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Cashew nut meal (*Anacardium occidentale L.*) in the feeding of growing rabbits

Farelo de castanha de caju (*Anacardium occidentale L.*) na alimentação de coelhos em crescimento

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Abstract

Two trials were conducted: (1) to determine the chemical composition, digestibility of nutrients and energy of cashew nut meal (CNM); and (2) to evaluate the effects of increasing its levels (0, 5, 10, 15, 20 and 25%) in diets for growing rabbits on performance, carcass characteristics and economic evaluation. The digestibility assay utilized 24 rabbits (55 days of age), distributed in a completely randomized design with two treatments and 12 repetitions, with one reference and another test feed composed of 70% basal diet and 30% CNM. The digestibility of dry matter, crude protein and gross energy from CNM were, respectively, 76.61, 61.71 and 56.53%. The digestible dry matter, digestible protein and digestible energy were, respectively, 74.28, 16.97 and 3,549 kcal/kg. The performance assay utilized 120 rabbits, with an average of 45 days of age and weight 1090 ± 151g, distributed in a completely randomized design with six treatments and 10 repetitions with two rabbits of the same sex per cage. The inclusion of CNM above 5% promoted a linear reduction in feed intake and improved feed conversion, without affecting weight gain and carcass characteristics to the 20% level of inclusion. There was also a linear reduction in feed cost per kilogram of weight gain and linear improvement in rates of economic efficiency and cost index up to 25% CNM inclusion. Based on these findings – and to not hurt performance – it is recommended to include up to 20% CNM in rabbits' diet.
Keywords: alternative feedstuff, economic analysis, *Oryctolagus cuniculus*, productive yield.

Resumo

Dois ensaios foram realizados: (1) para determinar a composição química, digestibilidade dos nutrientes e energia do farelo de castanha de caju (FCC) e avaliar os efeitos do aumento dos níveis (0, 5, 10, 15, 20 e 25%) em dietas para coelhos em crescimento sobre desempenho, características de carcaça e avaliação econômica. O ensaio de digestibilidade utilizou 24 coelhos (55 dias de idade), distribuídos em delineamento inteiramente casualizado, com dois tratamentos e 12 repetições, sendo uma ração

referência e outra ração teste composta por 70% de dieta basal e 30% de FCC. A digestibilidade da matéria seca, proteína bruta e energia bruta do FCC foram, respectivamente, 76,61; 61,71 e 56,53%. A matéria seca digestível, a proteína digestível e a energia digestível foram, respectivamente, 74,28; 16,97 e 3,549 kcal / kg. O ensaio de desempenho utilizou 120 coelhos, com média de 45 dias de idade e peso de 1090 ± 151g, distribuídos em delineamento inteiramente casualizado, com seis tratamentos e 10 repetições com dois coelhos do mesmo sexo por gaiola. A inclusão de FCC acima de 5% promoveu uma redução linear no consumo de ração e melhor conversão alimentar, sem afetar as características de ganho de peso e carcaça para o nível de inclusão de 20%. Também foi observada redução linear no custo de alimentação por quilograma de ganho de peso e melhora linear nas taxas de eficiência econômica e índice de custos até 25% de inclusão do FCC. Com base nesses resultados - e para não prejudicar o desempenho - é recomendável incluir até 20% de FCC na dieta de coelhos.
Palavras-chave: alimento alternativo, análise econômica, *Oryctolagus cuniculus*, rendimento produtivo.

Introduction

In rabbit farming, the feeding cost is elevated because of the dependence on corn, alfalfa hay and soybean meal. Despite their good nutritional values, these components may increase dietary costs due to variations of price during periods of the year and in some regions where they are not produced in sufficient quantities to meet demands. The growth of the agribusinesses and the increased production of waste have fostered an interest in studying the use of agricultural by-products as animal diet ingredients. However, the geographic location, availability, nutritional value and the costs of each ingredient should be evaluated. Among the waste, cashew nut meal (CNM) stands out; it comes from processing almond cashew nuts for human consumption. It is estimated that up to 30% of processed cashew nuts do not reach a minimum grade for use in human feeding, being designated to animal feeding[1].

