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EFFECTS OF INULIN AND A PROBIOTIC MIXTURE ON NUTRIENT DIGESTIBILITY AND NITROGEN BALANCE IN PIGLETS

EFEITO DA INULINA E DE PROBIÓTICOS SOBRE A DIGESTIBILIDADE DOS NUTRIENTES E BALANÇO DO NITROGÊNIO EM LEITÕES

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ADDITIONAL KEYWORDS

Bifidobacterium bifidum. Digestibility. Oligo-saccharides.

PALAVRAS CHAVE ADICIONAIS

Bifidobacterium bifidum. Digestibilidade. Oligo-ssacarídeos.

SUMMARY

This study aimed to evaluate different inulin and probiotic levels as supplement in diets for piglets on nutrient digestibility and nitrogen balance. Twenty four crossbred barrows (Pietrain x Landrace x Large White), with initial average weight of 18.00 ± 0.38 kg, were individually housed in metabolic cages. The experimental design was a completely randomized block, in a 2 x 3 factorial scheme (probiotic levels: 0.30 and 0.60 %; inulin levels: 0.00, 0.25 and 0.50 %), with four replications. The probiotic used was a mix of *Lactobacillus acidophilus*, *Streptococcus faecium* and *Bifidobacterium bifidum*. The inulin was the prebiotic used in this study, characterized as an indigestible carbohydrate formed by fructooligosaccharides. Inulin levels provided a quadratic effect ($p < 0.05$) on the digestibility coefficients of dry matter, organic matter and ether extract, and the better responses were obtained supplementing 0.194, 0.185 and 0.188 %. Quadratic effects were observed for the nitrogen excreted in feces, total nitrogen excretion, nitrogen efficiency use and nitrogen digestibility. The inulin levels of 0.194 and 0.216 %, in piglet diets, were the better for dry matter digestibility and total nitrogen excretion, respectively.

RESUMO

O objetivo deste trabalho foi avaliar o efeito de níveis de inulina e probióticos em rações para leitões sobre a digestibilidade dos nutrientes e balanço do nitrogênio. Foram utilizados 24 suínos mestiços (Pietrain x Landrace x Large White), machos castrados, com peso médio inicial de $18,00 \pm 0,38$ kg, alojados individualmente em gaiolas de metabolismo. O delineamento experimental utilizado foi o de blocos ao acaso em esquema fatorial 2 x 3, representado por dois níveis de probiótico (0,30 e 0,60 %) e três níveis de inulina (0,00; 0,25 e 0,50 %), com quatro repetições. O probiótico utilizado foi composto por *Lactobacillus acidophilus*, *Streptococcus faecium* e *Bifidobacterium bifidum*. A inulina foi o prebiótico utilizado, caracterizada como um carboidrato não digerível composto por frutoligosacarídeos. A inulina proporcionou efeito quadrático ($p < 0,05$) nos coeficientes de digestibilidade da matéria seca, matéria orgânica e extrato etéreo, e as melhores respostas foram obtidas com a suplementação de 0,194; 0,185 e 0,188 %. Efeitos quadráticos foram observados para o nitrogênio excretado nas fezes, excreção total de nitrogênio, eficiência de uso do nitrogênio e digestibilidade do nitrogênio. Os níveis de 0,194 e 0,216 % de inulina,

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na ração de leitões, foram os melhores para a digestibilidade da matéria seca e excreção total de nitrogênio, respectivamente.

INTRODUCTION

Alternative ingredients to substitute growth promoters in swine diets are studied and developed based on new concepts of food safety, such as prebiotics and probiotics that, when used together and with specificity, establishes the symbiotic concept and can be used in swine diets.

Probiotics are live cultures of organisms supplemented in pig diets that can beneficially affect the host animal by improving the microbial balance in the gut (Fuller, 1989), and may influence digestive process by increasing the population of beneficial microorganisms and activity of microbial enzymes, as well as improving nutrient digestibility and use.

Prebiotics are defined as a non-digestible food ingredient that beneficially affects the host by selectively stimulating the growth and/or activity of one or a limited number of bacteria in the colon (Gibson and Roberfroid, 1995). These compounds are indigestible oligosaccharides (Delzenne, 2003) not necessarily grouped by the structure, but according to their capacity to promote growth of certain beneficial bacteria (probiotics) in the gut (Kelly, 2008). Inulin is known as a prebiotic and consists of a mixture of fructan chains with a polymerizing degree varying from 2 to 60 (Roberfroid, 1993), is resistant to digestive enzymes, due to its glycoside β bonds (2 \rightarrow 1), and is believed to increase growth of beneficial bacteria (Zentek *et al.*, 2003).

