FULL ARTICLE

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Soluble and insoluble fibre sources in weaning piglets' diets

Fibras solúvel e insolúvel em dietas de leitões na creche

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ABSTRACT

This study evaluated the effect of diets containing low levels of soluble and insoluble fiber sources on performance, diarrhea score, chemical and physical characteristics of feces, and behavior in weaning piglets. Thirty-six weaned piglets of 30 days of age with an initial body weight of 8.8 kg were distributed in 36 pens using a completely randomized design in an experimental period of 21 days. The experimental treatments were the Control diet (CONT), the Control diet + 1% beet pulp inclusion (SBP), and the Control diet + 1% lignocellulose inclusion (LCE, Arbocel®). Feed and water were available *ad libitum*. Body weight and feed intake were measured weekly to calculate the average daily intake, weight gain, and feed conversion ratio. The fecal consistency was determined visually twice daily, classifying feces according to three scores. To determine fecal pH and concentration of fecal short-chain fatty acids (SCFA), samples of fresh feces were collected two weeks after weaning and measured by a digital pH meter and gas chromatography, respectively. The behavior of piglets was observed once a week, using four animals per treatment, from 14:00 to 16:00, every 12 min. Fibre sources had no effect (P>0.05) on performance, except in the period 15 to 21 days after weaning, which was a tendency (P=0.061) of feed intake decrease in SBP and LCE diets. Fiber sources did not affect the fecal consistency score (P>0.05). However, piglets fed SBP and LCE showed a tendency (P<0.10) to have less diarrhea incidence 15 to 21 days post-weaning and in the entire experimental period. Fecal pH and SCFA concentration were not influenced by fiber source (P>0.05), with acetic, propionic, and butyric acids representing around 71%, 19%, and 10% of the total, respectively. Fiber sources did not influence the social and feeding behavior of weaning piglets (P>0.05). Diets containing 1% fiber sources did not alter performance, diarrhea score, fecal pH, fecal SCFA concentration, or feeding and social behavior of weaned piglets.

Keywords: Beet pulp. Feed additive. Lignocellulose. Post-weaning. Short-chain fatty acids.

RESUMO

O estudo avaliou o efeito de dietas contendo baixos níveis de fontes de fibra solúvel e insolúvel sobre o desempenho, escore de diarreia, características químicas e físicas das fezes e comportamento de leitões desmamados. Trinta e seis leitões desmamados, com 30 dias de idade e peso vivo inicial de 8,8 kg, foram distribuídos em 36 baias, totalizando 12 repetições por tratamento, em um delineamento inteiramente casualizado. Os tratamentos experimentais foram: dieta controle (CONT), dieta controle + 1% de inclusão de polpa de beterraba (SBP) e dieta controle + 1% de inclusão de lignocelulose (LCE, Arbocel®). A ração e a água foram disponibilizadas *ad libitum* durante os 21 dias experimentais. O consumo médio diário de ração (CRM), ganho de peso diário (GPD) e a conversão alimentar (CA) foram medidos semanalmente. A consistência fecal foi determinada visualmente duas vezes por dia, classificando as fezes de acordo com três classificações. Amostras frescas de fezes, colhidas no 14° dia experimental, foram usadas para determinação do pH e ácidos graxos de cadeia curta (AGCC). O pH foi medido utilizando pHmetro digital, enquanto os AGCC foram determinados com auxílio de cromatografia gasosa. Para avaliar o comportamento foram observados quatro leitões por tratamento, uma vez por semana, das 14:00 às 16:00, a cada 12 minutos. As fontes de fibra não apresentaram efeito (P>0,05) sobre as variáveis de desempenho, exceto no período de 15 a 21 dias pós desmame, onde se observou uma tendência (P=0,061) de redução no consumo médio nos leitões que receberam as dietas contendo SBP e LCE. Não foi observado efeito das fontes de fibra sobre o escore de consistência fecal (P>0,05), embora leitões alimentados com SBP e LCE apresentaram uma tendência (P<0,10) de redução na incidência de diarreia no período de 15 a 21 dias pós desmame e no período total. O pH e a concentração de AGCC não foram influenciados pelas fontes de fibra (P>0,05), onde entres os tratamentos os perfis dos ácidos acético, propiônico e butírico foram semelhantes 71%, 19% e 10%, respectivamente.

