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Carcass traits and short-chain fatty acid profile in cecal digesta of piglets fed alfalfa hay and fructooligosaccharides

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ABSTRACT - The objective of this study was to evaluate the effects of the addition of the prebiotic fructooligosaccharide and/or alfalfa hay to piglet diets on carcass traits and short-chain fatty acid profiles in the cecal digesta. Seventy-two commercial crossbred piglets of both sexes, with an average initial weight about 6 kg and age of approximately 21 days, were distributed in a randomized block design, using a factorial scheme, which consisted of three alfalfa hay levels (0, 5, and 10%) and two fructooligosaccharide levels (0 and 0.3%). Fiber addition in the presence of the prebiotic exerted an effect on cecal digesta short-chain fatty acid, increasing the acetic and reducing the butyric acid concentrations. The meat quality was also affected by the treatments, water activity, water-holding capacity of meat, and especially the reduction of fat content and the increase of moisture. The treatments did not affect the pH and the ammonia content in the cecal digesta. Most carcass traits were not affected by the treatments, except for carcass weight and backfat thickness in points 1 and 2, that decreased with the inclusions of fiber and prebiotic. The addition of 5% alfalfa hay improves carcass and meat traits in growing pigs without any change in carcass weight, demonstrating the advantage of using this ingredient to obtain a healthy final product to the customers.

Key Words: backfat thickness, fiber, meat quality, prebiotic, swine

Introduction

Pork is the most important source of high-quality animal protein worldwide. Several nutritional strategies have been studied in an attempt to meet production requirements and to improve quality, such as a reduction in carcass fat. This can be achieved by including fibers to the animal diet, which reduce the energy consumed and provide benefits in carcass quality, characteristics sought by slaughterhouses and consumers.

The most challenging phase is the weaning of piglets because of the stress caused by the separation from the mother and the change in diet from liquid to solid. Consequently, these animals often suffer from diarrhea, causing problems in the development, or even death. In an attempt to reduce these losses, traditional growth promoters, such as antibiotics and chemotherapeutic agents, are added to the diet to improve animal performance due to their positive action on the microorganisms of the intestinal flora (Stefe et al., 2008). The use of antibiotics, as growth promoters in livestock, have been prohibited in Europe since 2006; therefore, additives such as prebiotics and probiotics are being studied as alternatives to the antimicrobial growth promoter. In general, studies have reported three different responses to the use of prebiotics: beneficial modulation of the host microbiota, a possible enhancer effect on the immune system and on certain anatomical aspects of the digestive system, and a consequent influence on animal performance (Budiño et al., 2010).

In pigs, only a small part of the components of dietary fibers is digested in the small intestine, providing the substrate for microbial fermentation in the large intestine. The main products of this fermentation are the short-chain fatty acids (SCFA): propionate, butyrate, and acetate. The calorie contribution of these SCFA in pigs has been estimated at 5 to 28% of maintenance energy requirements, depending on the frequency of feed intake and the dietary fiber level (NRC, 2012). These SCFA cause a reduction in intestinal pH, which is related to the growth inhibition

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of pathogenic bacteria and provides better conditions for the growth of probiotic microorganisms (McDonald et al., 2006). Thus, the inclusion of fiber-rich feeds combined with a prebiotic can improve the use of this material by the swine digestive system, as well as contribute to the improvement of meat quality by reducing the fat content.

The objective of this study was to evaluate the effects of the separate or combined administration of alfalfa hay fiber and fructooligosaccharide (FOS) on carcass characteristics, meat quality, and the SCFA profile, pH, and NH_3 of the cecal content.

Material and Methods

The present study was approved by the animal welfare committee in São Paulo, SP, Brazil. The facilities were two identical rooms with 18 elevated cages in each one. All cages were provided with a feeder and a nipple drinker; half of the cage floor was half solid and half slatted plastic; and the temperature was controlled using air conditioner, when necessary.