The use of prebiotics, probiotics or its combination as a symbiotic is an alternative to replace growth promoters without impairing the swine performance (Chiquieri *et al.*, 2006). Using a symbiotic in diets for weaned piglets, Shim *et al.* (2005) reported an increased villous height in the small gut, which is an indicative of improved nutrient

absorption. Pierce *et al.* (2005) observed an improvement in gross energy digestibility in piglet diets containing 1.50 % of inulin and a low lactose level.

Prebiotics may also reduce the nitrogen excretion to the environment. Besides, Lynch *et al.* (2007) reported that supplementing inulin in piglet diets may favor the bifidobacteria growing in the cecum, increase fecal nitrogen content and reduce the nitrogen amount in urine.

Therefore, the prebiotic's effect on the nitrogen contained in the diet occurs due to fermentation in the large gut, which induces changes in urine nitrogen excreted as urea (Zervas and Zijlstra, 2002). According to Nahm (2003), the result is a decrease in ammonia emission during waste storage and field application.

This study aimed to evaluate the effects of inulin and probiotic on nutrient digestibility and nitrogen balance in piglets.

MATERIAL AND METHODS

This study was carried out in the metabolism room, situated in the experimental of the Universidade Estadual do Oeste do Paraná, Brazil. The experimental procedures were in agreement with the Animal Welfare Committee of this Institution.

Twenty four crossbred barrows (Pietráin x Landrace x Large White), averaging 18.00 ± 0.38 kg of initial weight, were individually allotted and distributed in a completely randomized blocks design, in a 2 x 3 factorial scheme (probiotic levels – 0.30 and 0.60 %; inulin levels – 0.00, 0.25 and 0.50 %), with four replicates.

The probiotic used was a mix of *Lactobacillus acidophilus*, *Streptococcus faecium* and *Bifidobacterium bifidum*. The inulin was the prebiotic used in this study, characterized as an indigestible carbohydrate formed by fructooligosaccharides.

Experimental diets (**table I**) were formulated to achieve the nutritional requirements proposed by Rostagno *et al.* (2005). Barrows

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Table I. Centesimal, chemical and energetic composition of experimental diets. (Composição centesimal, química e energética das rações experimentais).

Probiotic	0.00	0.30	0.50	0.00	0.60	0.50
Inulin	0.00	0.25	0.50	0.00	0.25	0.50
Corn	56.66	56.66	56.66	56.66	56.66	56.66
Soybean meal	21.00	21.00	21.00	21.00	21.00	21.00
Dried whey	6.00	6.00	6.00	6.00	6.00	6.00
Fish meal	4.00	4.00	4.00	4.00	4.00	4.00
Corn gluten meal	3.00	3.00	3.00	3.00	3.00	3.00
Soybean oil	2.70	2.70	2.70	2.70	2.70	2.70
Sugar	2.00	2.00	2.00	2.00	2.00	2.00
Common salt	0.34	0.34	0.34	0.34	0.34	0.34
Limestone	0.31	0.31	0.31	0.31	0.31	0.31
Dicalcium phosphate	1.44	1.44	1.44	1.44	1.44	1.44
Choline chloride	0.20	0.20	0.20	0.20	0.20	0.20
L-lysine hydrochloride	0.52	0.52	0.52	0.52	0.52	0.52
DL-methionine	0.17	0.17	0.17	0.17	0.17	0.17
L-threonine	0.23	0.23	0.23	0.23	0.23	0.23
L-tryptophan	0.05	0.05	0.05	0.05	0.05	0.05
Antioxidant ¹	0.01	0.01	0.01	0.01	0.01	0.01
Organic acids ²	0.10	0.10	0.10	0.10	0.10	0.10
Vitamin supplement ³	0.12	0.12	0.12	0.12	0.12	0.12
Mineral supplement ⁴	0.05	0.05	0.05	0.05	0.05	0.05
Probiotic ⁵	0.20	0.20	0.20	0.40	0.40	0.40
Bifidobacteria ⁶	0.10	0.10	0.10	0.20	0.20	0.20
Inulin ⁷	0.00	0.25	0.50	0.00	0.25	0.50
Inert	0.80	0.55	0.30	0.50	0.25	0.00
Total	100.00	100.00	100.00	100.00	100.00	100.00
Calculated composition						
Metabolizable energy (kcal kg ⁻¹)	3,325	3,325	3,325	3,325	3,325	3,325
Crude protein (%)	19.67	19.67	19.67	19.67	19.67	19.67
Calcium (%)	0.83	0.83	0.83	0.83	0.83	0.83
Available phosphorus (%)	0.45	0.45	0.45	0.45	0.45	0.45
Sodium (%)	0.23	0.23	0.23	0.23	0.23	0.23
Potassium (%)	0.73	0.73	0.73	0.73	0.73	0.73
Chlorine (%)	0.37	0.37	0.37	0.37	0.37	0.37
Digestible lysine (%)	1.33	1.33	1.33	1.33	1.33	1.33
Digestible methionine + cystine (%)	0.75	0.75	0.75	0.75	0.75	0.75
Digestible methionine (%)	0.47	0.47	0.47	0.47	0.47	0.47
Digestible threonine (%)	0.85	0.85	0.85	0.85	0.85	0.85
Digestible tryptophan (%)	0.23	0.23	0.23	0.23	0.23	0.23

