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Finishing swine fed cashew bagasse bran

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ABSTRACT - The purpose of this study was to evaluate the digestibility of cashew bagasse bran as well as the performance of swine fed diets with different levels of inclusion of this by-product and their economic viability. In the digestibility trial, ten crossbred barrows weighing 60±6.86 kg were housed in metabolic cages. Five received standard feed and five received test feed with 300 g kg^{-1} cashew bagasse bran included. For the performance and economic viability study, forty crossbred pigs weighing 60±5.24 kg were allotted in a randomized block design with five treatments (0, 75, 150, 225, and 300 g kg^{-1} inclusion of cashew bagasse bran) and four replications. Daily feed intake, daily gain, feed conversion, partial gross income with and without allowance index, and partial net income with and without allowance index were evaluated. Data were subjected to analysis of variance and regression analysis. The treatment with 75 g kg^{-1} cashew bagasse bran provided the best results. Cashew bagasse bran can be included in the diet of finishing pigs up to the level of 300 g kg^{-1} without adversely affecting animal performance.

Key Words: alternative feed, crude fiber, pig, pseudo cashew

Introduction

Feeding is the most costly item on pig farms, representing 65% of total costs of the farming activity. In this respect, the possibility of earning profits from swine culture depends on proper feed planning, which involves availability of ingredients in adequate quantity and quality at prices that allow production. Given this scenario, there is a growing demand for alternative feeds in animal nutrition using by-products and industrial waste, especially because of the apparent nutritional value, abundance, and non-utilization of these wastes, besides the prospect of lower costs for the producer (Albuquerque et al., 2011).

In Brazil, the energy source for non-ruminant animals are corn and soybean meal. In recent years, the national demand for these inputs for animal feed has been higher than the production and availability. Thus, research on alternative products and by-products becomes essential, especially with those ingredients available throughout the off-season, or throughout the year (Arouca et al., 2012). Therefore, it is necessary and important to find alternative ingredients to solve or at least minimize this demand (Amorim et al., 2011).

The Food and Agriculture Organization of the United Nations (FAO, 2014) states that world production of cashew nuts grew 434% over the past 10 years, with Brazil accounting for 6.3% of the total. Because of the increased cashew processing in Brazil, this fruit has been studied for inclusion in feed for broiler chickens (Ramos et al., 2006; Lopes et al., 2005), sheep (Rodrigues et al., 2003), and pig (Farias et al., 2008).

As reported by Araújo (1983), Embrapa (1991), and Ramos et al. (2006), the pseudo dehydrated fruit of cashew tree contains 87.99, 85.85, and 88.70% dry matter; 8.11, 8.11, and 14.00% crude protein; 15.40, 6.82, and 12.07% crude fiber; 2.86, 3.16, and 4.15% ether extract; 0.28, 0.13, and 0.45% calcium; and 0.14, 0.14, and 0.30% phosphorus, respectively.

Farias et al. (2008) evaluated the cashew bagasse at four different inclusion levels (5, 10, 15, and 20%) and observed that weight gain (WG) and feed conversion (FC) of growing pigs were not influenced by the inclusion levels, evidencing that this by-product can be used at the maximum level tested.

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In this context, this study aimed to evaluate the digestibility of cashew bagasse, the performance of pigs fed diets with different inclusion levels of cashew bagasse bran (CBB), and the economic viability of these diets.

Material and Methods

The experiment was developed in Natal-RN, located in the coastal area of Brazil (38 m altitude, 05°47'40" South latitude, and 35°12'40" West longitude). The average precipitation in the region is 1,378.3 mm; the climate is a typical tropical type (Köppen's climate classification). The average temperatures and relative humidity in the region are 32 ºC (maximum), 23 ºC (minimum), and 81%, respectively. All animal procedures were approved by the Ethics Committee on Animal Use (no. 004/2011), and were carried out in accordance with the Guide for Animal Experiments from Universidade Federal do Rio Grande do Norte.

To determine the digestibility of cashew bagasse bran, ten barrows with an initial average weight of 60±6.86 kg were distributed individually into metabolic cages as described by Pekas (1968). A completely randomized block design with two treatments and five replications was used, considering the metabolic cage as the experimental unit. The experiment lasted fifteen days, nine of which were used for adaptation to metabolic cages and experimental diets, adjustment of voluntary intake, and regulation of feed intake. The last six days were used for feces collection.