Seventy-two piglets with a mean age of 21 days and an average initial body weight of 5.95±0.75 kg were divided into six treatments and six replications of two animals (one male and one female) per experimental unit. The pelletized alfalfa hay and/or the prebiotic FOS (Fortifeed® - Corn Products Brazil) were mixed with the other ingredients in a feed mill according to the treatments. The animals were subjected to the following treatments: a control diet without FOS; a control diet + 0.3% FOS; a diet containing 5% alfalfa without FOS; a diet containing 5% alfalfa + 0.3% FOS; a diet containing 10% alfalfa without FOS; a diet containing 10% alfalfa + 0.3% FOS. The alfalfa hay inclusion was calculated to increase the neutral detergent fiber content, in a considered not prejudicial ammount to the intake of piglets because their gastrointestinal tract are not totally developed. The FOS inclusion was according to the manufacturer's recommendation. The experimental diets, divided into three phases, according to the age of the animals, were formulated in such a way as to meet the minimal nutritional requirements of animals proposed by the NRC (2012). These formulations were based on the nutritional composition of feeds reported by Rostagno et al. (2011), with the usual ingredients that compose a piglet diet, such as corn, soybean meal, sugar (palatability), and soybean oil (Table 1: 21 to 28 days of age; Table 2: 29 to 42 days of age; and Table 3: 43 days to 59 days of age).

When the animals were 59 days of age, one piglet (a female) of each experimental unit was slaughtered in accordance with the norms of the technical regulations of stunning methods for slaughter (Ministério da Agricultura, 2000), using an electrical shock.

Cecal digesta samples were collected for the measurement of pH, the quantification of N-NH_3 content, and the analysis of SCFA profile. The pH was measured during sample collection with a portable pH-meter Lutron 221. The N-NH_3 content was measured in accordance with Fenner's methodology (Fenner, 1965). The SCFA concentration was determined by gas chromatography (Erwin et al., 1961).

The following analyses were performed for the evaluation of carcass traits: carcass weight; hot carcass weight after the removal of viscera; carcass length measured with a metal tape from the first rib to the *ischiopubic symphysis*, according to the Brazilian method of carcass evaluation (ABCS, 1973); and organ weight of the digestive system, as described by Jorgensen et al. (1996). These assessments were done on the day of slaughter. Cooling of the left half-carcasses was necessary for other procedures. Therefore, these carcasses were stored at 0 to

Table 1 - Percent composition and nutrient content of the diets (control, 5% alfalfa, and 10% alfalfa) offered to piglets during the pre-initial phase (21 to 28 days of age)

Ingredient (%)	Control	5% alfalfa	10% alfalfa
Alfalfa (hay)	-	5.000	10.000
Soybean meal, 46%	20.000	17.000	16.600
Corn[1]	37.800	33.800	24.570
Sugar	2.000	2.000	2.000
Soybean oil	0.200	2.000	6.500
Premix[2]	40.000	40.000	40.000
L-lysine (HCl, 78%)	-	0.120	0.166
L-threonine (98%)	-	0.040	0.080
DL-methionine (99%)	-	0.040	0.085
Total	100.000	100.000	100.000
Calculated values			
Energy (digestible) (kcal/kg)	3.267	3.180	3.225
Crude protein (%)	20.822	20.095	20.148
Lysine (digestible) (%)	1.709	1.700	1.700
Methionine (digestible) (%)	0.634	0.644	0.663
Met+Cys (digestible) (%)	0.983	0.965	0.965
Threonine (digestible) (%)	1.091	1.063	1.063
Tryptophane (digestible) (%)	0.263	0.240	0.230
Calcium (%)	0.621	0.684	0.754
Total phosphorus (%)	0.619	0.603	0.590
Sodium (%)	0.310	0.307	0.304
Neutral detergent fiber (NDF) (%)	6.280	7.590	8.820
NDF increment provided by alfalfa (%)	-	1.940	3.880

[1] Fructooligosaccharide was added to corn in the treatments in which the prebiotic was tested.

[2] Guaranteed levels per kg ration: vitamin A, 30,000 IU; vitamin D_3, 5,500 IU; vitamin E, 187.5 mg; vitamin K_3, 12.5 mg; vitamin B_1, 5.0 mg; vitamin B_2, 12.50 mg; vitamin B_6, 7.50 mg; vitamin B_{12}, 100 µg; folic acid, 1 mg; pantothenic acid, 75 mg; niacin, 125 mg; biotin, 0.75 mg; choline, 3,000 mg; calcium (max.), 21 g; phosphorus (min.), 12.20 g; fluoride (max.), 122 mg; sodium, 5.5 g; iron, 250 mg; copper, 30 mg; zinc, 250 mg; manganese, 100 mg; iodine, 2.48 mg; selenium, 1 mg; cobalt, 1.88 mg; crude protein (min.), 18%; lysine, 16,000 mg; methionine, 7,200 mg; threonine, 10,603.6 mg; lactose (min.), 20%; flavoring agent, 500 mg; metabolizable energy, 3,000 kcal/kg; antioxidant, 0.025%.