¹BHT; ²Propionic, formic and lactic acids; ³Vitamin A (8 000 000 IU); Vitamin D3 (1 200 000 IU); Vitamin E (20 000 mg); Vitamin K3 (2500 mg); Thiamine (1000 mg); Riboflavine (4000 mg); Vitamin B12 (20 mg), Niacin (25 000 mg); Pantothenic acid (10 000 mg); Biotin (50 g); Folic acid (600 mg); Vitamin C (50 000 mg), Antioxidant (125 mg); ⁴Zinc (80 000 mg); Fe (70 000 mg); Mn (40 000 mg); Cu (20 000 mg); I (800 mg); Co (500 mg); Se (500 mg), QSAD vehicle (1000 g); ⁵*Lactobacillus acidophilus*, *Streptococcus faecium*; ⁶*Bifidobacterium bifidum*; ⁷Inulin (96 %).

were fed twice a day (06 a.m. and 06 p.m.) and after each meal the water was freely offered. The individual feed intake was based on the metabolic weight ($BW^{0.75}$), established during the adjustment period.

The metabolism assay used a seven day adjustment period, followed by a five day period of total collection of feces and urine. Barrows were housed in stainless-steel metabolism cages (Pekas, 1968), equipped with feeders and compartments which allowed separated collection of feces and urine.

Ferric oxide (Fe_2O_3) was used to indicate the beginning and the end of fecal collection period. Feces were collected twice a day, placed into plastic bags and stored ($-18^{\circ}C$). Urine was collected continuously over the 5-day collection period into a plastic recipient, containing 20 mL of 1:1 chloridic acid (HCl), and a 5 % aliquot was placed into glass containers, identified and stored ($3^{\circ}C$).

Prior to laboratory analysis feces were thawed, mixed, dried ($55^{\circ}C$) and ground through a 1 mm screen. Dry matter (DM), nitrogen (N), ether extract (EE) and mineral matter (MM) were analysed in diets and feces, and N were determined in urine, as described by Silva and Queiroz (2002).

The coefficients of apparent digestibility of dry matter (DCDM), ether extract (DCEE), mineral matter (DCMM) and organic matter (DCOM) were determined according to Matterson *et al.* (1965). Nitrogen intake and total N excretion were determined to obtain the N balance.

Data was submitted to variance analysis through the statistical software SAEG-System for Statistical and Genetic Analyses, developed by the Federal University of Viçosa (UFV, 1999). Data was analyzed in a factorial scheme (probiotic x inulin), and were applied the regression procedures in case of significance.

RESULTS AND DISCUSSION

Significant interactions (inulin x probiotic) were not observed ($p>0.05$) for nutrient digestibility (table II). The probiotic

Table II. Apparent digestibility in diets for piglets supplemented with inulin and probiotics. (Digestibilidade de rações para leitões contendo inulina e probióticos).

Probiotic	Levels						Means						CV (%)	Prob	p Inu	p x I
	0	0.25	0.5	0.75	1.0	1.25	0.25	0.5	0.75	1.0	1.25	1.5				
Inulin	86.7	87.8	84.9	86.8	87.8	85.4	86.5	86.7	86.8	87.8	85.2	2.29	NS	0.044	NS	NS
DCDM	79.2	80.2	77.5	80.3	80.6	78.0	79.0	79.6	79.8	80.4	77.8	-	-	-	-	-
DIGDM	88.7	89.6	86.4	88.5	89.3	86.9	88.2	88.2	88.6	89.5	86.7	2.09	NS	0.021	NS	NS
DCOM	75.5	76.8	73.7	75.9	77.1	74.9	75.3	76.0	75.7	77.0	74.3	-	-	-	-	-
DIGOM	45.8	48.7	46.0	46.2	51.1	48.3	46.8	48.6	46.0	49.9	47.2	7.46	NS	NS	NS	NS
DCMM	2.0	2.5	2.4	2.4	2.6	2.5	2.3	2.5	2.2	2.6	2.5	-	-	-	-	-
DIGMM	82.7	86.5	77.3	80.9	82.2	76.1	82.1	79.7	81.8	84.4	76.7	4.11	NS	0.001	NS	NS
DCEE	4.9	5.2	4.6	5.0	4.9	4.6	4.9	4.8	5.0	5.1	4.6	-	-	-	-	-
DIGEE																

NS: non significant; DC= digestibility coefficient; DIG= digestible; DM= dry matter; OM= organic matter; MM= mineral matter; EE= ether extract.

studied did not affected ($p>0.05$) the nutrient digestibility, but inulin levels provided a quadratic effect ($p<0.05$) on the digestibility coefficients of dry matter, organic matter and ether extract, and the better responses were obtained supplementing 0.194, 0.185 and 0.188 % of inulin (**figure 1**), respectively, because above these levels the digestibility coefficients decreased, and Hedemann *et al.* (2001) reported that a decrease in the nutrient digestibility is not desired in piglet diets.