Treatments consisted of a control diet based on corn and soybean meal, formulated to meet the nutritional requirements for finishing pigs as described by Rostagno et al. (2005), and a test diet containing 700 g kg^{-1} of the control diet and 300 g kg^{-1} cashew bagasse bran. The experimental diets (Table 1) were distributed in two daily meals provided at 08.00 h and 15.00 h. The amount of feed was adjusted gradually, and at the end of the adaptation phase, the animals received the amount of feed according to the intake in the adaptation phase based on the metabolic weight ($BW^{0.75}$) of each experimental unit.

Water was provided *ad libitum*. The total fecal collection method without use of marker (Bayley, 1971) was adopted. Feces were collected daily at 07.00 h, weighed, macerated, and homogenized. An aliquot of 20% of the total content of feces of each animal was sampled and stored in a freezer at −5 °C.

After the collection period, feces were thawed at room temperature for six hours, homogenized, and then 600 g of feces from each sample were sampled and stored in a forced-air oven at 55 °C for 72 h. After pre-drying, samples were ground in a rotor-type mill with circular sieve size # 2 to determine crude protein (CP), neutral detergent fiber (NDF), acid detergent fiber (ADF), mineral matter (MM), gross energy (GE), EE ether extract, calcium (Ca) and phosphorus (P). Dry matter (DM), CP, and MM were determined according to Silva and Queiroz (2002); NDF and ADF according to the method proposed by Van Soest (1994); and Ca and P in accordance with the methods described by Zenebom et al. (2008). Gross energy (GE) was determined in a bomb calorimeter, and the digestibility of dietary components was determined according to the calculations described by Rodrigues (2010).

For the study of performance, forty crossbred pigs of a commercial strain (twenty gilts and twenty barrows) with an average initial weight of 60.0±5.24 kg were housed in pens with cement floors equipped with simple concrete feeder and nipple drinker. The animals were distributed in a randomized block design with five treatments and four replications. The criterion used for the formation of the blocks was animal weight. The experimental unit was represented by a gilt or barrow.

Dietary treatments (Table 1) were corn-soybean meal-based basal diet supplemented with different levels of cashew bagasse bran (0, 75, 150, 225, and 300 g kg^{-1}).

Table 1 - Proportions of ingredients in treatments with different cashew bagasse bran (CBB) levels

Ingredient	CBB inclusion level (g kg^{-1})				
	0	75	150	225	300
Corn	748.5	688.5	628.6	568.6	508.6
Soybean meal (45%)	221.5	206.4	191.4	176.4	161.3
Commercial supplement (evimix)[1]	25.0	25.0	25.0	25.0	25.0
Soybean oil	05.0	05.0	05.0	05.0	05.0
Cashew bagasse bran	0	75	150	225	300
Total	1,000	1,000	1,000	1,000	1,000
Calculated composition					
Digestible energy (kcal/kg)	3,400	3,258	3,114	2,971	2,827
Crude protein	165.0	165.0	165.0	165.0	165.0
Digestible lysine	6.9	6.7	6.4	6.1	5.9
Digestible methionine	2.5	2.5	2.4	2.4	2.4
Digestible tryptophan	1.6	1.5	1.4	1.3	1.2
Calcium	6.9	6.9	6.9	6.9	6.9
Total phosphorus	3.1	3.1	3.1	3.1	3.1
Available phosphorus	1.4	1.4	1.4	1.4	1.4
Sodium	1.7	1.7	1.7	1.6	1.6
Crude fiber	27.7	37.2	46.9	56.2	65.6
Neutral detergent fiber	116.8	158.9	201.1	243.2	285.3
Acid detergent fiber	042.8	070.5	098.1	125.8	153.4

[1] Guaranteed levels per kilogram: calcium (min) - 240 g; calcium (max) - 245 g; phosphorus (min) - 25 g; sodium (min) - 55 g; iron (min) - 3,200 mg; copper (min) - 5,000 mg; manganese (min) - 1,280 mg; zinc (min) - 2,400 mg; iodine (min) - 25.50 mg; cobalt (min) - 12.80 mg; selenium (min) - 9.60 mg; vitamin A (min) - 180 IU; vitamin D3 (min) - 32,000 IU; vitamin E (min) - 720 IU; vitamin K3 (min) - 36 mg; vitamin B1 (min) - 27 mg; vitamin B2 (min) - 108 mg; niacin (min) - 638 mg; pantothenic acid (min) - 362 mg; vitamin B6 (min) - 36 mg; folic acid (min) - 18 mg; biotin (min) 1.80 mg; vitamin - B12 (min) 580 mg; colistin - 200 mg; phytase - 17 U/g.