2 °C for 20 h for the evaluation of backfat thickness and loin eye area. Backfat thickness was measured at three different sites according to the USDA (1994): backfat thickness 1 was measured at the first thoracic vertebra, backfat thickness 2 was measured at the last thoracic vertebra, and backfat thickness 3 was measured at the last lumbar vertebra. The loin eye area was defined using the method described by ABCS (1973).

The *longissimus dorsi* muscle was cut for the following physical and chemical analyses of the fresh meat: pH, determined 24 h after slaughter with a DM-2 Digimed© pH meter; moisture content, determined as described Horwitz (2005); water activity, determined with an Aqualab CX-2 apparatus (Decagon Devices, Inc., Operators Manual version 3.0); fat percentage (total fat), determined as described by Horwitz (2005); water-holding capacity, determined as described by Hofmann et al. (1982).

A randomized block design was used to control initial differences in weight, which consisted of six treatments and six replications in a 3 × 2 factorial scheme (three levels of alfalfa hay and two levels of FOS). The experimental unit consisted of two animals (male and female). Analysis of variance was performed using the GLM procedure of the SAS software (Statistical Analysis System, version 9.0), considering the significant level at 5% (F test) ($P<0.05$). Two different contrast analyses were performed due to the interactions between treatments. Contrast 1 compared the diets without alfalfa hay with the remaining diets and contrast 2 compared the diets containing 5% alfalfa hay with the diets containing 10% alfalfa hay.

Results and Discussion

The data presented in this study are associated with the performance results of animals published in Budiño et al. (2015), in which no effect on performance parameters were obtained with the treatment diets.

No difference ($P>0.05$) in the molar percentage (mmol/L) of the SCFA studied was observed between the groups without FOS (Table 4). An increase ($P<0.05$) in the molar percentage of acetate was observed in piglets fed diet containing 0.3% FOS plus alfalfa hay when compared

Table 2 - Percent composition and nutrient content of the diets (control, 5% alfalfa, and 10% alfalfa) offered to piglets during initial phase 1 (29 to 42 days of age)

Ingredient (%)	Control	5% alfalfa	10% alfalfa
Alfalfa (hay)	-	5.000	10.000
Soybean meal, 46%	29.000	25.600	25.400
Corn[1]	47.900	42.910	34.710
Sugar	2.000	2.000	2.000
Soybean oil	1.100	4.300	7.600
Premix[2]	20.000	20.000	20.000
L-lysine (HCl, 78%)	-	0.011	0.015
L-threonine (98%)	-	0.040	0.070
DL-methionine (99%)	-	0.040	0.070
Total	100.000	100.000	100.000
Calculated values			
Energy (digestible) (kcal/kg)	3.337	3.318	3.304
Crude protein (%)	21.341	20.364	20.532
Lysine (digestible) (%)	1.529	1.500	1.500
Methionine (digestible) (%)	0.561	0.565	0.581
Met+Cys (digestible) (%)	0.898	0.870	0.870
Threonine (digestible) (%)	1.020	0.980	0.980
Tryptophane (digestible) (%)	0.280	0.254	0.245
Calcium (%)	0.728	0.790	0.860
Total phosphorus (%)	0.610	0.590	0.580
Sodium (%)	0.190	0.186	0.183
Neutral detergent fiber (NDF) (%)	8.440	11.270	10.860
NDF increment provide by alfalfa (%)	-	1.940	3.880

[1] Fructooligosaccharide was added to corn in the treatments in which the prebiotic was tested.
[2] Guaranteed levels per kg ration: vitamin A, 60,000 IU; vitamin D_3, 11,0000 IU; vitamin E, 375.0 mg; vitamin K_3, 25 mg; vitamin B_1, 10.0 mg; vitamin B_2, 25 mg; vitamin B_6, 15 mg; vitamin B_{12}, 200 µg; folic acid, 2 mg; pantothenic acid, 150 mg; niacin, 250 mg; biotin, 1.5 mg; choline, 4,000 mg; calcium (max.), 43.75 g; phosphorus (min.), 21.25 g; sodium, 10 g; iron, 500 mg; copper, 57.5 mg; zinc, 500 mg; manganese, 300 mg; iodine, 3.875 mg; selenium, 2 mg; cobalt, 3.75 mg; crude protein (min.), 21%; lysine, 16,250 mg; methionine, 11,250 mg; threonine, 13,500 mg; lactose (min.), 20%; antioxidant, 50 mg.