Such enhancements in nutrient digestibility were previously observed in piglet diets with low-lactose supplemented with inulin (Pierce *et al.*, 2005). The decrease in digestibility coefficients, observed for the

high inulin levels (**figure 1**), may be related to a reduction in the number of goblet cells in the jejunum, as observed in weanling pigs fed diets with 0.40 % inulin (Mair *et al.*, 2010), and Pickler *et al.* (2012) reported that the glycoproteins produced by goblet cells participate in the nutrient absorption.

However, higher inulin levels could demonstrate good results, depending on the lactose level used in the experimental diets. Lynch *et al.* (2009) observed an increase in digestibility of dry matter, organic matter and mineral matter in piglet diets containing lactose (5.00 %) and inulin (1.50 %), but this response were not observed with high lactose level (23.00 %). On the other hand, Lynch *et al.* (2007) evaluating

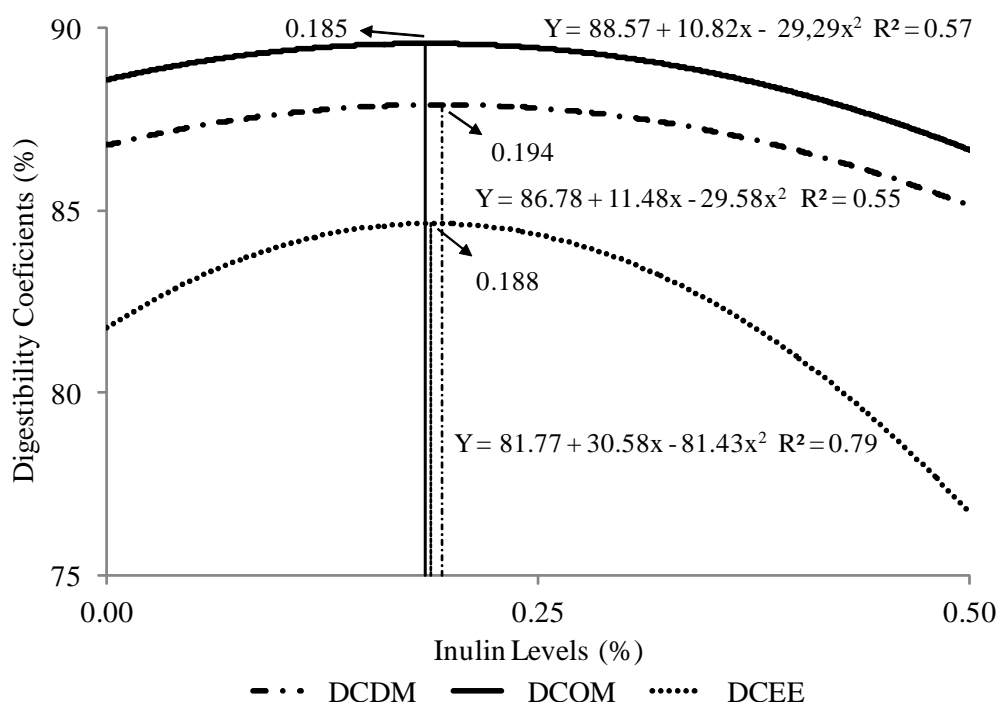


Figure 1. Digestibility coefficients of dry matter (DCDM), organic matter (DCOM) and ether extract (DCEE) affected by inulin levels in piglet diets. (Coeficientes de digestibilidade da matéria seca (DCDM), matéria orgânica (DCOM) e do extrato etéreo (DCEE) em função de níveis de inulina em rações para leitões).

diets with low and high levels of crude protein, supplemented with 0.00 and 1.25 % inulin, did not observe any effects of inulin in the digestibility of dry matter and organic matter for finishing pigs.

Evaluating the inclusion of *Enterococcus faecium* and inulin (2.00 %) in piglet diets Böhmer *et al.* (2005) reported a positive effect of inulin, and inulin with *E. faecium*, compared to the control diet and containing just *E. faecium*.