About the nutritional composition, depending on the planted variety and the type of processing during improvement, CNM appears as a protein concentrate (22–25% crude protein) with high energy value, due to the high content of lipids (36–45% ether extract). These characteristics highlight the potential of this ingredient to replace both the corn and soybean meal in feed for non-ruminants[2,3]. Besides, CNM has a high content of polyunsaturated fatty acids and the possibility to reduce feed costs due to the large supply of the product in the tropics[4]. It may become a promising alternative to replace foods that are traditionally used to provide energy in rabbits' diets while reducing the starch level and, hence, the risk of digestive disorders.

Dietary use of CNM has been proposed for animal feed[5,6]. According to Freitas et al.[7], in some regions of the world where CNM is available for animal feed, it has been compared to soybean grain and characterized as a moderate source of protein and an excellent source of energy. Besides, the low heat increment associated with the metabolism of lipids can favor the inclusion of this food in the feed for animals raised in high-temperature environments. However, information on the nutritional potential of this product to rabbits is scarce[8]. There is still the need for more studies on the nutritional value and energy of CNM in order to maximize the use of this ingredient in feed rabbits.

Given the above information, the objective of this study was (1) to determine the chemical composition, digestibility of nutrients and energy content from CNM; and (2) to evaluate the inclusion of increasing levels of this ingredient in diets for growing rabbits on performance, carcass characteristics and economic evaluation.

Material and methods

This study was financed in part by the Coordenação de Aperfeiçoamento de Pessoal de Nível Superior - Brasil (CAPES) - Finance Code 001.

The experimental procedures followed the protocols approved by the Ethics Committee on Animal Research (CEPA 10/2017) of Federal University of Ceará.

The raw material to obtain CNM used in this study was from Iracema Industry and Trading Cashew Nuts Ltda., located in the city of Fortaleza, Ceará, Brazil. The CNM comprised the waste of processing cashew nuts for human consumption, including whole almonds and pieces of almonds with stains due to the process of drying and inaccuracies from the machines. The processing for transformation of the material primarily involved a hammer mill grinding and sieving to facilitate incorporation into feed.

First, a digestibility trial was conducted to determine the nutrient digestibility and digestible energy (DE) value of the CNM. This experiment included 24 crossbred rabbits (New Zealand White × Californian) – 12 males and 12 females, aged 55 days with an average weight of 1203 ± 57g. They were distributed in a completely randomized design with two treatments and 12 repetitions, with one reference (Table 1) prepared in accordance with the nutritional recommendations of De Blas and Wiseman[9] for growing rabbits and a feed test with the inclusion of the CNM, in which the evaluated food replaced 30% of the reference diet, based on natural matter.

The animals were housed individually in metabolic cages, fitted with automatic water nipple drinkers and semi-automatic feeders of galvanized steel. At the bottom, the cages had nylon mesh to collect faeces. The cages were installed in a brick shed with a ceiling height of 3 m, with tile roofs of clay and sidewalls of screen. The trial lasted 11 days, of which 7 were for adaptation of animals to the facilities and diets and 4 days were used to collect faeces.

No medicinal treatment was used during the test, the animals received water and feed spontaneously throughout the experimental period and the rations were offered twice a day. Faeces were collected daily in the morning, placed in plastic bags and then stored in a freezer at -18°C. At the end of the collection period, they were homogenized and placed in a forced ventilation oven at 55°C for a 72 h to pre-dry, to be weighed and then ground, removing the pre-dried material sample for analysis.

Table 1. Ingredients and chemical composition of control diet

Ingredients	(%)
Ground corn	21.65
Alfalfa hay	22.08
Wheat bran	24.00
Tifton hay	17.00
Soybean meal	11.59
Soybean oil	1.13
Calcitic limestone	0.98
Dicalcium phosphate	0.34
Mineral/vitamin supplement[2]	0.30
Common salt	0.50
L-lysine HCl	0.26
DL-methionine	0.17
Total	100.00
Calculated composition[1]	
Digestible energy (kcal/kg)	2500
Crude protein (%)	16.00
Acid detergent fiber (%)	16.50
Neutral detergent fiber (%)	29.79
Starch (%)	21.96
Calcium (%)	0.8
Total phosphorus (%)	0.5
Met+Cis (%)	0.5
Total lysine (%)	0.7

[1]Based on the chemical composition values of the raw materials from the diets. [2]Vitamin-mineral supplement, composition per kilogram of product: vit A: 5,500,000 IU; vit D: 1,000,000 IU; vit E: 6,500 IU; vit K3: 1,250 mg; vit B1: 500 mg; vit B2: 2,502 mg, vit B6: 750 mg; vit B12: 7,500 mcg; biotin: 25 mg; niacin: 17.5 g; pantothenic acid: 6.030 mg; folic acid: 251 mg; choline: 35,000 mg; iron: 25 g; copper, 3,000 mg; cobalt: 50 mg; manganese: 32.5 g; zinc: 22.49 g; iodine: 32 mg; selenium: 100.05 mg.