Table 3 - Percent composition and nutrient content of the diets (control, 5% alfalfa, and 10% alfalfa) offered to piglets during initial phase 2 (from 43 days of age)

Ingredient (%)	Control	5% alfalfa	10% alfalfa
Alfalfa (hay)	-	5.000	10.000
Soybean meal, 46%	29.600	30.000	30.200
Corn[1]	63.195	56.390	48.188
Sugar	2.000	2.000	2.000
Soybean oil	1.000	2.400	5.300
Premix[2]	4.000	4.000	4.000
L-lysine (HCl, 78%)	0.020	0.010	0.047
L-threonine (98%)	0.015	0.020	0.055
DL-methionine (99%)	0.170	0.180	0.210
Total	100.000	100.000	100.000
Calculated values			
Energy (digestible) (kcal/kg)	3.419	3.315	3.282
Crude protein, (%)	19.500	20.218	20.360
Lysine (digestible) (%)	1.280	1.280	1.280
Methionine (digestible) (%)	0.547	0.547	0.562
Met+Cys (digestible) (%)	0.877	0.871	0.870
Threonine (digestible) (%)	0.800	0.800	0.800
Tryptophane (digestible) (%)	0.254	0.254	0.245
Calcium (%)	0.820	0.893	0.962
Total phosphorus (%)	0.593	0.592	0.583
Sodium (%)	0.185	0.184	0.181
Neutral detergent fiber (NDF) (%)	9.900	11.340	12.530
NDF increment provide by alfalfa (%)	-	1.940	3.880

[1] Fructooligosaccharide was added to corn in the treatments in which the prebiotic was tested.
[2] Guaranteed levels per kg ration: vitamin A, 262,500 IU; vitamin D_3, 55,000 IU; vitamin E, 1.875 mg; vitamin K_3, 100 mg; vitamin B_1, 50.0 mg; vitamin B_2, 125.0 mg; vitamin B_6, 75.0 mg; vitamin B_{12}, 1 µg; folic acid, 10 mg; pantothenic acid, 500 mg; niacin, 1,000 mg; biotin, 5.0 mg; choline, 10,000 mg; calcium (max.), 183 g; phosphorus (min.), 67 g; sodium, 36 g; iron, 2,000 mg; copper, 300 mg; zinc, 2,250 mg; manganese, 875 mg; iodine, 17.5 mg; selenium, 8.75 mg; cobalt, 16.25 mg; lysine, 7,000 mg; methionine, 5,000 mg; flavoring agent, 0.063%; antioxidant, 0.125%.

with the control group (0% alfalfa, 0% FOS). In contrast, there was a decrease (P<0.05) in the molar percentage of butyrate in animals fed diets containing 5 or 10% alfalfa hay compared with the control group. However, no difference (P>0.05) in the molar percentage of propionate was observed among the studied treatments.

One of the best known effects of prebiotics is the increase of SCFA production in the large intestine, which contributes to decline the pH and, consequently, reduces the capacity of pathogens to colonize the intestine (Gomes et al., 2011). The increase in the molar percentage of acetate is probably due to the higher amount of dietary fiber, whose main fermentation product is acetate. Martins et al. (2010) studied the effects of barley bagasse and wheat flour in piglets and concluded that the increased fiber contents, except for barley bagasse, resulted in an increase in SCFA produced in the cecum. Freire et al. (2000), evaluating different fiber sources (wheat bran, beet pulp, soybean hull, and alfalfa meal) in piglet diets, found no significant difference in the production of propionate, as was observed in the present study.

The addition of fiber sources to piglet diets has been shown to influence the fermented end-products in the large intestine. Furthermore, the types of fiber contained in the different sources directly affects the fatty acid profile. However, a change in this profile only occurs if the amount of substrate is efficient in modifying or increasing the intestinal microbiota (Solà-Oriol et al., 2011). In addition, the presence of a prebiotic can positively affect the colonization of fermentative bacteria and also influence the production of SCFA (Gomes et al., 2011).

According to Montagne et al. (2010), the addition of prebiotics and fiber sources to piglet diets exerts a direct effect on the intestinal microbiota, consequently altering the production of SCFA. A higher production of these acids promotes a reduction in pH, which in turn inhibits the development of populations of harmful, acid-sensitive bacteria, such as *Escherichia coli*, *Clostridium* sp., and *Salmonella* sp.. In addition, a reduction in intestinal pH improves the activity of digestive enzymes; however, no difference in pH cecal digesta samples was observed in the present study (P>0.05) (Table 4).