Não houve efeito das fontes de fibra sobre os comportamentos social e alimentar dos leitões (P>0,05). Dietas contendo 1% de fontes de fibra não alteram o desempenho, escore de diarreia, pH fecal, concentração de ácidos graxos voláteis nas fezes, bem como o comportamento alimentar e social de leitões desmamados.

Palavras-chave: Polpa de beterraba. Aditivo nutricional. Lignocelulose. Pós-desmame. Ácidos graxos de cadeia curta.

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Introduction

In commercial pig production systems, piglets are weaned between 3 and 4 weeks of age, facing social, environmental, and nutritional challenges. Therefore, piglet weaning is a stressful management practice that can alter normal intestinal functioning and microbiota diversity, impairing animal welfare and performance (Campbell et al., 2013; Guevarra et al., 2018; Moeser et al., 2017).

Including antibiotics in piglet diets as growth promoters have been widely used to mitigate weaning challenges. However, this practice has been discouraged to reduce the risk of bacterial antibiotic resistance, a severe problem for human and animal health (Canibe et al., 2022; Rahman et al., 2022). This has generated a growing interest in alternative additives with the potential to reduce the negative impacts of weaning (Heo et al., 2012).

It has been suggested that including certain types of fiber in piglet diets may help alleviate the negative consequences of weaning (Agyekum & Nyachoti, 2017; Chen et al., 2019). Fibers can be classified into soluble and insoluble, according to their solubility in water. Soluble fibers are highly fermentable, mainly in the large intestine, and their inclusion in the diet increases the population of bacteria and the production of short-chain fatty acids (SCFA). Insoluble fibers, on the other hand, have low fermentability, and their intake tends to increase intestinal motility and feces volume (Gieryńska et al., 2022).

Pregnant sows fed fiber-containing diets had a lower incidence of stereotyped behavior and improved welfare indicators (Agyekum & Nyachoti, 2017). However, there is little information about the impacts of the inclusion of soluble or insoluble fibers on the behavior of newly weaned piglets. For example, the impact of fiber inclusion on behavior can be direct (natural eating behavior) or indirect (reduced intestinal discomfort).

It was hypothesized that including low fiber levels in the diet improves performance and intestinal health, altering intake and social behavior in weaned piglets. Therefore, this study aimed to evaluate the effects of diets with added soluble and insoluble fiber on the performance, diarrhea score, feces characteristics, and behavior of piglets.

Material and Methods

The study was conducted in the Swine Research Laboratory of the Animal Science Department at the Federal University of Santa Maria, Santa Maria, RS, Brazil. The procedures adopted in this experiment followed the provisions of Federal Law n. 11,794 of October 8, 2008, and Decree n. 6,899 of July 15, 2009, under Case n. 9235210322 of the local Ethics Committee of Animal Use (CEUA).

Thirty-six weaned piglets of a commercial lineage, with 30 days of age and an initial body weight of 8.8 kg, were distributed in 36 pens using a completely randomized design, with 12 animals per treatment, in an experimental period of 21 days. The animals were housed in a facility with side curtains and raised pens with cast-iron floors with an area of 1 m^2; each pen was equipped with one stainless steel feeder and nipple drinker adjusted according to the animal's height.

The average temperature of the experimental facility was maintained within the thermal comfort zone, ranging from 26º C to 24º C between the first and last week of the study, respectively. A photoperiod of 12 h of light was adopted.

Feed and water were available *ad libitum*. The experimental treatments were: 1) Control diet (CONT); 2) Control diet + 1% of beet pulp inclusion (SBP); 3) Control diet + 1% lignocellulose inclusion (LCE, Arbocel®) (Table 1). The bromatological composition of feed (dry matter (DM), crude protein (CP), ashes (AS), and neutral detergent fiber (NDF)) was analyzed using the methodology of Silva & Queiroz (2009) (Table 2).

