http://dx.doi.org/10.1590/1678-4162-8501

Arq. Bras. Med. Vet. Zootec., v.68, n.4, p.1015-1022, 2016

Organic acids in diets of weaned piglets: performance, digestibility and economical viability

[*Ácidos orgânicos em dietas para leitões desmamados: desempenho, digestibilidade e viabilidade econômica*]

A.D.C.V. *Boas*[1], F.E.L. *Budiño*[2*], M.A.T. *Neto*[3], A. *Schmidt*[1], J.C. *Dadalt*[3], R.P. *Monferdini*[1], N.Y. *Sitanaka*[1], J.E. *Moraes*[2], C.C. *Pizzolante*[2]

[1]Aluno de pós-graduação – Instituto de Zootecnia - Secretaria de Agricultura e Abastecimento do Estado de São Paulo - Nova Odessa, SP
[2]Instituto de Zootecnia - Secretaria de Agricultura e Abastecimento do Estado de São Paulo - Nova Odessa, SP
[3]Faculdade de Medicina Veterinária e Zootecnia - Universidade de São Paulo - São Paulo, SP

ABSTRACT

Organic acids are used as feed additives to promote growth of weaned piglets since they prevent the occurrence of diarrhea. Thus, performance and digestibility assays were conducted and economic viability of diets was evaluated. In the performance assays, 64 hybrid piglets weaned with a mean weight of 5.87±0.31kg were divided in a randomized block design consisting of 4 treatments, 8 repetitions and 2 piglets per experimental unit (1 castrated male and 1 female). In the digestibility assay, 24 castrated male hybrid piglets with a mean weight of 8.21±0.79kg were individually assigned to 4 treatments and 6 repetitions. The treatments in the two assays were as follows: control, basal diet without addition of an acidifier; blend: inclusion of 0.5% of a mixture of organic acids; butyrate: inclusion of 0.1% of sodium butyrate; blend+butyrate: inclusion of 0.5% of a mixture of organic acids and 0.1% sodium butyrate. There was no effect (P>0.05) of the acidifiers on animal performance during the period studied. Organic acids exerted no effect (P>0.05) on the apparent digestibility coefficients of nutrients. Diets supplemented with sodium butyrate had an economic advantage for the period of 10-24 days. No episode of diarrhea was observed. This study demonstrated no effect of acidifier feed additives as growth promoters in complex diets for weaned piglets.

Keywords: acidifiers, additives, digestibility, performance, pigs

RESUMO

Ácidos orgânicos são utilizados como aditivos promotores de desempenho em leitões, pois podem prevenir a ocorrência de diarreias. Para tanto, foram conduzidos ensaios de desempenho, digestibilidade, e foi avaliada a viabilidade econômica das dietas. No desempenho, foram utilizados 64 leitões híbridos desmamados, com peso médio de 5,87±0,31kg, distribuídos em um delineamento em blocos ao acaso, com quatro tratamentos, oito repetições e dois leitões por unidade experimental (sendo um macho castrado e uma fêmea). Na digestibilidade, 24 leitões machos, castrados, híbridos, com peso médio de 8,21±0.79kg, foram alojados individualmente em quatro tratamentos e seis repetições. Em ambos os ensaios, os tratamentos foram: controle: dieta basal sem uso de acidificante; Blend: inclusão de 0,5% da mistura de ácidos orgânicos; butirato: inclusão de 0,1% de butirato de sódio; Blend+Butirato: inclusão de 0,5% da mistura de ácidos orgânicos e 0,1% butirato de sódio. Não houve efeito dos acidificantes (P>0,05) sobre o desempenho no período estudado. Não houve efeito dos ácidos orgânicos (P>0,05) sobre os coeficientes de digestibilidade aparente dos nutrientes. Dietas com suplementação de butirato de sódio apresentaram melhor vantagem econômica para o período de 10-24 dias. Não houve incidência de diarreia em nenhum período. Não ficou evidenciado o efeito dos aditivos acidificantes como promotores de crescimento em dietas complexas para leitões desmamados.