The results can vary depending on the type and quantity of added fiber, as well as the percentage of the prebiotic. A lack of a significant difference in cecal digesta pH has also been reported by Martins et al. (2010), who studied the effects of different fiber sources (wheat flour, unwashed, and washed barley bagasse) in piglet diets, and Pascoal et al. (2012), who evaluated the addition of pure cellulose, soybean hull, and citrus pulp to piglet diets.

No difference (P>0.05) in the N-NH_3 was observed among the treatments (Table 4), which indirectly suggests

Table 4 - Cecal digesta characteristics of piglets fed three levels of alfalfa hay (0%, 5%, and 10%) and two levels of fructooligosaccharide (0% and 0.3%)

FOS	Alfalfa			Mean±SD	Contrast	
	0%	5%	10%		1	2
		Acetate (mmol/L)				
0%	52.78±1.87	54.36±1.87	57.22±1.87	54.79±1.08	ns	ns
0.3%	51.65±1.87	56.52±1.87	56.89±1.87	55.02±1.08	*	ns
Mean	52.21±1.32	55.44±1.32	57.05±1.32		ns	ns
		Propionate (mmol/L)				
0%	33.14±2.21	30.63±2.21	31.60±2.21	31.79±1.28	ns	ns
0.3%	30.31±2.21	31.35±2.21	28.57±2.21	30.08±1.28	ns	ns
Mean	31.72±1.56	30.99±1.56	30.08±1.56		ns	ns
		Butyrate (mmol/L)				
0%	14.08±2.06	15.01±2.06	11.18±2.06	13.42±1.19	ns	ns
0.3%	18.03±2.06	12.13±2.06	14.53±2.06	14.90±1.19	*	ns
Mean	16.06±1.46	13.57±1.46	12.86±1.46		ns	ns
		pH				
0%	5.91±0.12	5.70±0.12	5.91±0.12	5.84±0.07	ns	ns
0.3%	5.77±0.12	5.88±0.12	5.75±0.12	5.80±0.07	ns	ns
Mean	5.84±0.09	5.79±0.09	5.83±0.09		ns	ns
		N–NH_3 (g/kg)				
0%	0.23±0.05	0.23±0.05	0.20±0.05	0.22±0.03	ns	ns
0.3%	0.35±0.05	0.32±0.05	0.22±0.05	0.29±0.03	ns	ns
Mean	0.29±0.03	0.27±0.03	0.21±0.03		ns	ns

FOS - fructooligosaccharides; SD - standard deviation; ns - not significant.
* Significant statistical difference (P<0.05).

that the fiber fermentation level was the same in all treatments. The physical properties of dietary fiber (water-holding capacity, viscosity, and solubility) influence ammonia levels, since the latter is the main source of nitrogen for microorganisms, and they decrease proteolytic fermentations, reducing the loss of nitrogen on farms (Jeaurond et al., 2008). The present study agrees with the results reported by Freire et al. (2003), who tested piglet diets, in which wheat was replaced by wheat bran. These authors concluded that the N-NH_3 concentration was not significantly affected by the level of dietary fiber. Possenti et al. (2008) also found no significant differences in the ruminal N-NH_3 concentration between cattle diets containing different levels of *Leucaena* in the presence or absence of yeast.

No difference (P>0.05) in carcass weight was observed among the groups of piglets fed diets without the FOS (Table 5). In contrast, in piglets fed diets containing 0.3% FOS, the contrasts demonstrated a reduction (P<0.05) in carcass weight for the diet containing 10% alfalfa compared with the diet containing 5%.

Rekiel et al. (2005) observed no differences in carcass parameters of pigs that received diets containing mannanoligosaccharides (MOS) and antibiotics. Bellé et al. (2009) studied the addition of 0.2% prebiotics (0.1% MOS + 0.1% FOS) to pig diets and also observed no significant differences in carcass weight when compared with pigs fed control diet (no addition of prebiotics). Gomes et al. (2006) investigated the effect of the addition of 8% neutral detergent fiber (NDF; Tifton hay) to pig diets and found no significant differences in carcass traits.