The chemical analysis of DM, MM, CP, EE, neutral detergent fiber (NDF) and acid detergent fiber (ADF) of the ingredients of the diets and faeces were performed according to the methods described by AOAC[10]; the energy analysis conducted in an adiabatic bomb calorimeter PARR Model 1241EA. To determine the levels of digestible protein (DP) and digestible dry matter (DDM) in the CNM, the equations of Matterson et al.[11] and the ED equation of Villamide[12] were used.

For performance trial, we used 120 female California X male New Zealand White hybrids, 6 weeks old and weighing 1090 ± 151g, 60 males and 60 females. The rabbits were housed in same-sex pairs in galvanized wire cages (80 x 60 x 45 cm, length, width, and height) with an automatic-type water nipple and semi-automatic feeder of galvanized steel, installed in an open brick shed, provided with the side protection screens, 7.60 m wide, ceiling height of 3 m and covering clay tiles.

The animals were weaned at 35 days of age and housed in collective cages, receiving water and commercial feed *ad libitum* up to 45 days of age, when they were weighed individually, identified and distributed in experimental cages based on weight so that all treatments maintained the same initial average weight.

Climate variables were monitored through four HOBO U10-003 dataloggers spread inside the shed, 120 cm from the floor, where the temperature and relative humidity were recorded during the 45-day trial period, at 10-min intervals. Rainfall data was obtained from the Meteorology Sector of the Department of Agricultural Engineering (DENA) of the Federal University of Ceará, located 300 m from the experimental shed. During the experiment, the average ambient temperature was 27.49°C, while the maximum and minimum temperatures were 31.64 and 24.32°C, respectively. The average relative humidity in the shed during the trial period of 83.16%. During the trial period, there was 485.1 mm rainfall, with 37 days of precipitation.

The experimental design was completely randomized, with six treatments and 10 repetitions; the experimental unit consisted of two animals. The treatments comprised a control diet – based on corn, alfalfa hay, soybean meal and wheat bran and other components – and the other diets had various levels of CNM inclusion: 5, 10, 15, 20 and 25%.

The experimental diets (Table 2) were formulated to keep the same nutritional level in accordance with the requirements for growing rabbits[9]. The nutritional values and digestible energy of CNM determined in the metabolic trial were considered. The diets were pelleted in a pelletizer (Silver CZ 350 model), steam, with an average temperature conditioner 70°C and up to 350 kg diet per hour. The die had a diameter of 4.0 mm, and the pellets were cut to 10 mm in length. Throughout the experimental period, the animals received food and water *ad libitum*, and food was provided in the morning and afternoon.

For the measurement of the performance variables, the animals were weighed at the start and end of the trial period, as well as the remains of the experimental diets, which were collected in plastic bags and quantified daily for correction of consumption. Average daily weight gain and the average daily feed intake data were obtained by determining the difference between weights. These values were used to calculate feed conversion.

Table 2. Composition and nutritional levels of the experimental diets for growing rabbits