Palavras-chave: acidificantes, aditivos, digestibilidade, desempenho, suínos

Recebido em 09 de junho de 2015
Aceito em 15 de novembro de 2015
*Autor para correspondência (*corresponding author*)
E-mail: fbudino@iz.sp.gov.br

INTRODUCTION

The global production of pork has increased substantially in recent decades as a result of the growing demand for animal protein. In the end of 2014, the world production was 110,606 (1,000 MT), with China leading the market, followed by the European Union, United States, and Brazil (ABPA, 2015).

Piglets are commonly weaned between 21 and 28 days of age. However, this phase, as well as subsequent days, is a critical period for animal development because of the stress caused by separation from the mother, formation of new batches and changes in the type of food and diet composition, associated with immaturity of the digestive system and drastic changes in the intestinal physiology of piglets (Corassa *et al*., 2006; Silva *et al*., 2008; Kumer *et al*., 2009). The pH of the digestive tract of piglets is high at this stage and the production of hydrochloric acid and digestive enzymes is insufficient (Tsiloyiannis *et al*., 2001). Digestion is further compromised by the administration of complex diets with a high protein content (Chiquieri, 2009), a fact favoring the proliferation of pathogenic microorganisms and development of intestinal disorders (Viola and Vieira, 2007; Bocklor *et al*., 2007). All of these factors contribute to the occurrence of post-weaning diarrhea, which can lead to the death of the animal or significant weight loss during subsequent phases (Corassa *et al*., 2006; Sanches *et al*., 2006).

Previous studies suggest that the development of pathogens in recently weaned piglets can be controlled by the use of feed additives such as organic acids and their salts, especially during the first two weeks after weaning (Partanen and Mroz, 1999; Freitas *et al*., 2006; Bocklor *et al*., 2007). Despite different action mechanisms, short-chain organic acids such as formic, citric, lactic, acetic and propionic acid can reduce the growth of microorganisms by exerting a specific antimicrobial effect or by reducing gastric pH (Partanen and Mroz, 1999; Biagi *et al*., 2007). Moreover, these acids have multifunctional properties that can affect different performance parameters. For example, in addition to modulating the gastrointestinal microbiota, butyric acid or sodium butyrate is the preferential energy source for intestinal cells and plays an important regulatory function in cell proliferation, cell differentiation, and apoptosis inhibition (Biagi *et al*., 2007; Claus *et al*., 2008; Mazzoni *et al*., 2008; Machinsky *et al*., 2010).

However, the results of studies evaluating the effect of adding organic acids to weaned piglet diets are still controversial (Zentek *et al*., 2013). Some studies observed improvement in performance and diet digestibility, with a consequent reduction in gastrointestinal disorders (Chiquieri *et al*., 2009; Machinsky *et al*., 2010; Braz *et al*., 2011), while others found no effects on these parameters (Freitas *et al*., 2006; Rego *et al*., 2012). It is still not possible to establish whether these variations are the result of differences in diet composition (Freitas *et al*., 2006) and in the types of acid tested, their concentrations and specific combinations (blend), or are due to synergism and/or antagonism between ingredients and these additives that could mask possible effects. Therefore, further studies are needed to establish the specific conditions in which these additives are effective.

In this study, the effect of supplementation of complex diets with organic acids on the performance of weaned piglets and nutrient digestibility, as well as its economic viability was evaluated. For this purpose, the effect of the inclusion of a mixture of lactic, formic and citric acid, combined or not with sodium butyrate was investigated.

MATERIAL AND METHODS

The present study was approved by the animal welfare committee of the Institute of Animal Science, São Paulo, Brazil (Certificate number 151).

The performance and digestibility experiments were conducted at the Pig Farming Sector of the Institute of Animal Science, Nova Odessa, São Paulo, Brazil.

Sixty-four hybrid piglets weaned at 21 days of age and weighing on average 5.87±0.31 kg were used. The animals were divided in a randomized block design consisting of four treatments and eight repetitions. Body weight and sex of pigs were used as criteria in the block formation. The pen where two animals were housed (one castrated male and one female) served as the experimental unit.

