and incidence and severity of diarrhoea (ID and ISD respectively). In experiment two, twenty-four piglets weaned at 17 days and weighing 5.7 kg, were implanted at 21 days of age with a T-cannula at the terminal ileum to measure the apparent ileal digestibility (AID) and the apparent total tract digestibility (ATTD) of nutrients. Piglets were fed one of four diets: a positive control diet with antibiotics (C+); a negative control diet without antibiotics (C–), and two diets without antibiotics added with DPP, or PPC. The results of experiment one showed that the DPP diet was the most consumed diet during the first week, and the ADG and FE were similar among treatments. During the second week and the total experimental period the ADFI, ADG, and FE were similar among

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diets. The ID was lower in the C+ diet than other diets. The ISD was lower in the C+ diet than DPP and DPP+PPC diets; piglets fed PPC diet were similar to piglets fed C+ and DPP and DPP+PPC diets. The results of digestibility showed that crude protein AID was higher in piglets fed C+ and PPC diets than C– and DPP diets. Dry matter ATTD and energy ATTD were higher for piglets fed PPC than other diets. Further, crude protein ATTD of DPP and PPC diets tended to have a similar digestibility to that of C+ diet. The results suggest that PPC is a potential controller of post-weaning diarrhoea.

Key words: weaning, piglets, potato protein, spray dried porcine plasma, digestibility

Weaning is associated with social, environmental, and nutritional stress factors that can lead to a reduction in the digestive capacity of piglets (Pluske et al., 1997; Lallès et al., 2004). Studies have shown that early weaning in pigs causes marked changes in the structure and function of the small intestine such as villous atrophy, crypt hyperplasia, decreased feed ingestion and nutrient absorption, and alterations in the intestinal barrier (Reis de Souza et al., 2012). Piglets are abruptly forced to adapt to the stressors that accompany weaning (Xiao et al., 2014). As a result, a reduction in feed consumption and growth, as well as an increase in susceptibility to gastrointestinal disorders and infections, is observed in the post-weaning phase (Van Noten et al., 2015). For approximately 60 years, antibiotics have been used (Li et al., 2017) in sub-therapeutic doses in starter diets for piglets to promote growth performance and nutrient digestibility (Cromwell et al., 2002; Gaskins et al., 2002; Li et al., 2017). However, the indiscriminate use of antibiotics has had negative effects because consumers are becoming increasingly concerned about drug residues in meat products and antibiotics provoke an imbalance in the gut microflora (Thacker, 2013). Heo et al. (2013) mentioned that antibiotics as growth promoters are known to modify the composition and (or) the activity of the intestinal microbiota, including both pathogenic and commensal bacteria. Generation of antibiotic resistant bacteria (ARB) develop in the gastrointestinal tract and the contamination and diffusion of ARB from livestock to humans is facilitated through the food chain (Tedeschi et al., 2017). This has led to controversy regarding public health, and therefore, the use of antibiotics in animal diet has been banned since 2006 in the European community (Huang et al., 2015). Thus, it is necessary to have alternatives to the use of antibiotics in animal nutrition. Some authors (Jin et al., 2008 a, b; Jin et al., 2009; Ohh et al., 2009) had mentioned that PPC and DPP reduced post-weaning nutritional stressors in a manner comparable to that affected by antibiotics. We hypothesize that some functional proteins (dehydrated porcine plasma (DPP) and potato protein concentrate (PPC)) could be included in starter diets to replace antibiotics and improve nutrient digestibility and faecal consistency, without negatively affecting the post-weaning development of piglets. To verify this, we conducted two experiments: a growth performance and a digestibility experiment.

Material and methods

The experiments were carried out in the Experimental Farm and the Metabolic Unit of the National Centre for Disciplinary Research in Physiology of the National Institute of Forestry, Crops and Livestock Research in Ajuchitlán, Querétaro. The chemical analyses were carried out in the Animal Nutrition Laboratory of the Faculty of Natural Sciences of the Autonomous University of Querétaro. The protocols followed the guidelines described in the Official Mexican Standards for the production, care, and use of experimental animals (Diario Oficial, 2001) and were reviewed and approved by the Bioethics Committee of the Faculty of Natural Sciences of the Autonomous University of Querétaro (72-1FCN2016).