Ingredient (kg)	Price of ingredients	CNM[1] inclusion level (%)					
		0	5	10	15	20	25
Alfalfa hay	$ 0.61	44.22	40.92	37.78	34.77	31.73	28.59
Wheat bran	$ 0.26	24.00	24.00	24.00	24.00	24.00	24.00
Ground corn	$ 0.21	22.72	23.33	21.70	18.47	15.54	13.91
Soybean meal (45%)	$ 0.46	4.79	3.60	2.77	2.21	1.59	0.77
Cashew nut meal	$ 0.19	0.00	5.00	10.00	15.00	20.00	25.00
Soybean oil	$ 0.90	1.70	0.50	0.00	0.00	0.00	0.00
Calcitic limestone	$ 0.06	0.69	0.77	0.83	0.88	1.06	1.12
Dicalcium phosphate	$ 0.96	0.32	0.34	0.37	0.41	0.46	0.49
Mineral/vitamin supplement[2]	$ 3.53	0.30	0.30	0.30	0.30	0.30	0.30
Common salt	$ 0.19	0.51	0.51	0.51	0.52	0.60	0.60
L-lysineHCl	$ 4.56	0.50	0.48	0.46	0.43	0.41	0.39
DL-methionine	$ 2.74	0.25	0.26	0.28	0.30	0.32	0.34
Inert[3]	$ 0.02	0.00	0.00	1.00	2.72	4.00	4.50
TOTAL	-	100.00	100.00	100.00	100.00	100.00	100.00
Calculated nutritional and energy composition							
Digestible energy (kcal/kg)		2.500	2.500	2.500	2.500	2.508	2.549
Crude protein (%)		16.00	16.02	16.01	16.01	16.02	16.12
Dry matter (%)		88.30	88.38	89.11	89.70	90.27	90.81
Ether extract (%)		4.43	4.76	6.73	8.70	10.67	12.64
Acid detergent fiber (%)		16.50	16.47	16.67	16.50	16.53	16.52
Neutral detergent fiber (%)		29.79	29.80	29.65	29.42	29.19	29.08
Starch (%)		21.96	22.17	21.04	18.96	17.05	15.92
Calcium (%)		0.80	0.80	0.80	0.80	0.85	0.85
Total phosphorus (%)		0.50	0.50	0.50	0.50	0.50	0.50
Sodium (%)		0.22	0.22	0.22	0.22	0.25	0.25
Total lysine (%)		0.73	0.73	0.73	0.73	0.73	0.73
Total methionine (%)		0.37	0.38	0.39	0.40	0.41	0.41
Total methionine + cystine (%)		0.52	0.52	0.52	0.52	0.52	0.52
Total threonine (%)		0.28	0.26	0.24	0.22	0.20	0.18
Total tryptophan (%)		0.09	0.09	0.08	0.07	0.07	0.06

[1]CNM, cashew nut meal, [2]Composition per kg of product: vit.A: 5,000 IU, vit.D3: 5,00 IU, vit.E: 10,000mg, vit.K3: 1,000mg, vit.B1: 1,000mg, vit.B2: 3,000mg, vit.B6: 1,250mg, vit.B12: 5,000mcg, pantothenic acid: 10,000mg, folic acid: 500,000mcg, nicotinic acid: 20,000mg, choline: 2,603.5mg, sulfur: 40,099.88mg, manganese: 20,000mg, copper: 3,000 mg, iron: 20,000 mg, zinc: 25,000 mg, cobalt: 500mg, iodine: 150mg, selenium: 50mg. [3]Inert: washed sand.

For the evaluation of carcass characteristics at 90 days of age, all the rabbits were sent to slaughter. Initially, the rabbits were weighed and subjected to fasting for 12 h; subsequently, they were weighed again to obtain weight at slaughter. Rabbits were stunned and then bled by cutting the jugular vein. The skin, legs, tail and head were then removed. The eviscerated carcass, liver, kidneys, heart and abdominal fat were weighed to calculate the carcass yield and proportions of the parts. The carcass yield (%) was obtained by the ratio of the weight of the hot eviscerated carcass by the slaughter weight of the rabbit and the final result multiplied by 100. The relative weight data (%) of liver, kidneys and heart were obtained by the relationship between the weight of the evaluated part and the live weight and percentage of abdominal fat was obtained by the ratio between the weight of the evaluated part and the hot carcass weight.

The hind legs were removed, weighed and dissected according to the method described by Blasco and Ouhayoun[13]. The right paw was used to obtain the meat/bone relationship according to the formula:

$$RC/O = \frac{Pca}{PO} \quad ,$$

where RC/O is the ratio meat/bone; Pca is the weight of the meat (g); and PO is the weight of bone (g) according to Rao et al.[14].

To check the economic feasibility of including CNM in the diets, the cost of feed per kilogram of body weight gain (Yi), was first determined according to Bellaver et al.[15], considering:

$Yi = (Qi \times Pi) / Gi$,

where Yi = cost of feed per kilogram of body weight gain of rabbits in the i-th treatment; Pi = price per kilogram of feed used in the i-th treatment; Qi = the quantity of feed consumed in the i-th treatment and Gi = weight gain of the i-th treatment.