An analysis of liver + gallbladder weight showed a higher mean weight (P<0.05) in the treatments with 0.3% FOS compared with those treatments without the prebiotic (Table 5). According to Martinez-Ramirez et al. (2008), organ weight varies according to energy and/or protein intake, suggesting that, if the same quantities of these components are maintained, the organ weights should be similar. In the present study, the diets were formulated to be isonitrogenous and isoenergetic; however, in the performance experiment carried out together with this analysis, a higher feed intake (P<0.05) was observed in animals receiving the diet with FOS (Budiño et al., 2015). This higher feed intake increases nutrient intake, which may explain the increase in liver + gallbladder weight (P<0.05).

An increase in empty stomach weight (P<0.05) was observed in animals fed 0.3% FOS compared with those that were fed diet without FOS (Table 5). Gomes et al. (2006) studied the addition of 8% NDF to nursery pig diets and observed an increase in stomach weight (percentage of live weight). In the study by Pond et al. (1988), the relative

Table 5 - Carcass and organ weight yield of piglets fed three levels of alfalfa hay (0%, 5%, and 10%) and two levels of fructooligosaccharide (0% and 0.3%)

FOS	Alfalfa			Mean±SD	Contrast	
	0%	5%	10%		1	2
		Carcass (kg)				
0%	15.98±0.79	16.69±0.79	14.68±0.79	15.78±0.45	ns	ns
0.3%	17.11±0.79	16.37±0.79	14.42±0.79	15.97±0.45	ns	*
Mean	16.54±0.56	16.53±0.56	14.55±0.56		ns	ns
		Liver + gallbladder (g)				
0%	542.78±32.54	589.35±32.54	499.18±32.54	543.77±18.79B	ns	ns
0.3%	654.77±32.54	612.42±32.54	584.27±32.54	617.15±18.79A	ns	ns
Mean	598.77±23.01	600.88±23.01	541.72±23.01		ns	ns
		Empty stomach (g)				
0%	178.30±10.89	195.23±10.89	174.93±10.89	182.82±6.29B	ns	ns
0.3%	219.45±10.89	191.22±10.89	204.65±10.89	205.10±6.29A	ns	ns
Mean	198.87±7.70	193.22±7.70	189.79±7.70		ns	ns
		Intestine mass (g)				
0%	1844.92±154.83	2302.33±154.83	2110.77±154.83	2086.00±89.39	ns	ns
0.3%	2280.97±154.83	2231.67±154.83	1931.93±154.83	2148.19±89.39	ns	ns
Mean	2062.94±109.48	2267.00±109.48	2021.35±109.48		ns	ns
		Carcass yield (%)				
0%	73.28±0.97	75.95±0.97	78.99±0.97	74.07±0.56	*	ns
0.3%	71.27±0.97	71.88±0.97	71.57±0.97	71.57±0.56	ns	ns
Mean	72.27±0.69	73.92±0.69	72.28±0.69		ns	ns

FOS - fructooligosaccharides; SD - standard deviation; ns - not significant.
A, B - Means followed by the same uppercase letter in the columns do not differ from F test (P<0.05).
* Significant statistical difference (P<0.05).

weight of the empty stomach increased when a high-fiber diet was offered (43% NDF obtained by the addition of 80% alfalfa meal). According to Serena et al. (2008), this data suggests partial morphological adaptations of the organs to the dietary fiber component.

There was no difference (P>0.05) in intestine mass among the treatments, indicating that the addition of dietary fiber or FOS did not affect the weight of this organ (Table 5). Gomes et al. (2006), evaluating the addition of 8% NDF to nursery pig diets, observed an increase in the mass of the large intestine and filled cecum. In addition, animals receiving the high-NDF diet presented a higher gut weight at the end of the finisher phase. In addition to the increase in gut weight, Pekas et al. (1983) also found a higher weight of the small intestine and colon in finishing pigs fed 50% alfalfa hay. In a subsequent study, Pond et al. (1988) showed that the relative mass of the small and large intestines increased when the animals were fed a high-fiber diet (43% NDF obtained by the addition of 80% alfalfa meal).

An increase in carcass yield (P<0.05) was observed in groups receiving diets without FOS and with 5 and 10% alfalfa when compared with the group receiving the control treatment (Table 5). These results could be related to the increase of fiber level that would increase the intake, but not the fat deposition. Similar results were reported by Pekas et al. (1983), who fed finishing pigs 50% alfalfa hay, and by Pond et al. (1988), who studied the use of high-fiber diets (43% NDF by the addition of 80% alfalfa meal). The authors observed a reduction in the hot carcass yield of pigs during the grower and finisher phases. In contrast, Gomes et al. (2008) found no effect of the increase in dietary NDF on hot carcass yield. Bellé et al. (2009), evaluating the addition of 0.2% prebiotics (0.1% MOS + 0.1% FOS) to pig diets, observed no difference (P>0.05) in carcass yield when compared with the control diet.