Table 1 – Ingredients and nutritional composition of experimental diets (1 to 21 days)

Ingredient (%)	CONT	SBP	LCE
Corn	26.600	26.600	26.600
Rice meal	26.550	26.550	26.550
Starch	1.600	0.150	0.150
Soybean meal	23.000	23.000	23.000
Soy protein concentrate	3.000	3.000	3.000
Whey powder	10.000	10.000	10.000
Sugar	2.000	2.000	2.000
Spray dried blood plasma	2.000	2.000	2.000
Soybean oil	1.550	2.000	2.000
Beet pulp	0.000	1.000	0.000
Purified cellulose	0.000	0.000	1.000
L-lysine	0.380	0.380	0.380
DL-methionine	0.180	0.180	0.180
L-threonine	0.100	0.100	0.100
Limestone	0.250	0.250	0.250
Dicalcium phosphate	1.700	1.700	1.700
Common salt	0.500	0.500	0.500
Mycotoxin adsorbent	0.250	0.250	0.250
Choline chloride	0.040	0.040	0.040
Premix microminerals [a]	0.150	0.150	0.150
Premix vitamins [b]	0.150	0.150	0.150
Total	100.000	100.000	100.000
Calculated nutritional composition			
ME, Mcal/kg	3354	3342	3342
CP, g/kg	197.20	197.20	197.20
Lysine dig., g/kg	13.90	13.90	13.90
Methionine dig., g/kg	4.70	4.70	4.70
Methionine+Cystine dig., g/kg	7.80	7.80	7.80
Threonine dig., g/kg	8.40	8.40	8.40
Calcium, g/kg	7.00	7.00	7.00
Standardized Phosphorus, g/kg	4.00	4.00	4.00
Sodium, g/kg	3.50	3.50	3.50
Insoluble fibre, g/kg	53.60	57.60	60.00
Soluble fibre, g/kg	13.20	17.30	13.50

CONT: Control diet; SBP: Control diet + 1% of beet pulp inclusion; LCE: Control diet + 1% lignocellulose inclusion (Arbocel®); ME= metabolizable energy; CP= crude protein. Added per product kilogram a: selenium, 450 mg; iron, 100 g; copper, 15 g; zinc, 150 g; cobalt, 500 mg; manganese 70g; e iodine 1.4000 mg. Added per product kilogram; b: vitamin A, 9.500.000 UI; vitamin D3, 1.400.000 UI; vitamin E, 55.000 mg; vitamin K, 1.900 mg; vitamin B1, 950 mg; vitamin B2, 3.300 mg; vitamin B6, 1.400 mg; vitamin B12, 9.500 mg; pantothenic acid, 9.500 mg; niacin, 14 g; folic acid, 700 mg; and biotin, 38 mg.

The average daily feed intake (ADFI) was calculated by the difference between the amount of feed offered and leftovers in the feeder at the end of each week. The piglets were weighed after a previous 12-h feed fasting period. The average daily body weight gain (DWG) was obtained by the difference in body weight of each animal in weekly weighing. The feed conversion ratio (FCR) was calculated by dividing weekly feed intake by weekly body weight gain.

Fecal consistency was determined twice a day (morning and afternoon) visually during the experimental period by two trained assessors. Feces were classified according to consistency as follows: 1 (normal feces), 2 (pasty feces), or 3 (liquid feces). Feces with a consistency score of 3 were considered diarrhea.

Table 2 – Bromatological composition of the experimental diets and the fiber source ingredients

	Experimental diets			Fibre sources ingredients	
	CONT	SBP	LCE	Beet pulp	Lignocellulose
DM (%)	88.84	88.99	89.20	88.86	88.52
MM (%)	7.18	7.08	6.77	0.80	6.25
CP (%)	21.35	21.19	20.63	8.92	2.80
NDF (%)	6.74	7.13	10.33	68.13	47.22
GE(Kcal/kg)	3853	3846	3875	3691	4131

CONT: Control diet; SBP: Control diet + 1% of beet pulp inclusion; LCE: Control diet + 1% lignocellulose inclusion (Arbocel®); DM: Dry matter; MM: mineral matter; CP: crude protein; NDF: neutral detergent fiber; GE: gross energy. Values are expressed in dry matter.

For the fecal pH determination, samples were collected at the end of the second week of the trial. The sample of 10 g of fresh feces from each animal was diluted in 100 ml of distilled water, and after agitation, the pH was measured using a digital pH meter.