Experiment 1 (Performance trial)

Eighty-four piglets (Fertilis 20 × G Performance, Genetiporc®) weaned at 22±3 days, and weighing 6.9±0.96 kg were used in the present study. The piglets were moved to a weaning room with a controlled environment (30°C and 28±2°C during the first and second week after weaning, respectively). The pens were elevated (38 cm from the floor), and they were 115 cm wide and 150 cm long (actual surface area 1.7 m^2). These pens had a nipple drinker, a feeder, and a grid plastic floor. The piglets were assigned to one of the four experimental diets according to a randomized complete block design with initial weight as a blocking factor. There were four pens with 6 pigs (24 pigs) per treatment and pen was used as the experimental unit for data analysis. The experimental diets used were: positive control with antibiotics (C+), dehydrated porcine plasma without antibiotics (DPP), potato protein concentrate without antibiotics (PPC), and potato protein concentrate and dehydrated porcine plasma without antibiotics (PPC+DPP). Diets were formulated using the principle of Ideal Protein, using the Standardized Ileal Digestibility of amino acids (Table 1). The DPP and PPC levels added to diets were the levels recommended by the producers. All diets furnished the nutritional requirements of the NRC (2012). Feed was offered three times a day at 9:00, 12:00, and 15:00 h, and feed intake was recorded daily. The piglets were weighed at weaning, and at the end of weeks one and two after weaning. Simultaneously, the average daily feed intake (ADFI), average daily gain (ADG), and feed efficiency (FE) were determined. The piglets had free access to water during the experiment.

The incidence (ID) and severity of diarrhoea were measured daily by direct observation by two different evaluators. The ID was measured as the number of days upon which diarrhoea was observed within each pen. The severity of diarrhoea was based on a daily visual evaluation of the faecal consistency, using a score from 0 to 3: where 0 indicated no diarrhoea; 1 slight diarrhoea; 2 moderate diarrhoea; and 3 severe, highly fluid diarrhoea (Ball and Aherne, 1987). The daily scores of each pen were summed over the first and second week to give an index of severity of diarrhoea (ISD) for each pen (Ball and Aherne, 1987).

Table 1. The centesimal and chemical composition of the experimental diets (experiment 1)

Item	Experimental diets			
	C+	DPP	PPC	DPP+PPC
Ingredients (%)				
maize	47.85	48.72	51.54	49.19
soybean meal	20.00	20.00	20.00	20.00
soy protein concentrate	11.65	5.35	5.86	0.59
dehydrated porcine plasma[1]	0.00	5.00	0.00	5.00
potato protein concentrate[2]	0.00	0.00	4.00	4.00
lactose	12.37	12.37	12.37	12.37
canola oil	2.00	2.00	2.00	2.00
HCl L-Lysine	0.45	0.37	0.64	0.43
L-Threonine	0.11	0.09	0.10	0.07
DL-Methionine	0.19	0.20	0.19	0.19
L-Tryptophan	0.01	0.01	0.03	0.02
salt	0.50	0.50	0.50	0.50
calcium carbonate	2.70	3.65	0.74	3.85
dicalcium phosphate	1.77	1.54	1.83	1.59
antibiotics[3]	0.20	0.00	0.00	0.00
mineral premix[4]	0.12	0.12	0.12	0.12
vitamin premix[5]	0.08	0.08	0.08	0.08
Chemical composition				
dry matter[6] (%)	90.13	89.62	89.49	89.41
crude protein[6] (%)	20.86	20.21	20.76	20.94
metabolizable energy[7] (kcal/kg)	3200	3200	3200	3200
total lysine[7]	1.47	1.50	1.62	1.57
digestible lysine[7]	1.37	1.37	1.37	1.37
digestible sulphur amino acids[7]	0.75	0.75	0.75	0.75
digestible threonine[7]	0.81	0.81	0.81	0.81
digestible tryptophan[7]	0.23	0.23	0.23	0.23
calcium[7]	1.54	1.49	1.00	1.50
phosphorus[7]	0.80	0.80	0.80	0.80