For the nitrogen balance there were no significant ($p>0.05$) interactive effects of inulin and probiotic (**table III**). The nitrogen intake was similar for the evaluated treatments because experimental diets were isonitrogenous and animals were fed based on metabolic weight ($BW^{0.75}$).

The probiotic used did not affect ($p>0.05$) the nitrogen balance variables, but a quadratic effect ($p<0.01$) was observed for the nitrogen excreted in feces (**figure 2**). According to Vanhoof and De Schrijver (1996), increased nitrogen excretion may be resulted from higher microbial activity in the large intestine and thus higher nitrogen incorporation in microbial protein excreted in feces. Hansen *et al.* (2010) observed higher bacterial activity in the upper colon in pigs fed a diet with 8.00 % inulin. *In vitro* studies to evaluate different indigestible carbohydrates, and bacterial isolates, demonstrated that inulin and starch increased bacterial nitrogen fixing, compared to cellulose, xylan and pectin (Bindelle *et al.*, 2007a; 2007b).

In the current study, the increase in inulin levels, higher than 0.170 %, increased the nitrogen excreted in feces. This inulin level is lower than 1.25 % used by Lynch *et al.* (2007) which observed higher amounts of nitrogen in swine feces when the animals were supplemented with 1.25 % inulin in the diet. However the nitrogen excreted in urine was not affected by the inulin levels. In the same way, Halas *et al.* (2010a) observed an increase in fecal nitrogen, but the urine nitrogen decreased in weanling pigs that

Table III. Nitrogen balance in piglets submitted to diets with containing inulin and probiotics. (Balanço de nitrogênio em leitões submetidos à dietas contendo inulina e probióticos).

Probiotic Inulin	Levels					Means					CV (%)	Prob	P Inu	p x l
	0	0.25	0.5	0	0.6	0.25	0.5	0.6	0.3	0.6				
NI (g/d)	55.0	55.0	54.1	56.3	58.9	58.9	54.5	54.7	54.7	56.6	55.7	NS	NS	NS
NEF (g/d)	4.4	4.1	5.6	4.5	4.2	4.2	5.5	4.7	4.7	4.7	4.5	NS	0.009	NS
NEUr (g/d)	9.1	9.1	10.1	9.7	6.5	6.5	9.3	9.4	9.4	8.5	9.4	NS	NS	NS
TNE (g/d)	13.5	13.2	15.7	14.2	10.7	10.7	14.8	14.1	14.1	13.2	13.9	NS	0.038	NS
NR (g/d)	41.5	41.8	38.4	42.1	48.2	48.2	39.8	40.6	40.6	43.4	41.8	NS	NS	NS
NEU (%)	75.5	76.4	70.1	75.6	81.7	81.7	72.4	74.0	74.0	76.6	75.6	NS	0.009	NS
ND (%)	91.9	92.4	89.7	91.8	92.8	92.8	89.7	91.3	91.3	91.4	91.9	NS	0.008	NS

NS: non significant; NI: nitrogen intake; NEF: nitrogen excreted in feces; NEUr: nitrogen excreted in urine; TNE: total nitrogen excretion; NR: nitrogen retention; NEU: nitrogen efficiency use; ND: nitrogen digestibility.

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received 4.00 or 8.00 % of inulin in diets, being a desired effect for the environment, since it decreases the ammonia emission due to fecal nitrogen be consisted primarily by bacterial protein, which is less susceptible to decomposition than the urea present in the urine, because urea is easily converted into ammonia and carbon dioxide by bacterial urease (Mroz *et al.*, 2000).

However, the levels of inulin used in these studies were higher than the ones used in the current research (0.00–0.50 %), and using a low-inulin level (0.40 %) in diets for growing pigs Loh *et al.* (2010) reported no effect on the nitrogen excretion, but the inulin tended to shift nitrogen excretion from urine to feces.

The inverse response obtained for

nitrogen excreted in feces and nitrogen digestibility (**figures 2 and 3**) also was found by Lynch *et al.* (2007) using more than 1.25 % inulin in diets for finishing pigs. Nevertheless, Lynch *et al.* (2009) observed an increased nitrogen digestibility in piglets supplemented with 1.50 % inulin in a diet containing 5.00 % lactose. According to these authors, inulin may increase the population of lactic bacterias, like bifido-bacteria. Their capacity to produce a wide variety of depolymerases and glycosidases, which acts over polysaccharides, may improve digestion. Even so, Vanhoof and De Schrijver (1996) and Halas *et al.* (2010b) did not report any differences on nitrogen digestibility after supplementing 6.00 and 8.00 % of inulin in piglet diets.