Four treatments were studied: T1 (control): basal diet without the addition of an acidifier; T2 (blend): inclusion of 0.5% of a mixture of organic acids; T3 (butyrate): inclusion of 0.1% of sodium butyrate; T4 (blend+butyrate): inclusion of 0.5% of a mixture of organic acids and 0.1% sodium butyrate. In T2, T3 and T4, kaolin was replaced with the respective acidifiers. The mixture of organic acids (blend) consisted of 21% lactic acid, 18% formic acid, and 10% citric acid. Microencapsulated sodium butyrate at a concentration of 30% was used.

The diets were fed to the piglets from 21 to 66 days of age, divided into three periods: pre-initial I (0 to 10 days postweaning), pre-initial II (10 to 24 days), and initial (24 to 45 days). The diets were formulated to meet the nutritional requirements of piglets during the nursery phase according to Rostagno *et al*. (2011). Analyses of the diets (CP, crude fiber, ether extract, ash, and starch) were performed according to AOAC (1975) standard methods at the Animal Science Institute, Nova Odessa, Sao Paulo State. Water and ration were available *ad libitum*. Tab. 1 shows the percent composition of the diets.

Table 1. Percent composition of the pre-initial I diet (0 to 10 days), pre-initial II diet (10 to 24 days) and initial diet (24 to 45 days)

Ingredients	Pre-initial I	Pre-initial II	Initial
Corn grain 7.5 %	33.21	50.90	61.16
Soybean meal 46%	20.00	24.00	30.00
Kaolin	0.60	0.60	0.60
Gelatinized rice flour	10.00	0.00	0.00
Blood plasma	2.00	1.50	0.00
Soybean oil	1.20	1.50	2.00
Whole milk powder	10.00	0.00	0.00
Sugar	4.00	5.00	3.00
Whey	16.00	13.50	0.00
Dicalcium phosphate	0.90	1.40	1.50
Limestone	0.00	0.00	0.70
Salt	0.00	0.05	0.50
DL-methionine	0.31	0.25	0.00
L-lysin 78%	0.50	0.67	0.20
L-tryptophane 98%	0.025	0.023	0.000
L-threonine 98%	0.20	0.20	0.00
Choline chloride 60%	0.05	0.05	0.05
Colistin 80	0.05	0.05	0.05
Antioxidant (1)	0.01	0.01	0.01
Flavoring agent (2)	0.025	0.025	0.000
Palatability agent (3)	0.05	0.05	0.02
Copper sulfate 35%	0.075	0.030	0.040
Vitamin supplement (4)	0.10	0.10	0.08
Mineral supplement(4)	0.10	0.10	0.09
Total	100.00	100.00	100.00
Calculated Nutritional Composition			
ME (Mcal/kg)	34.33	33.25	32.84
Crude protein (%)	18.14	17.61	18.62
Lactose (%)	16.05	10.12	5.00
Calcium (%)	0.47	0.52	0.70
Total phosphorus (%)	0.78	0.67	0.59
Digestible lysin (%)	1.34	1.31	0.99
Digestible methionine (%)	0.56	0.47	0.26
Digestible tryptophane (%)	0.22	0.20	0.19
Digestible threonine (%)	0.79	0.74	0.59

(1) Endox 5X commercial product; (2) Cream Sicle commercial product; (3) Power Sweet commercial product; (4) nutritional levels per kg ration: vitamin A – 10,000IU; vitamin D_3 – 1,650IU; vitamin E 60mg/kg; vitamin K – 20mg; vitamin B1 – 1.19mg; vitamin B2 – 4mg; vitamin B6 – 2.19mg; vitamin B12 – 22µg; folic acid – 0.39mg; pantothenic acid – 18mg; biotin – 0.15mg; niacin – 29.84mg; choline – 1113.74mg; copper – 273.10mg; iron – 90mg; iodine – 1.10mg; manganese – 40.2mg; selenium – 0.36mg; zinc – 117.8mg.