C+ = Control diet with antibiotic diet.
DPP= Dehydrated Porcine Plasma diet.
PPC= Potato Protein Concentrate diet.
DPP+PPC= Dehydrated Porcine Plasma+ Potato Protein Concentrate diet.
[1]AP920 Porcine Animal Plasma, APC.
[2]Protamyl™ PF, Avebe.
[3]Linco Spectin premix: 2.2 g lyncomicine, 2.2 g spectinomicine (Zoetis, USA).
[4]Mineral premix furnished by kg: Cu 14.4 mg; I 0.96 mg; Fe 120 mg; Mn 39 mg; Se 0.3 mg; Zn 144 mg; Co 0.72 mg.
[5]Vitamin premix furnished by kg: vitamin A 12,800 IU; vitamin D 2,400 IU; vitamin E 64 IU; vitamin K 3.2 mg; niacin 56 mg; pantothenic acid 40 mg; riboflavin 11.2 mg; vitamin B_{12} 4.8 µg; thiamine 3.2 mg; pyridoxine 4.8 mg; biotin 320 µg; folic acid 1.6 mg.
[6]Analysed values.
[7]Estimated values.

Table 2. The centesimal and chemical composition of the experimental diets (experiment 2)

Item	Experimental diets			
	C+	C–	DPP	PPC
Ingredients (%)				
maize	48.47	48.67	50.72	50.17
soybean meal	20.00	20.00	20.00	20.00
soy protein concentrate	11.84	11.84	5.40	6.23
dehydrated porcine plasma[1]	0.00	0.00	5.00	0.00
potato protein concentrate[2]	0.00	0.00	0.00	4.00
lactose	12.37	12.37	12.37	12.37
corn oil	2.80	2.80	2.23	2.44
HCl L-Lysine	0.44	0.44	0.46	0.85
L-Threonine	0.11	0.11	0.09	0.10
DL-Methionine	0.20	0.20	0.20	0.20
L-Tryptophan	0.01	0.01	0.01	0.02
salt	0.50	0.50	0.50	0.50
calcium carbonate	0.75	0.75	0.94	0.74
dicalcium phosphate	1.77	1.77	1.54	1.84
antibiotics[3]	0.20	0.00	0.00	0.00
bio choline	0.04	0.04	0.04	0.04
mineral premix[4]	0.12	0.12	0.12	0.12
vitamin premix[5]	0.08	0.08	0.08	0.08
titanium dioxide	0.30	0.30	0.30	0.30
Chemical composition				
dry matter[6] (%)	90.34	90.77	91.72	91.86
crude protein[6] (%)	20.95	20.96	20.33	20.38
metabolizable energy[7] (kcal/kg)	3200	3200	3200	3200
total lysine[7]	1.47	1.47	1.56	1.79
digestible lysine[7]	1.37	1.37	1.37	1.37
digestible sulphur amino acids[7]	0.75	0.75	0.75	0.75
digestible threonine[7]	0.81	0.81	0.81	0.81
digestible tryptophan[7]	0.23	0.23	0.23	0.23
calcium[7]	0.80	0.80	0.80	0.80
phosphorus[7]	0.70	0.70	0.70	0.70

C+ = Control diet with antibiotic diet.
DPP= Dehydrated Porcine Plasma diet.
PPC= Potato Protein Concentrate diet.
DPP+PPC= Dehydrated Porcine Plasma + Potato Protein Concentrate diet.
[1]AP920 Porcine Animal Plasma, APC.
[2]Protamyl™ PF, Avebe.
[3]Linco Spectin premix: 2.2 g lyncomicine, 2.2 g spectinomicine (Zoetis, USA).
[4]Minerals premix furnished by kg: Cu 14.4 mg; I 0.96 mg; Fe 120 mg; Mn 39 mg; Se 0.3 mg; Zn 144 mg; Co 0.72 mg.
[5]Vitamin premix furnishes by kg: vitamin A 12,800 IU; vitamin D 2,400 IU; vitamin E 64 IU; vitamin K 3.2 mg; niacin 56 mg; pantothenic acid 40 mg; riboflavin 11.2 mg; vitamin B_{12} 4.8 µg; thiamine 3.2 mg; pyridoxine 4.8 mg; biotin 320 µg; folic acid 1.6 mg.
[6]Analysed values.
[7]Estimated values.