Water and feed were provided *ad libitum*. The cashew bagasse bran was obtained from the extraction of cashew pulp. Then the residue (bagasse) was dried and crushed.

The animals were weighed every 14 days to determine daily feed intake (DFI), daily weight gain (DWG), and feed conversion (FC).

Upon reaching a mean weight of 90±6.8 kg, the animals were slaughtered. The following carcass data were obtained: backfat thickness (BT), loin depth (LD), and hot carcass weight (HCW), in accordance with Bridi and Silva (2009). These data were used to study the economic viability.

Feed costs were determined from the total feed intake of each animal during the experimental period and the cost per kilogram of feed.

The economic viability of the diets was calculated according to Ramos et al. (2006), considering the ratio of total average cost (TAC, $) to average weight gain (kg). The following variables were used for calculation: average feed intake (kg), average weight gain (kg), feed cost ($/kg), total feed cost, and average body weight (kg).

The allowance index was calculated as determined by Fávero et al. (1997). For that, first the percentage of lean meat (%LM) (Equation 1) was determined, as proposed by Guidone (2000):

$$\%LM = 65.92 - 0.685 * BT + 0.094 * LD - 0.026 * HCW \quad \text{(Eq. 1)}$$

$$AI = 37.04721 + 0.094412 * HCW + 1.144822 * \%LM - 0.00005306\,7 * HCW * \%LM + 0.00001833\,6 * HCW2 + 0.000409 * \%LM2 \quad \text{(Eq. 2)}$$

To determine income, it was necessary to calculate the return from sale of pigs. Therefore, two calculations were made, with and without the inclusion of the allowance index (Fávero et al., 1997). The AI equation was excluded from the calculations, since the slaughterhouses of that region did not adopt this practice with the producer.

$$\text{Final price (\$)} = AI * [\text{inicial pig price per kg}/0.7145]\ HCW \quad \text{(Eq. 3)}$$

$$\text{Final price (\$)} = \text{final weight} * \text{carcass price per kg} \quad \text{(Eq. 4)}$$

Partial gross income and partial net income were calculated with and without the allowance index (Equations 5 and 6).

$$\text{Partial gross income with allowance index (PGIAI)} = \text{f pig AI} - \text{i pig} \quad \text{(Eq. 5)}$$

$$\text{Partial gross income (PGI)} = \text{final weight} - \text{initial weight} \quad \text{(Eq. 6)}$$

$$\text{Partial net income with AI} = \text{PGIAI} - \text{feed cost} \quad \text{(Eq. 7)}$$

$$\text{Partial net income} = \text{PGI} - \text{feed cost} \quad \text{(Eq. 8)}$$

The final gross income and the net income were not calculated, because the purpose of this study was to determine the feed cost rather than the production cost.

Data of production performance and economic viability were subjected to analysis of variance. Regression analysis was performed for the effect of CBB levels, using polynomial models. All statistical analyses were performed using procedures PROC MIXED and PROC REG of SAS (Statistical Analysis System, version 9.1).

Results and Discussion

The present results differ from those reported by Farias et al. (2008), who found digestibility coefficients for DM of 224 g kg^{-1}, CP of 123 g kg^{-1}, and crude fiber of 219.2 g kg^{-1}. According to Paiva et al. (2004) and Câmara (2010), there are different nuts classifications, which are normalized according to the specifications of the Association of Food Industries (AFI, 2008) in the United States, and the Technical Regulation for Cashew Nut, Ministry of Agriculture (Brasil, 2009). The divergence of results may be due to the methods of planting, variety or cashew tree, and factors that can change the chemical composition of the material.

According to Oliveira et al. (2005), several factors affect digestibility, including the absence of endogenous enzymes required for he fiber digestion in the pig digestive system. Santos et al. (2005) reported that the gastrointestinal tract of the pig is not capable to store large amounts of food, causing an increased rate of digesta passage through the gastrointestinal tract and less contact time between digesta and digestive enzymes and absorptive cells of the small intestine. Another factor that can interfere with feed digestibility is the presence of fiber sources (pectin, fructans, and β-glucans) containing viscous polysaccharides, leading to increased viscosity due to contact of soluble fiber with the aqueous environment of the intestinal lumen. As also reported by Gomes et al. (2006), this may have hindered the action of endogenous enzymes in the digestion of nutrients, decreasing their utilization by the animal.