The following performance variables were evaluated: daily feed intake, average daily gain, and feed conversion. The animals were weighed at the beginning and at the end of each period studied, corresponding to days 1, 10, 24 and 45 of the experiment. Leftover and wasted feed were weighed weekly for the determination of feed intake.

Twenty-four hybrid piglets with an initial mean weight of 8.21±0.79kg were used for digestibility evaluation. The experimental design consisted of random blocks with four treatments and six repetitions. The animals were housed in metabolic cages similar to the model suggested by Pekas (1968).

The animals were adapted for 10 days prior to assessment. The assays were performed consecutively using the same animals for the three assays. The animals remained in the same treatment since the initial allocation before adaptation.

The diets used in the digestibility experiment had the same formulation as those used in the performance assay (pre-initial I, pre-initial II, and initial diet) and the diet composition and nutritional value are shown in Tab. 1. The total fecal collection method was used, adding 1.5% of ferric oxide (Fe_2O_3) as a marker to the diets. The beginning and end of the collection period were determined by the occurrence of stained feces. Urine was collected daily and the samples were frozen until the time of laboratory analysis. The nitrogen analyses of feces and urine were performed according to AOAC (1975), at the Department of Animal Nutrition and Production, FMVZ – University of São Paulo.

Economic viability was evaluated for the pre-initial I (0-10 days), pre-initial II (10-24 days) and initial (24-45 days) periods and for the total period (0 to 45 days). First, feed cost per kilogram live weight gain (in R$) was determined. Next, the economic efficiency index (EEI) was calculated as suggested by Bellaver *et al*. (1985), *apud* Tavernari *et al*. (2009), as follows:

$$Y_i = (P_i * Q_i) / G_i$$

where Y_i is feed cost per kilogram live weight gain in the i^{th} treatment; P_i is the price per kilogram feed used in the i^{th} treatment; Q_i is the amount of feed consumed in the i^{th} treatment, and G_i is the weight gain in the i^{th} treatment. The EEI was then calculated as follows:

$$EEI = (MCe/ CTei) * 100$$

where *MCe* is the lowest feed cost per kilogram gain observed in the treatments; CTe_i is the cost of treatment *i* considered.

The costs of the ingredients used for the elaboration of the diets were based on the prices valid in São Paulo on August 13, 2013.

The data of the performance and digestibility experiments were analyzed using the PROC GLM module (General Linear Models) of the SAS program (Statistical Analysis System, 2001).

RESULTS AND DISCUSSION

Daily feed intake, average daily gain or feed conversion did not differ significantly (P>0.05) between treatments during the three periods studied (0-10, 0-24 and 0-45 days) (Tab. 2).

These results are consistent with those reported in a previous study (Gomes *et al*. 2007) that evaluated the performance of piglets from 15 to 36 days of age supplemented with fumaric acid combined or not with butyric and formic acid which performance parameters was not affected by treatments. A study evaluating the effect of a growing proportion of mixtures of organic acids based on lactic acid also found no significant differences in daily feed intake or average daily gain (Freitas *et al*., 2006). On the other hand, the inclusion of different levels of fumaric acid in the diet (Miguel *et al*., 2011), as well as the use of different combinations of formic acid, lactic acid, propionic acid and sodium butyrate (Braz *et al*., 2011), significantly improved different performance parameters, including average daily gain, in post weaning piglets.