Then, the economic efficiency index (EEI) and the cost index (CI), proposed by Fialho et al.[16], were calculated:

$EEI = (MCei/S, TeI) \times 100$ and

$CI = (STeI/MCei) \times 100$,

where MCei = lower cost of feed per kg gain observed between treatments and STei = cost of the i-th treatment considered. In the calculation, the price of ingredients in values practiced at the time of the experiment in the city of Fortaleza (Table 2) was considered.

Statistical analysis was performed using the statistical program and the statistical model used for the analysis of variance was:

$Yijk = \mu + Ni + Sj + Nsij + eijk$,

where μ is the general average; Ni is the effect of the level of inclusion of CNM (i = 0, 5, 10, 15, 20 and 25%); Sj is the effect of sex (j = male and female); Nsij is the effect of the level of inclusion i on the j sex; and eijk is the effect of the error.

The degrees of freedom regarding the levels of CNM inclusion, excluding the control diet (level zero of CNM inclusion), were unfolded into polynomials, to establish the curve that best describes the behavior of the data. To compare the results obtained with each of the inclusion levels about the feed without the inclusion of the ingredient (0%), Dunnett test at 5% probability was used.

Results and discussion

The weight of the rabbits was on average 1090 ± 151 g at the beginning of the balance trial and 2238 ± 198 g at the end of the balance trial. This means that the average daily weight gain during the trial period was 24.96 g, which is in the normal range for rabbits at that age. There were no cases of mortality or morbidity during the test.

Evaluating the chemical composition of CNM (Table 3), the findings are similar to results obtained by EMBRAPA[2], with variations due to the type and the applied processing time and, in case of plant foods, factors such as soil, climate, type of farming, genetic variability and food storage conditions can influence the composition[17,18,19,20].

Table 3. Chemical composition and energy values of the cashew nut meal (dry matter basis)[1].

Nutrients and energy	CNM[2]
Dry matter (%)	96.96
Gross energy (kcal/kg)	6278.85
Crude protein (%)	27.50
Ether extract (%)	36.09
ADF (%)	20.34
NDF (%)	27.25
Mineral matter (%)	3.18

[1]Analyses performed at the Laboratory of Animal Nutrition (LANA) Of the Department of Animal Science of UFC. CNM[2], cashew nut meal. ADF, acid detergent fiber (%); NDF, neutral detergent fiber (%).

The coefficient of apparent digestibility of dry matter, crude energy and CP and the experimental ingredients are listed in Table 4. The value of the apparent digestibility coefficient for crude protein CNM (61.71%) is below the value reported by Scapinello et al.[21] for soybean meal (87.65%) in growing rabbits. This result may be associated with the quality of the protein in a food source. When raw materials are processed, they are exposed to high temperatures, which may denature protein and interfere with the digestibility of this by-product.

The gross energy value of the residue found in this study was 6278.85 kcal/kg, while the digestible energy was 3549.49 kcal/kg. According to Villamide et al.[22], the DE values of foods rich in protein do not consider the high energy losses that occur in the urine or the energy cost necessary for the synthesis of urea in the liver, which may have occurred in this study. Similarly, the DE values of high-fat foods are underestimated because fatty acids are retained in the body much more efficiently than other nutrients for energy production.

Table 4. Digestibility coefficients, digestible nutrients and digestible energy of the cashew nut meal for growing rabbits.

Nutrients and energy	Digestibility coefficient (%)	Digestible nutrients and digestible energy
Dry matter (%)	76.61	74.38%
Protein (%)	61.71	16.97%
Energy (kcal/kg)	56.53	3,549.49 kcal/kg

According to the results (Table 5), there was no significant interaction between the levels of CNM inclusion and sex on the assessed performance variables.