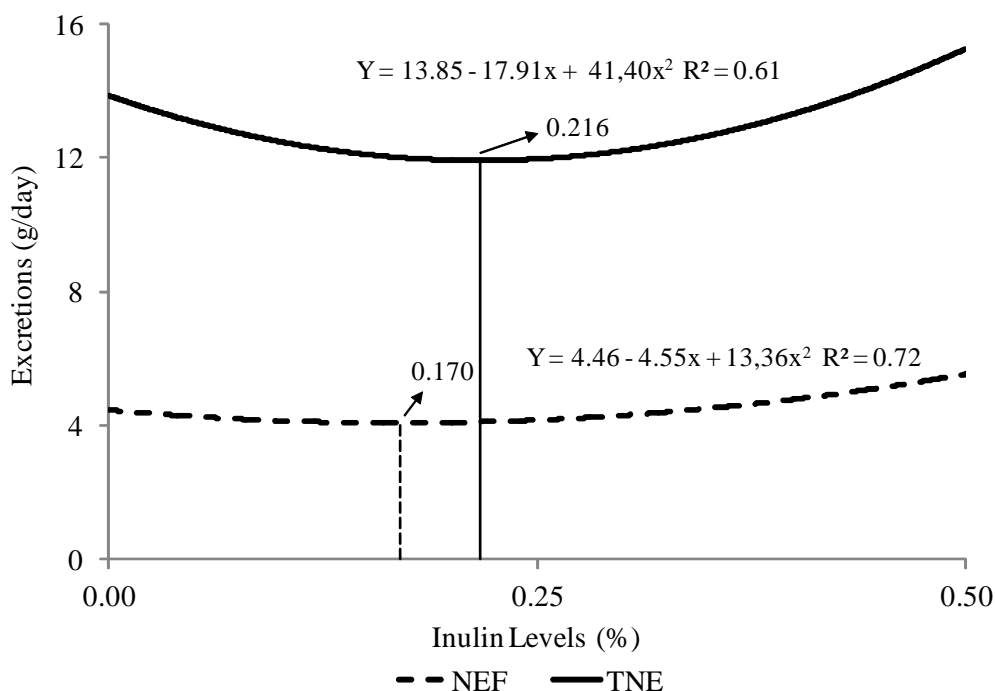


Figure 2. Effect of inulin levels in piglet diets on nitrogen excreted in feces (NEF) and total nitrogen excretion (TNE). (Efeito de níveis de inulina na ração sobre o nitrogênio excretado nas fezes (NEF) e excreção total de nitrogênio (TNE) em leitões).

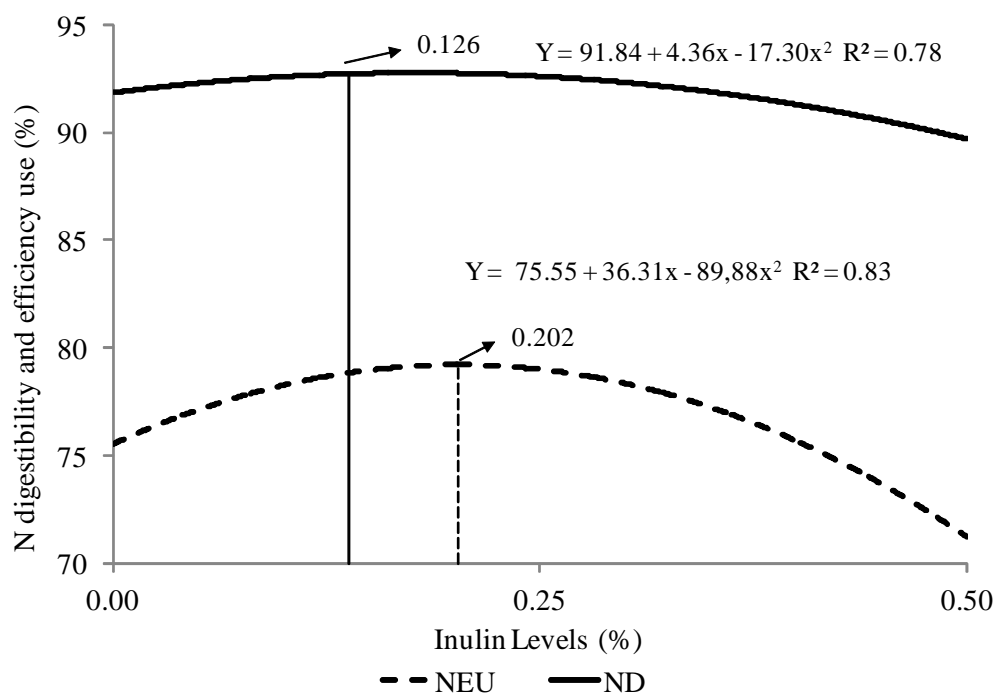


Figure 3. Effect of inulin levels in piglet diets on nitrogen efficiency use (NEU) and nitrogen digestibility (ND). (Efeito de níveis de inulina na ração sobre a eficiência de uso do nitrogênio (NEU) e digestibilidade do nitrogênio (ND) em leitões).