Using gas chromatography, the short-chain fatty acids concentration (SCFA) was determined in feces samples collected at the end of the second week of the study. The samples were prepared following the methodology of Del Valle et al. (2018), and the reading was performed on a Shimadzu© GC-2010 Plus chromatograph equipped with AOC-20i automatic injector, Stabilwax-DATM capillary column (30m, 0.25mm ID, 0.25μm df, Restek©) and flame ionization detector (FID).

The piglets' behavior analysis was observed once a week using video-monitoring camera images, observing four animals per treatment, totaling 12 animals. The observations were made in the period from 14:00 to 16:00, being observed 11 periods within this 2 h (14:00; 14:12; 14:24; 14:36; 14:48; 15:00; 15:12; 15:24; 15:36; 15:48; and 16:00). The observations of the images were performed only by two trained observers, and the data were collected every 12 min focal sampling methodology, and the observed behavioral patterns were: feeding behavior (eating and drinking); locomotion behavior (walking from one side to the other in pen); resting behavior (lying down, sitting and sleeping); playful behavior (playing, rolling and running); and exploratory behavior (rooting, sniffing, chewing), following the methodology of Aluwé et al. (2016).

The performance, fecal pH, SCFA concentration, and behavior data were analyzed by analysis of variance (ANOVA) using a generalized linear model procedure after the assumption of residual normality and homoscedasticity of variances, and the comparison between treatments was performed.

Tukey's test with a 5% significance level was used. The non-parametric Kruskal-Wallis test was applied for the fecal consistency score, which failed the normality and homoscedasticity presupposition. Differences between treatments were considered significant for P<0.05, and values at 0.05 < P < 0.10 were discussed as tendencies.

Results

There was no effect (P>0.05) of fiber sources on the performance of weaned piglets in the evaluated periods, except a tendency of decreased feed intake in piglets receiving diets containing fiber sources (beet pulp and lignocellulose; P=0.061) 15 to 21 days post-weaning (Table 3).

The fecal consistency score was not influenced (P>0.05) by the source of fiber used in the diet. However, piglets fed a diet with SBP showed a tendency (P<0.10) of lower fecal consistency score in the period from 15 to 21 days and considering the whole experimental period (Table 4).

The inclusion of fiber sources in the piglets' diet did not change the feces' pH (P>0.05) and SCFA concentration (Table 5). Furthermore, the fecal SCFA profile was similar between treatments, with acetic, propionic, and butyric acids representing around 71%, 19%, and 10% of the total, respectively.

None of the feeding (eating and drinking) or social (resting, exploring, walking, and playing) behavioral variables were influenced (P>0.05) by the fiber sources in the diet (Figure 1). Most of the piglets' time was spent in resting activities (≅48%), then in eating behavior (25%), followed by exploring behavior (≅17%). Walking, playful, and drinking behavior accounted for about 10% of the total time.

Discussion

Between 15- and 21 days post-weaning, there was a tendency towards greater feed consumption (>10%) by animals consuming a diet containing supplementary sources of soluble and insoluble fiber. These results may be associated with improved intestinal condition caused by fiber intake, which has also been observed in other studies (Pascoal et al., 2012; Silva-Guillen et al., 2022). On the other hand, considering that there were no substantial differences in the chemical composition of the experimental diets, it was expected that greater consumption would result in more significant weight gain. This did occur, as piglets ingesting diets with fiber had more significant absolute weight gain between the 15th and 21st days (8.5%), although not of sufficient magnitude to generate statistically significant differences.

The tendency for less liquid feces (diarrhea) in piglets fed SBP (soluble fiber) is in line with the results found by Chen et al. (2019), who also observed a lower incidence of diarrhea in piglets that received a mixture containing 0.5% soluble fiber. It is known that fiber stimulates the production of gut SCFA (Awati et al., 2016; Jha & Berrocoso, 2015). The SCFA, especially butyrate, is the energy substrate for absorptive cells and reduces digesta pH, inhibiting the growth of many species of pathogenic bacteria and improving gut health (Metzler-Zebeli et al., 2010; Zhao et al., 2018). However, in our study, no differences were detected in the levels of short-chain fatty acids that would justify the results.