Table 5. Performance of rabbits[1] fed diets containing different levels of cashew **nut meal**

Inclusion level (%)	Final weight (kg)	Feed intake (g/rabbit/day)	Weight gain (g/rabbit/day)	Feed conversion (g/g)
0	2.32	93.54	25.64	3.68
5	2.42	92.51	26.81	3.48
10	2.38	88.64	26.49	3.37
15	2.33	82.05*	25.45	3.25*
20	2.22	74.39*	23.91	3.14*
25	2.13*	64.41*	21.48*	3.01*
Sex				
Male	2.25[a]	81.76	24.11[a]	3.40[a]
Female	2.35[b]	83.39	25.81[b]	3.24[b]
Mean	2.30	82.57	24.96	3.32
SEM[2]	0.03	10.84	2.84	0.59
ANOVA[3]		P-value		
Level	0.0044	0.0001	0.0046	0.0001
Sex	0.0348	0.3654	0.0431	0.0310
Level× Sex	0.0845	0.7805	0.8999	0.5188
Linear	0.0002	0.0001	0.0001	0.0001
Quadratic	0.4653	0.0967	0.2047	0.9670

[1] n=20 rabbits/treatment; SEM[2], standard error of mean; ANOVA[3], analysis of variance. [a,b]means followed by different letters in the column differ (P<0.05) by the F test.* Differs statistically compared with the control treatment by Dunnett's test (P<0.05).

The inclusion of CNM in the diets promoted a linear reduction in final weight at 90 days of age (Y = 2.41 – 0.0091X; R^2 = 0.64), feed intake (Y = 101.5 – 1.41X; R^2 = 0.98) and weight gain (Y = 28.8 – 0.264X, R^2 = 0.91) and a linear improvement in feed conversion (Y = 3.60 – 0.023X; R^2 = 0.99). On the other hand, when comparing the results obtained with the different CNM inclusion levels with those obtained with the control diet, rabbits fed CNM levels from 15% consumed less feed and showed better food conversion while weight gain and final weight differed only for rabbits fed 25% CNM, whose weight gain and slaughter weight were lower than the group fed the control diet.

The lower weight gain among the rabbits fed the diet containing 25% CNM and the control group might be associated with low consumption, as indicated by the results from the ingestion and utilization of the feed nutrients. In turn the improvement in feed conversion can be associated with this lower feed intake at increasing levels of CNM with better digestive efficiency and metabolism without causing significant changes in the rabbit weight gain up to 20% CNM inclusion.

With regard to the effect of sex on performance, females had higher weight gain, final weight and better feed conversion than males. These results can be understood by the precocity of females, who tend to achieve a higher weight gain, better feed conversion and higher fat accumulation than males. The results obtained for the performance difference between males and females in this study corroborate the data found by Iyeghe-Erakpotobor and Adeyegun[23] who found that females are heavier than males at the same age.

Regarding nutrient and energy intake (Table 6), CNM inclusion in the diets promoted a linear reduction in digestible energy intake (Y = 252.54 – 3.388X; R^2 = 0.98), in crude protein intake (Y = 16.24 – 0.2234X; R^2 = 0.98) and dry matter (Y = 89.52 – 1.169X; R^2 = 0.92) and promoted a linear increase in EE intake (Y = 3.884 + 0.1888X; R^2 = 0.93).

When comparing the results obtained with the different CNM inclusion levels with those obtained with the control diet, rabbits fed CNM levels from 15% showed lower intake of nutrients (CP and dry matter) and digestible energy, following the same trend of the results obtained with the daily intake of experimental diets. In contrast, as the CNM inclusion level increased from 10%, there was also an increase in fat intake.

Voluntary feed intake is mainly regulated by the amount of energy from feed that is available for metabolic processes. In addition, the diets were formulated to be isocaloric and isoproteic. Hence, it had been expected that the feed intake would not vary among treatments. However, it should be considered that the greater inclusion of the CNM, which has a high content of unsaturated fatty acids[7,24], may result in the effect on food intake.

The increase of fat in the diet of rabbits can cause satiety by chemotactic appetite regulation and release of cholecystokinin. This factor is released by the presence of a greater amount of lipids in the gastrointestinal tract; it leads to pyloric constriction and thus reduces the gastric emptying rate[25]. This phenomenon increases the time food is retained the gastrointestinal tract, promoting greater digestion and better absorption of nutrients from food. There may also be benefits related to the extra caloric effect of fats, including increased nutrient availability of other feed ingredients and extra metabolic effects of fat. The latter results in improved energy efficiency, due to increased net energy feed from the lower heat increment of fats(26). Thus, the increased availability of energy in feed containing CNM also may have contributed to the lower feed intake compared to the control group animals.