The results obtained for nitrogen excreted in feces, and urine, influenced the total nitrogen excretion ($p < 0.05$), showing the better excretion at a level of 0.216 % inulin (**figure 2**). Although total nitrogen excretion was affected by the inulin and nitrogen intake remained constant, there was no difference in nitrogen retention (**table III**). This effect was also evidenced by a quadratic effect observed for nitrogen efficiency use (**figure 3**), which is the percentage of nitrogen retained, showing that the supplementation of 0.202 % inulin provided the better efficiency, that is proximate of 0.216 % found for total nitrogen excretion. Lynch *et al.* (2007) and Vanhoof and De Schrijver (1996) did not obtain significant response for the efficiency of

nitrogen utilization according to inulin levels studied. Likewise, Mountzouris *et al.* (2006) evaluated two indigestible carbohydrates (oligofructose and transgalactoligosaccharides) as supplement in piglet and did not observe significant effects on the efficiency of nitrogen use.

CONCLUSIONS

The inulin levels of 0.194 and 0.216 %, in piglet diets, were the most effective for dry matter digestibility and total nitrogen excretion, respectively.

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REFERENCES

- Bindelle, J.; Buldgen, A.; Michaux, D.; Wavreille, J.; Destain, J.P. and Leterme, P. 2007a. Influence of purified dietary fibre on bacterial protein synthesis in the large intestine of pigs, as measured by the gas production technique. *Livest Sci*, 109: 232-235.
- Bindelle, J.; Buldgen, A.; Wavreille, J.; Agneessens, R.; Destain, J.P.; Wathelet, B. and Leterme, P. 2007b. The source of fermentable carbohydrates influences the *in vitro* protein synthesis by colonic bacteria isolated from pigs. *Animal*, 1: 1126-1133.
- Böhmer, B.M.; Branner, G.R. and Roth-Maier, D.A. 2005. Precaecal and faecal digestibility of inulin (DP 10-12) or an inulin/*Enterococcus faecium* mix and effects on nutrient digestibility and microbial gut flora. *J Anim Physiol An N*, 89: 388-396.
- Chiquieri, J.M.S.; Soares, R.T.R.N.; Souza, J.C.D.; Hurtado Nery, V.L.; Ferreira, R.A. y Ventura, B.G. 2006. Probiótico y prebiótico en la alimentación de cerdos en crecimiento y terminación. *Arch Zootec*, 55: 305-308.
- Delzenne, N.M. 2003. Oligosaccharides: state of the art. *P Nutr Soc*, 62: 177-182.
- Fuller, R. 1989. Probiotics in man and animals - A Review. *J Appl Bacteriol*, 66: 365-378.
- Gibson, G.R. and Roberfroid, M.B. 1995. Dietary modulation of the human colonic microbiota: introducing the concept of prebiotics. *J Nutr*, 125: 1401-1412.
- Halas, D.; Hansen, C.F.; Hampson, D.J.; Kim, J.C.; Mullan, B.P.; Wilson, R.H. and Pluske, J.R. 2010a. Effects of benzoic acid and inulin on ammonia-nitrogen excretion, plasma urea levels, and the pH in feces and urine of weaner pigs. *Livest Sci*, 134: 243-245.
- Halas, D.; Hansen, C.F.; Hampson, D.J.; Mullan, B.P.; Kim, J.C.; Wilson, R.H. and Pluske, J.R. 2010b. Dietary supplementation with benzoic acid improves apparent ileal digestibility of total nitrogen and increases villous height and caecal microbial diversity in weaner pigs. *Anim Feed Sci Tech*, 160: 137-147.
- Hansen, C.F.; Phillips, N.D.; La, T.; Hernandez, A.; Mansfield, J.; Kim, J.C.; Mullan, B.P.; Hampson, D.J. and Pluske, J.R. 2010. Diets containing inulin but not lupins help to prevent swine dysentery in experimentally challenged pigs. *J Anim Sci*, 88: 3327-3336.
- Hedemann, M.S.; Pedersen, A.R. and Engberg, R.M. 2001. Exocrine pancreatic secretion is stimulated in piglets fed fish oil compared with those fed coconut oil or lard. *J Nutr*, 131: 3222-3226.
- Kelly, G. 2008. Inulin-type prebiotics - A review: Part 1. *Altern Med Rev*, 13: 315-329.
- Loh, T.C.; Wang, W.S. and Foo, H.L. 2010. Effects of dietary protein and inulin on growth and nitrogen balance in growing pigs. *J Appl Anim Res*, 38: 55-59.
- Lynch, B.; Callan, J.J. and O'Doherty, J.V. 2009. The interaction between dietary crude protein and fermentable carbohydrate source on piglet post weaning performance, diet digestibility and selected faecal microbial populations and volatile fatty acid concentration. *Livest Sci*, 124: 93-100.
- Lynch, M.B.; Sweeney, T.; Callan, J.J.; Flynn, B. and O'Doherty, J.V. 2007. The effect of high and low dietary crude protein and inulin supplementation on nutrient digestibility, nitrogen excretion, intestinal microflora and manure ammonia emissions from finisher pigs. *Animal*, 8: 1112-1121.
- Mair, C.; Plitsner, C.; Pfaffl, M.W.; Schedle, K.; Meyer, H.H.D. and Windisch, W. 2010. Inulin and probiotics in newly weaned piglets: effects on intestinal morphology, mRNA expression levels of inflammatory marker genes and haematology. *Arch Anim Nutr*, 64: 304-321.
- Matterson, L.D.; Potter, L.M. and Stutz, M.W. 1965. The metabolizable energy of feed ingredient for chickens: research report. University of Connecticut. Storrs. Connecticut. 11 pp.
- Mountzouris, K.C.; Xypoleas, I.; Kouseris, I. and Fegeros, K. 2006. Nutrient digestibility, faecal physicochemical characteristics and bacterial glycolytic activity of growing pigs fed a diet supplemented with oligofructose or trans-galactooligosaccharides. *Livest Sci*, 105: 168-175.
- Mroz, Z.; Moeser, A.J.; Vreman, K.; Van Diepen, J.T.M.; Van Kempen, T.; Canh, T.T. and Jongbloed, A.W. 2000. Effects of dietary carbohydrates and buffering capacity on nutrient digestibility and manure characteristics