No difference (P>0.05) in carcass length was observed among the studied treatments (Table 6). Backfat thickness, at the three sites studied, was not affected (P>0.05) by the addition of FOS (Table 6). A reduction (P<0.05) in backfat thickness 1, measured at the first thoracic vertebra, was observed in the groups receiving the diets without FOS but with 5 and 10% alfalfa, when compared with group receiving the control treatment. Mean backfat thickness 2, measured at the last thoracic vertebra, was reduced (P<0.05) in the treatments with alfalfa compared with the treatments without this fibrous ingredient. No difference (P>0.05) in backfat thickness 3, measured at the last lumbar vertebra, was observed among the studied treatments (Table 6).

An analysis of loin eye area showed no difference (P>0.05) among the studied treatments (Table 6). The reduction in backfat thickness and body fat and the

Table 6 - Carcass characteristics of piglets fed three levels of alfalfa hay (0%, 5%, and 10%) and two levels of fructooligosaccharide (0% and 0.3%)

FOS	Alfalfa			Mean±SD	Contrast	
	0%	5%	10%		1	2
		Length (cm)				
0%	49.83±1.08	49.50±1.08	48.17±1.08	49.17±0.62	ns	ns
0.3%	51.58±1.08	51.92±1.08	48.83±1.08	50.78±0.62	ns	ns
Mean	50.71±0.76	50.71±0.76	48.50±0.76		ns	ns
		Backfat thickness 1 (mm)				
0%	11.19±1.01	6.76±1.01	8.46±1.01	8.81±0.59	**	ns
0.3%	9.98±1.01	7.91±1.01	8.38±1.01	8.76±0.59	ns	ns
Mean	10.59±0.72	7.33±0.72	8.42±0.72		ns	ns
		Backfat thickness 2 (mm)				
0%	4.18±0.54	2.66±0.54	3.13±0.54	3.32±0.31	ns	ns
0.3%	3.70±0.54	3.38±0.54	2.40±0.54	3.16±0.31	ns	ns
Mean	3.94±0.38	3.02±0.38	2.75±0.38		*	ns
		Backfat thickness 3 (mm)				
0%	3.15±0.42	2.50±0.42	2.28±0.42	2.64±0.24	ns	ns
0.3%	3.06±0.42	2.91±0.42	3.33±0.42	3.10±0.24	ns	ns
Mean	3.10±0.30	2.71±0.30	2.80±0.30		ns	ns
		Loin eye area (cm^2)				
0%	14.94±1.08	14.48±1.08	15.17±1.08	14.86±0.62	ns	ns
0.3%	14.08±1.08	13.42±1.08	14.08±1.08	13.86±0.62	ns	ns
Mean	14.51±0.76	13.95±0.76	14.63±0.76		ns	ns

FOS - fructooligosaccharides; SD - standard deviation; ns - not significant.
* Significant statistical difference (P<0.05).
** Significant statistical difference (P<0.01).

increase in muscle mass production resulted in improved carcass quality, although they are generally associated with lower body weight gain of pigs fed fibrous diets. Therefore, if muscle percentage in the carcass increases and subcutaneous fat decreases with increasing levels of dietary fiber, these changes in carcass composition would represent indirect effects of the low carcass weight of pigs fed dietary fiber since the amount of lean meat of these carcasses generally increases with decreasing carcass weight (Jha and Berrocoso, 2015).

Varel et al. (1984), studying growing pigs fed 35% alfalfa meal, observed depressive effects on carcass traits, including lower carcass weight, lower loin eye area, and lower backfat thickness. Bellé et al. (2009), testing the addition of 0.2% prebiotics (0.1% MOS + 0.1% FOS) to pig diets, found no difference in backfat thickness when compared with pigs fed the control diet. The results presented here are according with these authors and it can suggest that the fibers and energy levels are the most important factor when evaluating the carcass traits.

The discordance between the results obtained might be due to factors such as differences in the animal genetics, level, composition and processing of dietary fiber, presence of antinutritional factors, environmental effects, age of the animals, and/or differences among the animal groups studied (Jha and Berrocoso, 2015). The addition of fiber to the diet of pigs destined to slaughter permits better control of carcass standards by adjusting body weight gain to lean meat yield, an approach that guarantees a higher yield of lean meat due to lower subcutaneous fat content (Gomes et al., 2008).