Experiment 2 (Digestibility trial)

Twenty-four piglets weaned at 17±0.90 days of age and weighing 5.7±0.57 kg were used. The piglets were blocked by their initial weight, creating six blocks with four piglets each with similar weight. The blocks were distributed among the four experimental diet treatments (Table 2): positive control with antibiotics (C+); negative control without antibiotics (C–); dehydrated porcine plasma without antibiotics (DPP) and potato protein concentrate without antibiotics (PPC). We added 3 g/kg titanium oxide to the diets as a digestibility marker. The piglets were housed in metabolic cages (0.60 m × 0.72 m × 0.45 m), raised to 0.70 m from the floor. The cages were provided with a feeder, a nipple drinker, and trays for the collection of faeces and urine separately. Lateral divisions allowed the piglets to have eye contact to reduce the stress. The cages were in a room with controlled temperature (30±2°C). Between the age of 17 and 20 days, the piglets were taught to drink water and consume solid feed using a milk/starch mixture (80% dehydrated milk and 20% corn starch). At day 21, a "T" cannula was fitted at the terminal ileum (Reis de Souza et al., 2000). The day after surgery, the piglets received 100% of the milk/starch mixture (M). The experimental diets (D) in Table 2 and M were combined from the second to the fourth day post-surgery, and they were offered in the following proportions: day 2, 25% D/75% M; day 3, 50% D/50% M; day 4, 75% D/25% M. From day 5 onwards, the piglets consumed 100% of the experimental diet fed to piglets at 30 g/kg of BW. On days 21 and 22 post-weaning, faeces were collected directly from the mesh located under each cage at 8:00 h. Faeces were deposited in previously labelled bags and frozen at –20°C. At the end of the experimental period, faeces were homogenised, dried in a forced air oven at 60°C for 48 h, and ground using a 1 mm sieve. Ileal collection began at 9:00 h on the 22nd and 23rd post-weaning days and lasted 8 h each day. Ileal digesta were collected in 10 cm × 15 cm plastic bags that were fixed with rubber to the cannula. These bags contained 2 mL of 0.2 N HCl, to stop all enzymatic and fermentative activity, and were changed when they were filled. Ileal digesta of each animal were deposited in a container, frozen at –20°C, lyophilised, and ground using a 1 mm sieve. The content of dry matter and crude protein (AOAC, 2002), titanium (Myers et al., 2004), and gross energy measured by calorimetry (Bateman, 1970) in diets, ileal digesta, and faeces were determined to estimate the coefficients of dry matter apparent ileal digestibility (DMAID) and crude protein apparent ileal digestibility (CPAID); and dry matter apparent total tract digestibility (DMATTD), crude protein apparent total tract digestibility (CPATTD) and gross energy apparent total tract digestibility (EATTD) (Reis de Souza et al., 2001).

The results were analysed using the General Linear Model procedure of the statistical package SAS (2008). Means were compared using the Student-Newman-Keuls test (Steel and Torrie, 1980).

Results

Growth performance, and incidence and severity of diarrhoea

In the first week after weaning, a diet effect ($P<0.001$) on ADFI was observed (Table 3). DPP was the most consumed diet. C+ diet had an intermediate ADFI, and the PPC and DPP+PPC diets had lower ADFI values, which were similar to that of the C+ diet. In this week, the ADG and FE did not vary (P>0.05) among treatments (Table 3).

Table 3. Effect of dietary protein source on piglet performance (experiment 1)

Growth performance	Experimental diets				P-value	SEM
	C+	DPP	PPC	DPP+PPC		
Body weight						
initial (g)	6.847	6.849	6.851	6.868	P>0.05	196
final (g)	8.744	8.737	8.585	8.612	P>0.05	264
First week						
ADFI (g)	116 ab	132 a	92 b	102 b	P<0.001	3.16
ADG (g)	26	30	–5	2	P>0.05	7.25
FE	0.22	0.23	-0.05	0.01	P>0.05	0.07
Second week						
ADFI (g)	338	358	328	337	P>0.05	7.71
ADG (g)	254	227	253	249	P>0.05	10.19
FE	0.75	0.63	0.77	0.74	P>0.05	0.03
Total period						
ADFI (g)	226	245	210	220	P>0.05	4.36
ADG (g)	140	129	123	126	P>0.05	5.45
FE	0.62	0.52	0.59	0.58	P>0.05	0.03