However, the digestibility of neutral detergent fiber (152.2 g kg^{-1}) and acid detergent fiber (130.5 g kg^{-1}) indicates that part of the fiber content of diet was exploited by the microbiota of the large intestine (Table 2). In this process, microorganisms produce protein by adsorbing amino acids and peptides from the fiber matrix, leading to low digestibility of crude protein, since there is increased excretion of endogenous fecal nitrogen (Shulze et al., 1994). In addition, the intestinal epithelium desquamation caused by the fiber content also increases endogenous nitrogen in feces, resulting in a reduction of this coefficient. Ramos et al. (2007) studied growing broilers fed cashew bagasse and found that the metabolizability coefficient of crude protein was reduced with increasing dietary fiber.

The gross energy of CBB was 4,085 kcal/kg, while the digestible energy was 2,470 kcal/kg. These results differ from those observed by Farias et al. (2008), who found 1,123 kcal/kg of digestible energy. Certainly, these differences are due to different capacities to absorb fibrous foods in growing and finishing pigs. Santos et al. (2005) argue that the gastrointestinal tract of finishing pigs has a larger size, with high cecum microbial population (*Bacteroides succinogenes*, *Ruminococcus flavefaciens*, *Bacteroides ruminícola*, and *Ruminococcus álbuns*) fermenting cellulose, hemicellulose, and pectin.

The high digestible energy of CBB found in this study suggests that the pigs utilized the short-chain fatty acids resulting from the fiber fermentation by bacteria. These fatty acids (Kien et al. 2007) also contribute to the increase in blood supply to the collon, rate of intestinal epithelial cell turnover, and abnormal intestinal motility; and to improve the production of protective mucus lining the intestine wall.

The Ca (5 g kg^{-1}) and P (3.5 g kg^{-1}) levels in CBB are in accordance with the findings reported by Ramos et al. (2006), who investigated the inclusion of CBB in the diet of broilers in the final phase and found similar levels of Ca (4.5 g kg^{-1}) and P (3 g kg^{-1}). However, these results do not ensure full utilization of these minerals by pigs, since P may be complexed with phytic acid present in vegetables. The availability of P from ingredients of plant origin for monogastric animals is one third of the total analyzed because pigs have no enzymes capable of breaking down phytic acid molecules and release the compounds. In addition, P utilization depends mainly on the Ca:P ratio, presence of vitamin D, intestinal pH, age of the animal, and sex (Moreira et al., 2010).

Table 2 - Coefficients of digestibility and gross energy, digestible energy, mineral matter, Ca, and P in cashew bagasse bran

Variable	Digestibility coefficient (g kg^{-1})
Dry matter	442.6
Crude protein	082.0
Acid detergent fiber	130.5
Neutral detergent fiber	152.2
Variable	Value
Gross energy (kcal/kg)	4,081
Digestible energy (kcal/kg)	2,470
Mineral matter	066.1
Calcium	5.0
Phosphorus	3.5

No significant difference (P>0.05) was observed in feed intake and animal weight gain for all treatments (Table 3). However, different CBB levels significantly influenced (P<0.05) feed conversion (FC), with unfavorable results with increasing CBB levels. These results confirm the digestibility trial, indicating that high levels of dietary fiber limit the utilization of nutrients by finishing pigs. Ramos et al. (2006) reported that the feed conversion decreased with every percentage unit CBB inclusion. According to Gomes et al. (2008), inclusion of high levels of dietary fiber in the diet of pigs may cause desquamation of the intestinal epithelium, decreasing villi and cells secreting absorptive digestive enzymes, thus reducing the use of nutrients by the animal.

Although no statistical difference was observed in feed intake, the animals tended to increase their intake until the fourth treatment. The probable cause of this behavior is that pigs feed in attempt to meet their energy requirements, and it is observed that the energy level of the treatment diminishes as the inclusion of cashew bagasse bran is increased. However, from the forth treatment onwards, a reduction was observed in feed intake and weight gain. The amount of soluble fiber present in these treatments possibly caused a greater sense of satiety to the animals, since some non-amylaceous polysaccharides present in fibrous feedstuffs like gums, mucilages, pectins, and glucans, when in contact with the aqueous environment of the intestinal lumen, are solubilized, forming viscous substances that can slow gastric emptying and consequently increase the time of the digesta in the intestine thus giving the sensation of satiety.