- in finishing pigs. *J Anim Sci*, 78: 3096-3106.
- Nahm, K.H. 2003. Influences of fermentable carbohydrates on shifting nitrogen excretion and reducing ammonia emission of pigs. *Crit Rev Env Sci Tec*, 30: 135-186.
- Pekas, J.C. 1968. Versatile swine laboratory apparatus for physiologic and metabolic studies. *J Anim Sci*, 27: 1303-1306.
- Pickler, L.; Hayashi, R.M.; Lourenço, M.C.; Miglino, L.B.; Caron, L.F.; Beirão, B.C.B.; Silva, A.V.F. e Santin, E. 2012. Avaliação microbiológica, histológica e imunológica de frangos de corte desafiados com *Salmonella enteritidis* e Minnesota e tratados com ácidos orgânicos. *Pesquisa Vet Brasil*, 32: 27-36.
- Pierce, K.M.; Callan, J.J.; McCarthy, P. and O'Doherty, J.V. 2005. Performance of weanling pigs offered low or high lactose diets supplemented with avilamycin or inulin. *Anim Sci*, 80: 313-318.
- Roberfroid, M. 1993. Dietary fibre, inulin and oligofructose: a review comparing their physiological effects. *Crit Rev Food Sci*, 33: 103-148.
- Rostagno, H.S.; Albino, L.F.T.; Donzele, J.L.; Gomes, P.C.; Oliveira, R.F. de; Lopes, D.C.; Ferreira, A.S. e Barreto, S.L.T. 2005. Composição de alimentos e exigências nutricionais. Tabelas brasileiras para aves e suínos. 2ª ed. Editora UFV. Viçosa. 186 pp.
- Shim, S.B.; Verstegen, M.W.A.; Kim, I.H.; Kwon, O.S. and Verdonk, J.M.A.J. 2005. Effects of feeding antibiotic-free creep feed supplemented with oligofructose, probiotics or synbiotics to suckling piglets increases the preweaning weight gain and composition of intestinal microbiota. *Arch Anim Nutr*, 59: 419-427.
- Silva, D.J. and Queiroz, A.C. 2002. Análise de alimentos: métodos químicos e biológicos. 3ª ed. Editora UFV. Viçosa. 235 pp.
- UFV. 1999. Universidade Federal de Viçosa. Manual de utilização do programa SAEG (Sistema para análises estatísticas e genéticas). Editora UFV. Viçosa. 59 pp.
- Vanhoof, K. and De Schrijver, R. 1996. Nitrogen metabolism in rats and pigs fed inulin. *Nutr Res*, 16: 1035-1039.
- Zentek, J.; Marquart, B.; Pietrzak, T.; Ballevre, O. and Rochat, F. 2003. Dietary effects on *Bifidobacteria* and *Clostridium perfringens* in the canine intestinal tract. *J Anim Physiol An N*, 87: 397-407.
- Zervas, S. and Zijlstra, R.T. 2002. Effects of dietary protein and fermentable fiber on nitrogen excretion patterns and plasma urea in grower pigs. *J Anim Sci*, 80: 3247-3256.