For carcass characteristics (Table 7), CNM inclusion in the diet influenced carcass yield, the meat/bone ratio and the proportion of liver and heart.

Table 6. Nutrient and energy intake of rabbits[1] fed diets containing different levels of cashew nut meal.

Inclusion level (%)	Digestible energy intake (kcal/rabbit/day)	Crude protein intake (g/rabbit/day)	Ether extract intake (g/rabbit/day)	Dry matter intake (g/rabbit/day)
0	233.85	14.97	4.14	82.60
5	231.28	14.82	4.40	81.76
10	221.59	14.19	5.97*	78.98
15	205.13*	13.14*	7.14*	73.60*
20	186.33*	11.90*	7.93*	67.07*
25	164.19*	10.38*	8.14*	58.50*
Sex				
Male	205.01	13.10	6.22	73.02
Female	209.12	13.36	6.35	74.48
Mean	207.07	13.23	6.29	73.75
SEM²	3.89	0.25	0.22	1.35
ANOVA³		P-value		
Level	0.0001	0.0001	0.0001	0.0001
Sex	0.3655	0.3657	0.4395	0.3672
Level× Sex	0.7830	0.7814	0.9298	0.7875
Regression				
Linear	0.0001	0.0001	0.0001	0.0001
Quadratic	0.1709	0.1235	0.0532	0.0745

[1] n=20 rabbits/treatment; SEM², standard error of mean; ANOVA³, analysis of variance. [a,b]means followed by different letters in the column differ (P<0.05) by the F test.* Differs statistically compared with the control treatment by Dunnett's test (P<0.05).

Table 7. Carcass characteristics of growing rabbits[1] fed diets containing increasing levels of cashew nut meal

Inclusion level (%)	Carcass yield	M/B[4]	Liver[5]	Heart	Kidneys	Abdominal fat
0	58.14	7.97	2.51	0.20	0.64	2.65
5	57.96	8.15	2.43	0.21	0.63	2.81
10	58.23	7.70	2.54	0.20	0.61	2.64
15	57.22	7.60	2.72	0.21	0.63	2.52
20	57.01	7.73	2.83*	0.22*	0.66	2.57
25	55.30*	7.10*	2.95*	0.23*	0.64	2.20
Sex						
Male	57.16	7.58	2.75[a]	0.21	0.63	2.37[b]
Female	57.42	7.80	2.57[b]	0.21	0.64	2.69[a]
Mean	57.29	7.69	2.66	0.21	0.64	2.53
SEM[2]	1.55	0.61	0.37	0.01	0.07	0.58
ANOVA[3]			P-value			
Level	0.0042	0.0845	0.0001	0.0053	0.6918	0.1462
Sex	0.5605	0.2388	0.0016	0.6428	0.5698	0.0173
Level × Sex	0.9790	0.8154	0.1130	0.6908	0.0605	0.7450
Regression						
Linear	0.0007	0.0053	0.0001	0.0013	0.3380	0.0090
Quadratic	0.1053	0.6673	0.8733	0.8315	0.9264	0.8359

[1] n=20 rabbits/treatment; SEM[2], standard error of mean; ANOVA[3], analysis of variance; [4]M/B, meat/bone ratio. [5]Ratio between the organ weight and the rabbit live weight after feed deprivation. [a,b]means followed by different letters in the column differ (P<0.05) by the F test.* Differs statistically compared with the control treatment by Dunnett's test (P<0.05).

According to regression analysis, excluding the control treatment, carcass yield ($Y = 59.03 - 0.13X$; $R^2 = 0.79$), the meat/bone ratio ($Y = 8.19 - 0.037X$, $R^2 = 0.74$) and the percentage of abdominal fat ($Y = 2.95 - 0.027X$; $R^2 = 0.95$) decreased linearly with the addition of CNM in the diets. These values were proportional to lower consumption and weight gain obtained in the performance test, which reflected the weight of slaughter of these animals. Comparing the increasing CNM levels in the feed with regard to the treatment without CNM, 25% CNM inclusion in the diets negatively influenced the carcass yield and meat deposition in the carcass of rabbits, decreasing the meat/bone ratio. This outcome suggests that the muscle protein deposit is less than the control treatment, because there is a reduction in the deposition of the meat mass. The meat/bone ratio in the control treatment was similar to that obtained by Gomes et al.[27], who also worked with growing rabbits and obtained a meat/bone ratio of 7.43.