Table 2. Initial and final live weight, daily feed intake (DFI), average daily gain (ADG) and feed conversion (FC) of weaned piglets from 1 to 45 days of the experiment

	Control[1]	Blend [1]	Butyrate[1]	Blend + butyrate[1]	CV (%)[2]	P value
Body weight (kg)						
Initial	5.86	5.86	5.87	5.87	0.10	0.926
Final	27.71	28.90	28.93	29.75	2.91	0.3739
0 - 10 days						
DFI (g)	516	539	530	592	6.08	0.4253
ADG (g)	389	407	386	454	7.69	0.3291
FC	1.34	1.35	1.40	1.32	2.46	0.8607
0 - 24 days						
DFI (g)	971	1037	992	1113	6.12	0.1526
ADG (g)	675	718	728	794	6.79	0.0893
FC	1.44	1.45	1.37	1.40	2.67	0.3919
0 - 45 days						
DFI (g)	1619	1728	1695	1755	3.46	0.4002
ADG (g)	971	1024	1024	1061	3.64	0.2805
FC	1.68	1.69	1.65	1.66	0.99	0.9088

[1]Lack of effect between treatments by the Tukey test (P>0.05). [2] CV (%): coefficient of variation.

The absence of differences between treatments may be due to the presence of relatively high levels of dicalcium phosphate and limestone in the diet of piglets. Sources such as dicalcium phosphate and limestone possess a high buffering capacity (Levic, 2005) which often confers a high basic pH to the piglet's intestinal content, a fact that may have masked the effect of organic acids in the diets tested. In fact, high buffering capacities were obtained with dicalcium phosphate and a vitamin/mineral mixture in complex diets used for piglets (Bockor *et al.*, 2007).

The lack of effect of the experimental diets may also be associated with the use of milk ingredients such as whole milk powder and whey at inclusion levels of 10.0% to 16.6% in order to meet the minimum lactose levels. In weaning piglets, lactose derived from milk products is converted into lactic acid, producing desirable changes in gastric development (Bockor *et al.*, 2007). However, the presence of milk products can reduce the efficacy of acidifiers because of their palatability and fermentation effect and consequent acidification of the gastrointestinal tract (Silva *et al.*, 2008). This would explain the observation that the use of organic acids is more effective in the case of simple cereal-soybean meal-based diets compared to more complex diets that contain milk ingredients or animal origin proteins (Partanen and Mroz, 1999).

An important characteristic of the tested diets is that all of them contained the antimicrobial additive colistin. This is a common practice on Brazilian factory farms which use a type of growth promoter. In general, the use of antibiotics in diets increases the growth rate, improves feed conversion and reduces mortality due to infections, especially by moderately controlling pathogenic microorganisms that colonize the gastrointestinal tract (Lovatto *et al.*, 2005). These features possibly contributed to maintain animal health and reduced the effect of the acidifiers in the treatments evaluated.

In the present study, no episodes of diarrhea were observed in the piglets over the experimental period. In addition to the fact that the assays were conducted in an experimental farm environment with adequate cleaning standards, the presence of zinc oxide (Arantes *et al.*, 2007), copper sulfate (Rutz and Lima, 2001) and colistin (Lovatto *et al.*, 2005) in the diets may have inhibited the growth of microorganisms in the gastrointestinal tract. Several authors suggested that the challenges imposed by the rearing environment, variations in environmental conditions and stressors associated with animal management favor the action of organic acids and potentiate their effects (Silva *et al.*, 2008). Hence, the decreased challenge during the assays may have reduced the expression of the characteristics of organic acids related to animal performance.

Finally, the lack of differences in piglet performance between treatments may be attributed to the use of a complex diet (Kiefer and Quadros, 2006). Acidifiers are more effective in improving the performance of weaned piglets when added to simple diets based on cereals and soybean meal compared to complex diets containing milk products (Miguel *et al.*, 2011) and animal origin protein (Silva *et al.*, 2008).

Tab. 3 shows the digestibility coefficients and energy content of the pre-initial I, pre-initial II and initial diets. No significant differences (P>0.05) were observed between treatments, i.e., supplementation with organic acids in the form of blend, sodium butyrate or the combination of the two products did not influence apparent fecal digestibility of dry matter, crude protein, gross energy or digestible and metabolizable energy. These results are consistent with previous studies that found no effects of supplementation of piglet diets with fumaric acid (Miguel *et al.*, 2011) or sodium butyrate combined with phytogenic compounds on digestibility parameters. In a study in which the use of butyric acid influenced crude protein digestibility (Mackinsky *et al.*, 2010), the diet used was simple (no addition of milk products) and the animals were already in the beginning of the growth phase.