Table 3 – Performance of weaned piglets fed diets with different sources of fiber

	CONT	SBP	LCE	SEM	p-value
0 to 7 days					
DWG, kg/d	0.284	0.290	0.300	0.018	0.825
ADFI, kg/d	0.401	0.383	0.377	0.025	0.788
FCR, kg/d	1.426	1.325	1.294	0.072	0.415
8 to 14 days					
DWG, kg/d	0.543	0.595	0.539	0.023	0.202
ADFI, kg/d	0.744	0.802	0.733	0.028	0.205
FCR, kg/d	1.361	1.367	1.375	0.052	0.983
15 to 21 days					
DWG, kg/d	0.721	0.794	0.772	0.027	0.184
ADFI, kg/d	1.013[b]	1.135[a]	1.108[a]	0.034	0.061
FCR, kg/d	1.414	1.445	1.447	0.057	0.895
1 to 21 days					
DWG, kg/d	0.506	0.548	0.525	0.017	0.231
ADFI, kg/d	0.705	0.755	0.721	0.022	0.284
FCR, kg/d	1.396	1.383	1.383	0.039	0.964

CONT: Control diet; SBP: Control diet + 1% of beet pulp inclusion; LCE: Control diet + 1% lignocellulose inclusion (Arbocel®); SEM: square error of the mean; DWG: daily weight gain; ADFI: average daily feed intake; FCR: feed conversion ratio. [a,b]lowercase letters indicate a tendency by Tukey's test (P<0.10).

Table 4 – Fecal consistency of weaned piglets fed diets with different sources of fibre[1]

	CONT	SBP	LCE	SEM	p-value
Days 1 to 7	1.33	1.25	1.26	0.072	0.712
Days 8 to 14	1.32	1.06	1.16	0.085	0.101
Days 15 to 21	1.22[a]	1.00[b]	1.07[ab]	0.072	0.094
Days 1 to 21	1.29[a]	1.11[b]	1.16[ab]	0.055	0.064

CONT: Control diet; SBP: Control diet + 1% of beet pulp inclusion; LCE: Control diet + 1% lignocellulose inclusion (Arbocel®); SEM: square error of the mean. [1]Data are means from 10 to 12 observations by measure; Fecal consistency scores: 1 (normal feces), 2 (pasty feces) or 3 (liquid feces). [a,b]lowercase letters indicate a tendency by Tukey's test (P<0.10).=

Table 5 – Short chain fatty acids concentration and pH in faeces of weaned piglets fed diets with different sources of fibre

SCFA (mmol/kg)	CONT	SBP	LCE	SEM	p-value
Acetic	43.89	44.55	44.26	1.64	0.960
Propionic	12.46	12.02	10.76	0.83	0.343
Butyric	6.36	5.93	6.12	0.49	0.824
Total	62.71	62.5	61.14	2.61	0.902
pH	6.42	6.57	6.58	0,10	0.504

SCFA: short chain fatty acids; CONT: Control diet; SBP: Control diet + 1% of beet pulp inclusion; LCE: Control diet + 1% lignocellulose inclusion (Arbocel®); SEM: square error of the mean.