C+ = Control diet with antibiotic diet.
DPP= Dehydrated Porcine Plasma diet.
PPC= Potato Protein Concentrate diet.
DPP+PPC= Dehydrated Porcine Plasma + Potato Protein Concentrate diet.
SEM: standard error of the mean.
a, b – means in the same row with different letters differ (P<0.001).

In the second week after weaning and during the total period, ADFI, ADG and FE were similar (P>0.05) among animals fed with different diets (Table 3). No effects of the protein source or the use of antibiotics in the diet were evident. However, there was an increase in ADFI and ADG, and consequently, on FE during the second week after weaning in relation to the first week after weaning. During the total experimental period (14 days), diets without antibiotics, regardless of the protein source, had a similar effect on performance as that of the diet with antibiotics (P>0.05) (Table 3).

Incidence and severity of diarrhoea

During the first week after weaning, diarrhoea incidence was lower (P<0.05) in piglets fed the diet with antibiotics (C+), than in animals fed the other diets (Table 4). Piglets fed C+ had the lower (P<0.05) severity index, and piglets fed the diet containing both protein sources (DPP+PPC) had the higher value. Piglets fed DPP, and PPC diets had a similar index to both groups. At the second week post-weaning, diarrhoea incidence was affected (P<0.01) by diets. Those fed C+ had reduced diarrhoea compared to piglets fed other diets (i.e., DPP, PPC, and DPP+PPC). The diarrhoea severity index was lower (P<0.05) in piglets fed C+ than that observed in piglets fed DPP and DPP+PPC diets. Piglets fed PPC diet had a similar diarrhoea severity index to both groups (Table 4).

Table 4. Effect of dietary protein source on incidence and severity of diarrhoea (experiment 1)

Diarrhoea score	Experimental diets				P-value	SEM
	C+	DPP	PPC	DPP+PPC		
Week 1						
ID (days)	0.5 b	2.5 a	2.3 a	2.8 a	P<0.05	0.25
ISD	0.1 b	0.5 ab	0.6 ab	0.8 a	P<0.05	0.08
Week 2						
ID (days)	0.8 d	6.3 c	4.5 c	4.8 c	P<0.01	0.45
ISD	0.1 b	1.4 a	0.8 ab	1.1 a	P<0.05	0.14

C+ = Control diet with antibiotic diet.
DPP= Dehydrated Porcine Plasma diet.
PPC= Potato Protein Concentrate diet.
DPP+PPC= Dehydrated Porcine Plasma + Potato Protein Concentrate diet.
SEM: standard error of the mean.
a, b – means in the same row with different letters differ (P<0.05).
c, d – means in the same row with different letters differ (P<0.01).

Nutrient digestibility

DMAID did not differ between treatments. However, the CPAID was higher (P<0.001) in piglets fed with the C+ and PPC diets than that in piglets fed with C– and DPP diets. DMATD and EATD were higher (P<0.01) in piglets fed with PPC diet than in those fed other diets (i.e., C+, C–, and DPP) (Table 5). There was a tendency (P=0.06) that diets with DPP and PPC had a similar CPATD as that of diet with antibiotics (C+) and higher than that of the C– diet (Table 5).

Table 5. Effect of dietary protein source on nutrient digestibility (experiment 2)

Item (%)	Experimental diets				P-value	SEM
	C+	C–	DPP	PPC		
DMAID	70.2	70.3	69.0	71.4	P>0.05	0.42
CPAID	78.4 a	72.5 b	71.3 b	77.8 a	P<0.001	0.41
DMATTD	82.1 d	81.0 d	82.9 d	86.1 c	P<0.01	0.37
EATTD	82.5 d	80.6 d	83.6 d	86.9 c	P<0.01	0.38
CPATTD	78.7 f	75.9 e	79.6 f	81.7 f	P<0.06	0.58

C+ = Control diet with antibiotic.
C– = Control diet without antibiotic.
DPP= Dehydrated Porcine Plasma diet.
PPC= Potato Protein Concentrate diet.
SEM: standard error of the mean.
a, b – means in the same row with different letters differ (P<0.001).
c, d – means in the same row with different letters differ (P<0.01).
e, f – means in the same row with different letters differ (P<0.06).