Table 3. Apparent digestibility coefficients of dry matter (DCDM) and crude protein (DCCP), nitrogen retention coefficient (NRC), digestible energy (DE) and metabolizable energy (ME) of the pre-initial I, pre-initial II and initial diets fed to weaned piglets

Variable	Control[1]	Blend[1]	Butyrate[1]	Blend + butyrate[1]	CV%[2]	P value
Pre-initial I phase						
DCDM (%)	91.91	92.00	92.13	92.86	0.46	0.5855
DCCP (%)	89.37	87.07	88.8	89.15	1.17	0.2246
NRC (%)	80.99	78.51	80.55	80.07	1.35	0.2485
DE (kcal/kg)	3596	3591	3604	3622	0.38	0.7583
ME (kcal/kg)	3527	3529	3546	3563	0.47	0.7011
Pre-initial II phase						
DCDM (%)	91.19	90.60	91.30	90.74	0.37	0.8917
DCCP (%)	89.51	86.81	88.15	87.06	1.40	0.3937
NRC (%)	83.81	80.86	81.31	81.39	1.62	0.3887
DE (kcal/kg)	3570	3531	3570	3546	0.53	0.7708
ME (kcal/kg)	3523	3493	3525	3512	0.41	0.8890
Initial phase						
DCDM (%)	89.67	89.55	89.97	89.89	0.21	0.9742
DCCP (%)	87.58	86.83	88.05	88.00	0.64	0.7759
NRC (%)	71.5	72.82	72.6	73.13	0.97	0.824
DE (kcal/kg)	3515	3506	3524	3518	0.21	0.9786
ME (kcal/kg)	3442	3449	3469	3457	0.33	0.8977

[1]Lack of effect between treatments by the Tukey test (P>0.05). [2]CV (%): coefficient of variation.

Analysis of economic viability (Tab. 4) showed that the control diet was the most efficient, and consequently the least expensive, during all phases, except for the pre-initial II period (10 to 24 days) when treatment with sodium butyrate was more efficient, showing lower cost per kilogram weight gain and EEI. Since the pre-initial II phase only comprises 14 days of the total period (45 days) and all diets including acidifiers were more expensive, our results suggest that the inclusion of acidifiers in complex diets such as those used in the present study is economically unviable.

Table 4. Cost per kilogram feed (R$/kg ration), feed cost per kilogram live weight gain (R$/kg WG) and economic efficiency index (EEI) obtained for the different phases and for the total period of the experiment

Phase	Control	Blend	Butyrate	Blend + butyrate
Pre-initial I (0 to 10 days)				
R$/kg feed	1.7820	1.8471	1.8018	1.8670
R$/kg WG	2.3604	2.4480	2.4728	2.4307
EEI%	100.00	96.42	95.45	97.10
Pre-initial II (10 to 24 days)				
R$/kg feed	1.2547	1.3199	1.2746	1.3397
R$/kg WG	1.8508	1.9541	1.7338	1.9183
EEI%	93.68	88.72	100.00	90.38
Initial (24 to 45 days)				
R$/kg feed	0.7093	0.7745	0.7292	0.7943
R$/kg WG	1.2784	1.4186	1.3360	1.4476
EEI%	100.00	90.11	95.69	88.31
Total (0 to 45 days)				
R$/kg ration	1.1174	1.1825	1.1372	1.2024
R$/kg WG	1.8633	1.9945	1.8815	1.9889
EEI%	100.00	93.42	99.03	93.69

Calculated based on the price of the raw materials on August 13, 2013.

CONCLUSION

Our results suggest that, under the conditions studied, the addition of acidifiers (blend and sodium butyrate) as growth promoters to highly digestible complex diets does not alter the performance or nutrient digestibility of piglets during the nursing phase. Considering the cost of these ingredients, their use is not recommended under these conditions.