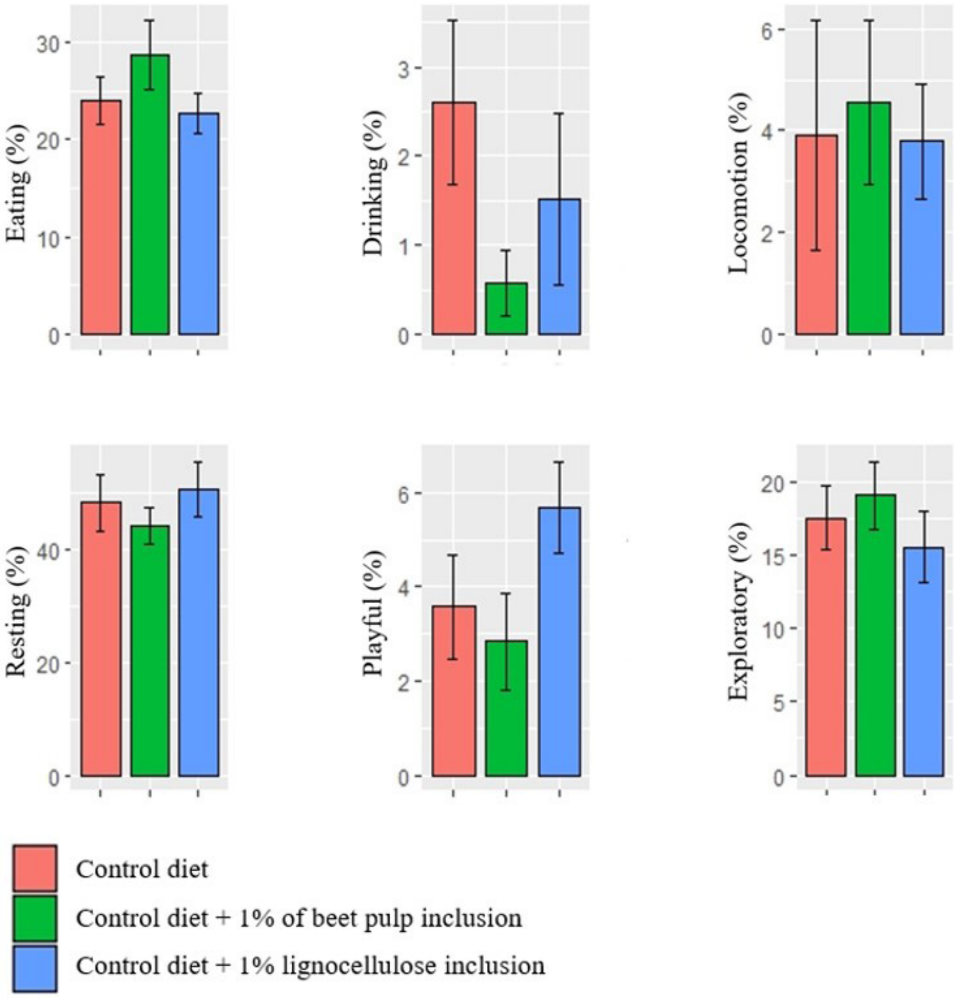

Figure 1 – Social and feeding behaviour of weaned piglets fed diets with different sources of fibre.

Weaning represents a stressful piglet period (Moeser et al., 2017). However, piglets' age and weight positively influence their post-weaning adaptability (van der Meulen et al., 2010). In this study, the animals were weaned at an average age of 30 days and weight of 8.8 kg, older and heavier than usual (21/28 days old and 6.5/7.5 kg body weight). This may have contributed to the effects of the fiber not occurring to the expected degree.

Social stress is one factor that has more impact on animal welfare in the first days of the post-weaning period (Marchant-Forde et al., 2020). In our study, the animals were housed individually, which may have also mitigated the post-weaning challenge and helped to explain the results.

SBP and LCE were included at 1% dosages in feed, i.e., as a feed additive. However, it is possible that the differences in fiber levels between treatments were not significant enough to lead to differences in performance results. Jeaurond et al. (2008) showed that the inclusion of 5% SPB in diets increased the weight gain of piglets with an initial body weight of 6.23 kg. Including 1.5% to 2% lignocellulose promotes gut development and health and increases performance (Flis et al., 2017). However, Chen et al. (2019), adding 1% soluble fiber, 1% insoluble fiber, or a 1% mixture, found no effect on performance except for feed efficiency in the diet containing an added fiber mixture.

Conclusion

Adding 1% beet pulp and lignocellulose to weaned pig diets does not impact overall performance and reduces the incidence of diarrhea. No changes were observed in fecal pH, the concentration of short-chain fatty acids in feces, or the feeding and social behavior of the weaned piglets.

Conflict of Interest

All co-authors have seen and agree with the contents of the manuscript and there is no financial interest to report.

Ethics Statement

All actions reported in this manuscript were carried out following the procedures set out in Federal Law No. 11,794 of October 8, 2008, and in Decree No. 6,899 of July 15, 2009, approved by the Ethics Committee on the Use of Animals (CEUA) of the Federal University of Santa Maria, under Process n. 9235210322.

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