Discussion

Growth performance and diarrhoea incidence

The development of piglets in the post-weaning phase can be used as an indicator of their health and comfort status (Tao et al., 2016), as body weight loss after weaning is a consequence of the stress to which the animal is exposed, particularly during the first week after weaning, owing to the physiological and immunological changes they undergo (Campbell et al., 2013). Tao et al. (2016) observed that body weight gain decreases mainly on day four after weaning, recovering gradually by day seven after weaning. The reduction in body weight was attributed mainly to the low feed intake after weaning, which provokes a period of temporary undernutrition (Bruininx et al., 2001; Campbell et al., 2013). The change from milk to a solid diet based on starch and vegetable proteins causes the gastrointestinal tract to undergo adaptation because it is not prepared to digest these nutrients. This situation produces morphological and functional changes that can cause disorders in feed intake and alterations in the digestive process, preventing the animal from achieving its protein and energy requirements. This leads to an initial reduction in body weight, which is then followed by low daily weight gain and consequently a delay in growth (Reis de Souza et al., 2012). In the present study, during the first week after weaning, piglets fed PPC showed reduced feed intake and consequently loss in body weight. Some authors (Kerr et al., 1998) report that the presence of steroid glycol-alkaloids in potato protein could cause a bitter taste, mainly resulting from α-chaconin and small amounts of α-solanin (Vlachojannis et al., 2010). This could explain the low feed intake of pigs fed the PPC diet in the first week after weaning, when piglets are more sensitive to the change from milk to solid feed. Piglets subjected to the remaining treatments had very poor ADG, even those fed the control diet with antibiotics, which had an intermediate feed intake, and those fed the diet with DPP, an ingredient that promoted higher feed intake, mainly in the first week after weaning (Pérez-Bosque et al., 2016; Dong and Pluske, 2007). In mice (Thomson et al., 1995) and piglets (Pierce et al., 2005), higher feed intake has been reported during the first week after weaning in animals fed porcine plasma diets. The highest ADFI of piglets fed the DPP diet resulted numerically in higher ADG and FE in that week. The effect of porcine plasma on feed intake supports the hypothesis of Torrallardona (2010) that the addition of porcine plasma to diets improves its taste and feed efficiency, especially when the feed is not medicated. Torrallardona and Solà-Oriol (2009) evaluated the preference of pigs for different protein sources and observed that pigs had a significantly lower preference for potato protein than for DPP. Nevertheless, the growth performance results obtained by Kerr et al. (1998) suggest that low-glycoalkaloid potato protein can be an effective replacement for a portion of the spray-dried animal plasma in diets for weanling pigs. According to Campbell et al. (2013), even if feeding and management conditions are improved in the first week after weaning, it is impossible to eliminate the adverse physiological effects of weaning. However, piglets must adapt to all weaning stressors quickly to be productive and efficient. The extent and duration of feed intake depression in the post-weaning stage are variable, but the complete recovery of the pre-weaning metabolizable energy intake level takes approximately two weeks after weaning (Le Dividich and Sève, 2000). In the present study, during the second week after weaning, it was observed that the animals increased their feed intake and their weight gain in relation to the first week after weaning, regardless of protein source or antibiotic inclusion. The main effects associated with the inclusion of antimicrobial additives, such as antibiotics, in diets for piglets are the prevention of digestive disorders, better feed utilization, and better performance (Close, 2000). In the present study, piglets fed the positive control diet with antibiotics had acceptable performance, but not necessarily better than that of animals subjected to the other treatments. The incorporation of PPC and DPP reduced post-weaning nutritional stressors in a manner comparable to that effected by antibiotics, most likely owing to their antimicrobial properties (Jin et al., 2008 a, b; Jin et al., 2009; Ohh et al., 2009). Porcine plasma maintains the integrity of the intestinal barrier and decreases the production of inflammatory cytokines (Pérez-Bosque et al., 2016); potato protein contains a Snakin-1 antimicrobial peptide (Almasia et al., 2017).