It was found that the increase in CBB levels in the diet of finishing pigs significantly (P<0.05) affected the variables backfat thickness, percentage of lean meat, partial gross income with allowance index, and partial gross income (Table 4). For the variables backfat thickness and percentage of lean meat, the inclusion of 75 g kg^{-1}

Table 3 - Mean values for the performance test of finishing pigs fed diets containing cashew bagasse bran (CBB)

Variable	CBB inclusion level (g kg^{-1})					SEM	P-value	CV (%)
	0	75	150	225	300			
Daily feed intake (kg)	2.622	2.702	2.975	3.035	2.690	0.39	0.401	12.91
Daily gain (kg)	0.869	0.876	0.900	0.867	0.789	0.003	0.669	17.9
Feed conversion*	3.01b	3.15a	3.33ab	3.54a	3.42ab	0.005	0.001	5.92

Values followed by letters in the row (cashew bagasse bran levels) differ significantly (P<0.05) by Tukey's test.
*Linear effect (P<0.05).
SEM - standard error of the mean; CV - coefficient of variation.

Table 4 - Mean values for the effect of cashew bagasse bran (CBB) on the variables of the economic viability study

Variable	CBB inclusion level (g kg⁻¹)					SEM	P-value	CV (%)
	0	75	150	225	300			
Final weight (kg) ns	181.50	179.30	183.85	182.35	179.15	4.64	0.97	6.30
Feed intake (kg) ns	160.06	160.97	180.01	184.78	152.79	6.69	0.03	16.13
Backfat thickness (mm)	37.07a	26.88b	34.60a	31.42a	28.35a	2.06	0.04	19.82
Loin depth (mm) ns	111.05	114.60	108.75	113.80	108.60	2.48	0.19	3.75
Hot carcass weight (kg) ns	147.25	144.92	148.02	146.27	138.22	3.90	0.65	6.84
Lean meat (%)	113.08a	120.54b	114.51a	117.20a	119.18a	1.47	0.03	3.90
Allowance index (%) ns	1.76	1.82	1.77	1.79	1.83	0.01	0.36	2.89
Partial gross income AI ($)	217.71a	221.31b	219.16a	217.18a	197.14a	12.6	0.01	6.01
Partial gross income ($)	213.39a	208.64a	221.23b	215.80a	192.3a	18.46	0.02	7.50
Partial net income AI ($) ns	153.36	160.21	162.31	160.76	146.07	9.15	0.30	7.39
Partial net income ($) ns	160.45	147.4	164.62	159.37	152.11	16.09	0.30	7.59

Values followed by letters in the row (cashew bagasse levels) differ significantly ($P<0.05$) by the t test.
SEM - standard error of the mean; CV - coefficient of variation; ns - not significant for polynomial regression; AI - allowance index.

CBB in the diet provided better results (26.88 mm and 120.54%, respectively). When comparing these results with control (0 g kg^{-1} CBB inclusion), backfat thickness decreased by 37.9% and the percentage of lean meat increased by 6.60%. These results differ from those found by Farias et al. (2008), who observed no significant effects on backfat thickness when CBB was included in the diet of pigs. Similarly, Figueiredo et al. (2012) investigated the inclusion of cassava foliage hay (0, 100, 150, and 200 g kg^{-1}) in the diet of finishing pigs and found no effect on backfat thickness. A similar response was observed by Amorim et al. (2011), who found no effect of citrus pulp levels (0, 50, 100, and 150 g kg^{-1}) on the variables backfat thickness and percentage of lean meat.

Regarding the partial gross income with allowance index, the diet with 75 g kg^{-1} CBB showed significantly superior results as compared with the other treatments. The formulation containing 300 g kg^{-1} CBB presented results significantly lower than the other treatments, which in turn did not differ statistically. The variable partial gross income presented significantly higher results with 150 g kg^{-1} CBB inclusion, and a significantly lower result for 300 g kg^{-1} CBB, resulting in an increase of 15.04%.

Therefore, the inclusion of cashew bagasse bran in the diet of finishing pigs at 75 g kg^{-1} improved the carcass fat cover degree, thus providing better quality cuts to consumers, besides increasing producers profit in slaughterhouses that use the allowance index. By contrast, for the producer that uses slaughterhouses without the bonus, the most suitable diet is that with inclusion of 150 g kg^{-1} CBB. However, income levels are dependent on prices that vary throughout the year, which are influenced by the exchange rate, rate of inflation, and circumstances of the domestic and international markets.

Conclusions

Cashew bagasse bran can be included in diet of finishing pigs up to the level of 300 g kg^{-1} without adversely affecting animal performance. The inclusion of 75 g kg^{-1} cashew bagasse bran can improve pork quality and increase the partial gross income. Considering only the partial gross income, 150 g kg^{-1} cashew bagasse bran is the most suitable inclusion level in the diet of finishing pigs.

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