The increased relative weight of organs such as liver ($Y = 2.29 + 0.026X$; $R^2 = 0.99$) and heart (Y = 0.196 + 0.001X; R^2 = 0.69) could be attributed to fat deposits around cardiac muscle and an indirect effect due to the increase of metabolic activity in the liver(28), since it actively participates in lipid metabolism, or even by deposition in hepatocytes by an excess of triglycerides available for storage. Effects that are inherent in the sexual dimorphism on carcass characteristics of variables showed that females had a higher percentage of abdominal fat deposition relative to males. These data agree with Lima et al.(29) and Foku et al.(30). Those studies stated that the abdominal fat deposits tend to be greater in female rabbits.

It can be seen that the inclusion of the CNM in the growth phase of rations (Table 8) showed a linear decrease in the cost with feeding per kilogram of weight gain (Y = 4.97 – 0.062X, R^2 = 0.99), linear increase in economic efficiency ratio (Y = 66.78 + 1.32X; R^2 = 0.99) and a linear reduction in the cost index (Y = 144.93 – 1.84X; R2 = 0.99).

Table 8. Economic evaluation of the inclusion of cashew nut meal in the feeding of growing rabbits[1]

Inclusion level (%)	Price/kg of diet (U$)	Cost with feeding (R$/kg of gain)	Economic efficiency index (%)	Cost index (%)
0	0.42	5.23	66.00	152.00
5	0.40	4.69*	74.00	137.00*
10	0.38	4.33*	80.00*	126.00*
15	0.36	4.01*	86.00*	117.00*
20	0.35	3.72*	93.00*	108.00*
25	0.34	3.43*	100.00*	100.00*
Sex				
Male	-	4.34[a]	81.00[b]	127.00a
Female	-	4.13[b]	85.00[a]	120.00b
Mean	-	4.23	83.00	123.50
SEM[2]	-	1.02	16.36	16.32
ANOVA[3]			P-value	
Level	-	0.0001	0.0001	0.0001
Sex	-	0.0294	0.0397	0.0298
Level× Sex	-	0.5184	0.5887	0.5171
Regression				
Linear	-	0.0237	0.0164	0.0180
Quadratic	-	0.1104	0.1741	0.1220

[1] n=20 rabbits/treatment; SEM[2], standard error of mean; ANOVA[3],, analysis of variance. [a,b]means followed by different letters in the column differ (P<0.05) by the F test.* Differs statistically compared with the control treatment by Dunnett's test (P<0.05).

When compared by Dunnett's test (5%), 5% and higher CNM inclusion produced cost results with food, EEI and IC that were significantly better than those obtained with the control diet, which had the highest cost per kilogram produced and, consequently, lower levels of economic efficiency and cost from 45–90 days of age.

The present results for CNM inclusion on economic viability in the diet of rabbits are similar to those reported by Freitas et al.[7]. Those authors evaluated the inclusion of CNM in feed for broilers and a found linear reduction in the cost with feeding, linear increase in economic efficiency ratio and linear reduction in the cost index as the CNM has been increasing in the feed to the level of 25%. These results indicate the economic feasibility of using CNM in diets of growing rabbits; however, the geographic location, availability and costs of transportation of this ingredient should be considered. It is noteworthy that 25% CNM inclusion in diets showed better financial performance. However, all evaluated CNM inclusion levels showed better financial performance than the control. Although CNM has the same cost for maize, it has a lower price compared to alfalfa hay and soybean meal.

During the period of growth, weight gain and carcass characteristics of rabbits fed with 20% CNM were similar to the control group. While further increasing CNM inclusion might improve economic viability, production might be compromised. Thus, it can be inferred that it is most economical to include up to 20% CNM in feed for rabbits that will be slaughtered. This finding corroborates the values indicated by Akinnusi et al.[8] for 45–90-day-old rabbits.

Conclusions

The digestibility coefficients of CM, CP and gross energy of CNM were, respectively, 76.61, 61.71 and 56.53%. The DDM, digestible protein and digestible energy, based on dry matter, were, respectively, 74.28, 16.97 and 3549 kcal/kg.
These results indicate that 20% CNM inclusion in a rabbit's diet improves production yield and the economic viability of production without damaging the nutritional efficiency of the diet.

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