ACKNOWLEDGEMENTS

We thank Coordenação de Aperfeiçoamento de Pessoal de Nível Superior (CAPES) for the fellowship granted to Andréia Donizeti Chagas Vilas Boas.

REFERENCES

ASSOCIAÇÃO BRASILEIRA DE PROTEÍNA ANIMAL. *Relatorio anual, 2015*. São Paulo: ABPA, 2015. Available from: <http://abpa-br.com.br/setores/suinocultura/publicacoes/relatorios-anuais>. Accessed in: october, 15th. 2015.

ARANTES, V.M.; THOMAZ, M.C.; KRONKA, R.N. *et al*. Níveis de zinco na dieta de leitões recém-desmamados sobre o perfil de parâmetros sangüíneos. *Ciênc. Anim. Bras*., v.8, p.193-205, 2007.

BELLAVER, C.; FIALHO, E.T.; PROTAS, J.F.S. *et al*. Radícula de malte na alimentação de suínos em crescimento e terminação. *Pesqui. Agropecu. Bras*., v.20, p.969-974, 1985.

BIAGI, G.; PIVA, A.; MOSCHINI, M. *et al*. Performance, intestinal microflora, and wall morphology of weanling pigs fed sodium butyrate. *J. Anim. Sci*., v.85, p.114-119, 2007.

BOCKOR, L.; DAHLKE, F.; MAIORKA, A. *et al*. Comparação de medidas da capacidade tamponante de matérias-primas e dietas utilizadas para leitões. *Arch. Vet. Sci.,* v.12, p.1-76, 2007.

BRAZ, D.B.; COSTA, L.B.; BERENCHTEIN, B. *et al*. Acidificantes como alternativas aos antimicrobianos promotores de crescimento de leitões. *Arch. Zootec.,* v.60. p.745-756, 2011.

CHIQUIERI, J.; SOARES, R.T.R.N.; LYRA, M.S. *et al*. Ácidos orgânicos na alimentação de leitões desmamados. *Arch. Zootec*., v.58, p.609-612, 2009.

CLAUS, R.; GUNTHNER, D.; LETZGUSS, H. Effects of feeding fat-coated butyrate on mucosal morphology and function in the small intestine of the pig. *J. Anim. Physiol. Anim. Nutr.,* v.91, p. 312-318, 2008.

CORASSA, A.; DARCI, C.L.; OSTERMANN, J.D. *et al*. Níveis de ácido fólico em dietas contendo ácido fórmico para leitões de 21 a 48 dias de idade. *Rev. Bras. Zootec*., v.35, p.462-470, 2006.

FREITAS, L.S.; LOPES, D.C.; FREITAS, A.F. *et al*. Avaliação de ácidos orgânicos em dietas para leitões de 21 a 49 dias de idade. *Rev. Bras. Zootec.,* v.35, p. 1711-1719, 2006.

GOMES, F.E.; FONTES, D.O.; SALIBA, E.O.S. *et al*. Ácido fumárico e sua combinação com os ácidos butírico ou fórmico em dietas de leitões recém desmamados. *Arq. Bras. Med. Vet. Zootec*., v.59, p.1270-1277, 2007.

KIEFER, C.; QUADROS, A.R.B. Efeito da acidificação de dietas simples e complexas sobre o desempenho de leitões nas fases iniciais de crescimento. *Rev. Ceres*, v.53, p.179-187, 2006.

KUMMER, R.; GONÇALVES, M.A.D.; LIPPKE, R.T. *et al*. Fatores que influenciam o desempenho dos leitões na fase de creche. *Acta Sci. Vet.,* v.37, p.195-209, 2009.

LEVIC, J. Understending the buffering capacity feedstuffs. *Biotechnol. Anim. Husb.,* v.21, p.309-313, 2005.