Post-weaning diarrhoea (PWD) is typically present during the first two weeks after weaning (Escobar et al., 2014). Pluske (2013) reviewing about PWD mentioned that the gastrointestinal tract of piglets at weaning endures rapid changes that produce alterations in digestion, absorption, and their barrier function. These changes could be divided into an acute phase, lasting 5–7 days after weaning, and an adaptive phase that occurs after this. For piglets to attain a similar dry matter intake observed before weaning they use around 7–14 days. During the first week after weaning (acute phase), the low feed intake affects the barrier function disrupting the structure of tight junctions increasing mucosal permeability and causing diarrhoea (Shi et al., 2018; Spreeuwenberg et al., 2001). During the second post-weaning week, the feed intake increases and that could explain the increment on diarrhoea incidence and severity index as reported previously (Escobar et al., 2014; Pluske, 2013). The surplus of substrate at intestinal lumen due to higher feed intake increases the presence of fermentable substrates (mainly protein) promoting the growth of pathogenic bacteria, and consequently toxic metabolites, which can produce diarrhoea (Escobar et al., 2014; Wu et al., 2015).

Nutrient digestibility

Morphological and functional changes in the gastrointestinal tract of piglets have been reported to occur during the process of adaptation to solid diets in the post-weaning period. These changes have led to a considerable interest in the development of management and feeding strategies to stimulate bowel development and health in recently weaned piglets (de Lange et al., 2010). In the present study, the antibiotics added to the diet improved the total tract digestibility of nutrients in weaned pigs, which is in line with the results reported previously (Hu et al., 2008; Jin et al., 2008 a, b; Choi et al., 2011; Yoon et al., 2012, 2013). However, our results also showed that ileal digestibility increases with the use of an antibiotic. This is probably due to the lower thickness and epithelial cell turnover of the small intestine, which allow increased absorption in response to reduced growth and metabolic activities of gut microbiota and its harmful effect on the intestinal morphology (Jin et al., 2008 a, b; Choi et al., 2011).

Antimicrobial peptides obtained from potato proteins can prevent the development of antimicrobial resistance, conferring protection via alternative mechanisms, such as the maintenance of intestinal homeostasis and modulation of the host inflammatory response (Wang et al., 2016). Previous studies have reported the positive effects of the antimicrobial peptides on the performance of weaned piglets (Jin et al., 2009; Yoon et al., 2012, 2013). The improvement in the total apparent digestibility by antimicrobial peptides supplemented in piglets' diets could be due to three factors: 1) modulation of the intestinal environment; 2) improvement of the intestinal microbial balance, and 3) stimulation of the mucosal immune system (Wang et al., 2007; Jin et al., 2008 a, b; Tang et al., 2009). Jin et al. (2008 b) reported a higher nutrient digestibility of dry matter and crude protein in piglets fed diets supplemented with peptides derived from potato proteins. Jin et al. (2009) observed a similar apparent faecal digestibility of dry matter and crude protein and apparent ileal digestibility of amino acids among pigs fed antibiotic and refined potato protein diets. The growth promoting action of these peptides is related to the improvement in nutrient digestibility and intestinal health (Wang et al., 2016). In the present study, the total tract digestibility of the PPC diet exceeded that of the diet with antibiotics (C+); however, at the ileal level, the effects were similar for dry matter and crude protein among PPC and C+ diets. The present results are in line with those of Tuśnio et al. (2011), who reported that PPC is well digested by young piglets.

Conclusion

The DPP and PPC can be included in antibiotic-free diets for weaned piglets, without negatively affecting their post-weaning performance, and faecal consistency. The presence of an antibiotic in the diet improves the apparent ileal digestibility of crude protein. The ileal crude protein digestibility of the PPC diet was comparable to that of the diet with antibiotics; while the total energy digestibility was higher. Use of PPC as a protein source is therefore recommended in diets for newly weaned piglets as a potential alternative to antibiotic growth promoters, and as a controller of post-weaning diarrhoea.

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