An increase ($P<0.05$) in the moisture content of meat was observed in piglets fed diets containing 0.3% FOS when compared with the control group and a decrease ($P<0.05$) in fat content in meat were observed in piglets fed diets containing 0.3% FOS and 5 or 10% alfalfa when compared with the control group (Table 7).

There was no difference ($P>0.05$) in meat pH among the studied treatments (Table 7). The pH in live muscles of pigs ranges from 7.0 to 7.2. Muscle pH declines during the conversion from muscle to meat and the final pH is important for the determination of pork quality. According to Boler et al. (2011), under normal conditions, the pH of pork decreases to values of 5.3 to 5.7 within a period of 24 h after slaughter, a fact also observed in the present study.

No difference ($P>0.05$) in water activity was observed for piglets fed diet without FOS (Table 7). In contrast, for the diets containing 0.3% FOS, an increase ($P<0.05$) in water activity was found for animals fed 10% alfalfa compared with those receiving 5% alfalfa.

Water activity indicates the strength of forces that bind water to other non-water components and, consequently, the amount of water available for the

Table 7 - Meat traits of the *longissimus dorsi* muscle of piglets fed three levels of alfalfa hay (0%, 5%, and 10%) and two levels of fructooligosaccharide (0% and 0.3%)

FOS	Alfalfa			Mean±SD	Contrast	
	0%	5%	10%		1	2
		Moisture (%)				
0%	74.47±0.39	75.55±0.39	74.85±0.39	74.95±0.22	ns	ns
0.3%	74.24±0.39	75.45±0.39	75.60±0.39	75.10±0.22	*	ns
Mean	74.35±0.27	75.50±0.27	75.22±0.27		ns	ns
		Fat (%)				
0%	5.41±0.47	4.30±0.47	4.75±0.47	4.82±0.27	ns	ns
0.3%	5.78±0.47	4.69±0.47	4.46±0.47	4.98±0.27	*	ns
Mean	5.59±0.33	4.49±0.33	4.61±0.33		ns	ns
		pH				
0%	5.46±0.10	5.53±0.10	5.44±0.10	5.48±0.06	ns	ns
0.3%	5.60±0.10	5.57±0.10	5.55±0.10	5.57±0.06	ns	ns
Mean	5.53±0.07	5.55±0.07	5.49±0.07		ns	ns
		Water activity				
0%	0.9933±0.0006	0.9938±0.0006	0.9930±0.0006	0.9934±0.0003	ns	ns
0.3%	0.9937±0.0006	0.9932±0.0006	0.9950±0.0006	0.9939±0.0003	ns	*
Mean	0.9935±0.0004	0.9935±0.0004	0.9940±0.0004			
		Water-holding capacity				
0%	0.31±0.01	0.28±0.01	0.28±0.01	0.29±0.009	ns	ns
0.3%	0.33±0.01	0.29±0.01	0.27±0.01	0.29±0.009	*	ns
Mean	0.32±0.01	0.29±0.01	0.27±0.01		ns	ns

FOS - fructooligosaccharides; SD - standard deviation; ns - not significant.
* Significant statistical difference ($P<0.05$).

growth of microorganisms and for different chemical and biochemical reactions (Ordónez, 2005). The values found in the present study agree with Silliker (1980), who defines fresh meat as a high-moisture food, with water activity of 0.98 or higher, allowing the growth of pathogenic bacteria and microorganisms that cause food spoilage.

A reduction (P<0.05) in the water-holding capacity of meat was observed in piglets fed diets containing 0.3% FOS and alfalfa compared with the control group (Table 7).

The water-holding capacity is defined as the ability of meat to retain water during the application of some external force (cutting, heating, grinding, or pressing) and is influenced by different factors such as pH variation. In this respect, the formation of lactic acid and the consequent post-mortem pH decline reduce the water-holding capacity of meat. This trait affects the appearance and weight loss of the meat before cooking, the behavior of meat during cooking, and juiciness during mastication. A reduced water-holding capacity, therefore, compromises meat quality (Araújo, 1995).

Conclusions

The addition of 5% alfalfa hay allows improvement in some carcass and meat traits in growing pigs without any change in carcass weight, comparing the result with the diets without and with 10% alfalfa hay. These findings demonstrate the advantage of using this fibrous feed ingredient, providing a better final product to the customers that are more worried about buying healthy products.

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