LOVATTO, P.A.; OLIVEIRA, V.; HAUPTLI, L. *et al*. Alimentação de leitões na creche com dietas sem aditivos antimicrobianos, com alho (*Allium sativum*, L.) ou colistina. *Cienc. Rural*, v.35, p.656-659, 2005

MACHINSKY, T.G.; KESSLER, A.M.; RIBEIRO, A.M.L. *et al*. Digestibilidade de nutrientes e balanço de Ca e P em suínos recebendo dietas com ácido butírico, fitase e diferentes níveis de cálcio. *Ciênc Rural*., v.40, p. 2350-2355, 2010.

MAZZONI, M.; GALL, M.L.; FILIPPI, S. *et al*. Supplemental sodium butyrate stimulates different gastric cells in weaned pigs. *J. Nutr.,* v.138, p.1426-1431, 2008.

MIGUEL, W.C.; TRINDADE NETO, M.A.; BERTO, D.A. *et al*. Suplementação de acidificantes em rações de leitões desmamados: desempenho e digestibilidade. *Braz. J. Vet. Res. Anim. Sci.*, v.48, p.141-146, 2011.

OFFICIAL methods of analysis. 12. ed. Washington: Willian Horwitz, 1975. 1094 p.

PARTANEN, K.H.; MROZ, Z. Organic acids for performance enhacement in pig diets. *Nutr. Res. Rev.,* v.12, p.117-145, 1999.

PEKAS, J.C. Versatile swine laboratory apparatus for physiologic and metabolic studies. *J. Anim. Sci.,* v.27, p.1303-130, 1968.

REGO, J.C.C.; FERREIRA, R.A.S.; BRITO, C.F. *et al*. Acidificação da dieta ea digestibilidade de nutrientes em leitões. *Rev. Acad. Ciênc. Agrár. Ambient*., v.10, p.105-111**,** 2012.

ROSTAGNO, H.S.; ALBINO, L.F.T.; DONZELE, J.L. *et al. Tabelas brasileiras para aves e suínos*: composição de alimentos e exigências nutricionais. Viçosa: UFV, 2011. 252 p.

RUTZ, F.; LIMA, G.J.M.M. O uso de antimicrobianos como promotores de crescimento no Brasil. In: CONGRESSO BRASILEIRO DE VETERINÁRIOS ESPECIALISTAS EM SUÍNOS, 2001, Porto Alegre, RS. *Anais...* Concórdia, SC: CNPSA, 2001. 10p. CD-ROM.

SANCHES, A.L.; LIMA, J.A.F.; FIALHO, E.T. *et al*. Utilização de probiotico, prebiotico e simbiótico em rações de leitões ao desmame. *Ciênc. Agrotec*., v.30, p.774-777, 2006.

SAS: language reference. Version 8, Cary: SAS2001. 1042p.

SILVA, A.M.R.; BERTO, D.A.; LIMA, G.J.M. *et al*.. Valor nutricional e viabilidade econômica de rações suplementadas com maltodextrina e acidificante para leitões desmamados*. Rev. Bra.s Zootec.,* v.37, p. 286-295, 2008.

TAVERNARI, F.C.; DUTRA, JUNIOR, W.M.; ALBINO, L.F.T. *et al*. Efeito da utilização de farelo de girassol na dieta sobre o desempenho de frangos de corte. *Rev. Bras. Zootec.,* v.38, p.1745-1750, 2009.

TSILOYIANNIS, V.K.; KYRIAKIS, S.C.; VLEMMAS, J. *et al*. The effect of organic acids on the control of porcine post-weding diarrhea. *Res. Vet. Sci.*, v.70, p.287-293, 2001.

VIOLA, E.S.; VIEIRA, S.L. Suplementação de acidificantes orgânicos e inorgânicos em dietas para frangos de corte: desempenho zootécnico e morfologia intestinal. *Rev. Bras. Zootec*., v.36, p.1097-1104, 2007.

ZENTEK, J.; FERRARA, F.; PIEPER, R. *et al*. Effects of dietary combinations of organic acids and medium chain fatty on the gastrointestinal microbial ecology and bacterial metabolites in the digestive tract of weaning piglets. *J. Anim. Sci.,* v.91, p.3200-3210, 2013.