Cottonseed cake as a substitute of soybean meal for goat kids

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ABSTRACT

The aim of this study was to evaluate the intake, apparent nutrient digestibility, nitrogen balance, and intake behaviour of crossbred Boer goat kids fed with diets contain cottonseed cake. It was utilised 32 crossbred Boer goat kids, with average body weight of 16 ± 2 kg, distributed in a completely randomised experimental design, in four experimental diets, with levels of substitution of soybean meal by cottonseed cake, in 0%, 33%, 66% and 100%, respectively. There was no significant effect \((p > 0.05)\) of cottonseed cake levels on the intake of nutritional components, except for ether extract that behaved in a quadratic manner \((p < 0.05)\). The digestibility of the nutritional components and the nitrogen balance were not altered as a function of the levels of cottonseed cake in the diet \((p > 0.05)\). The average daily weight gain and feed conversion were not altered \((p > 0.05)\) by the amounts of cottonseed cake. Rumination efficiency \((\text{minutes/kg of NDF})\) and feeding frequency \((\text{number of visits to the trough/24h})\) were not altered \((p < 0.05)\) as function of the cottonseed cake levels, however, feeding, rumination, and idleness times, as well as the other feeding efficiency and activities frequency were not influenced. Hence, cottonseed cake can be totally substituted soybean meal in diets for crossbred Boer goat kids in feedlot, once it does not alter the productive performance, intake and digestibility of nutritional components and nitrogen balance of the animals.

Introduction

The use of coproducts from the biodiesel production in ruminant feed appears as a possibility to contribute to the growth of agricultural activities, both in production performance and profitability in the production system (Oliveira et al. 2012).

As described by Silva et al. (2015), among the ingredients of diets for ruminants, soybean meal is the most used as a protein source in the concentrate. Soybean meal has high protein concentration (46% crude protein as fed, Palmieri et al. 2016), however, it is a high-cost ingredient. Therefore, it is necessary to search for alternative foods to replace traditional foods. Among these coproducts, cottonseed cake, derived from the extraction of cottonseed oil (\textit{Gossypium hirsutum}) for the production of biodiesel or for human nutrition, appears as a high nutritional value food alternative. Emphasizing the high crude protein content of 34.3%–48.9% and the high energetic potential of digestible energy of 3.22–3.44 Mcal/kg (Gadelha et al. 2011). Despite the high nutritional value, cottonseed cake presents in its composition gossypol, a phenolic compound produced by the cotton pigment glands (Câmara et al. 2016), which can promote clinical intoxication, liver damage, reproductive toxicity and immune imperil (Gadelha et al. 2014). Nevertheless, it is relevant to note that ruminants are tolerant to gossypol toxicity, and, therefore, are able to consume cottonseed cake without deleterious effects on performance (Hawkins et al. 1985).

A previous study by Silva et al. (2016) demonstrated that the substitution of soybean meal for cottonseed cake in lambs did not influence nitrogen balance, microbial synthesis efficiency, and intake...
behaviour. As pointed out by the authors, it is important to analyse how food acts on animal intake, since the inclusion of new ingredients in the diet can influence the intake behaviour, acceptability, and, consequently, the productive performance of the animals. However, studies evaluating the effect of different levels of inclusion of cottonseed cake in goat diets are still scarce.

Thus, the objective of this study was to evaluate the effect of soybean meal substitution by cottonseed cake on intake and nutrient digestibility, nitrogen balance, and intake behaviour in crossbred Boer goat kids.

**Materials and methods**

**Location of the experiment**

This study was performed according with the recommendations on the Guide of the National Council of Animal Experimentation Control (CONCEA). The protocol was approved by the Committee on the Ethics of Animal Experiments of the Federal University of Bahia, Bahia State, Brazil (Permit Number: 08/2013).

The experiment was conducted at the Experimental Farm of São Gonçalo dos Campos, which belongs to the Veterinary Medicine and Animal Science School of the Federal University of Bahia (UFBA), from December 2012 to February 2013. The experimental area is located at 12°23’ 57.51” in South latitude and 38°52’ 44.66” in West longitude, being characterised by an annual temperature around 26°C, relative air humidity of 85%, and rainfall index around 1200 mm.

**Animals, facilities and food management**

Thirty-two crossbred Boer goats were used, with an average body weight of 16 ± 2 kg, distributed in a completely randomised design, with four treatments and eight repetitions. Four experimental diets were formulated to be isonitrogenous, according to the recommendations of the NRC (2007) for gains of 150 g d⁻¹ and were given twice daily at 09 and 16 h, in a complete diet system.

The foods offered daily were weighed on a digital scale and the supply was adjusted so that the surplus represented approximately 10% of the amount of dry matter supplied. The ingredients proportion utilised in the experimental diets.

**Table 1. Chemical composition of the ingredients in the experimental diets.**

| Item                      | Tifton-85 hay | Ground corn | Soybean meal | Cottonseed cake |
|---------------------------|---------------|-------------|--------------|-----------------|
| Dry matter, g/kg          | 911.80        | 891.70      | 930.70       | 926.80          |
| Mineral matter, g/kg DM   | 60.80         | 12.20       | 64.00        | 65.10           |
| Crude protein, g/kg DM    | 51.00         | 65.08       | 500.05       | 230.10          |
| Ether extract, g/kg DM    | 1.13          | 4.39        | 1.87         | 15.61           |
| Neutral detergent fibre, g/kg DM | 752.30 | 131.00 | 156.40 | 519.10 |
| Acid detergent fibre, g/kg DM | 380.50 | 37.20 | 77.20 | 290.40 |
| NDFapa, g/kg DM           | 692.60        | 920.20      | 680.40       | 434.00          |
| Lignin, g/kg DM           | 53.60         | 10.80       | 8.50         | 11.63           |
| Total carbohydrates, g/kg DM | 876.90 | 870.00 | 781.00 | 710.80 |
| Non-fibrous carbohydrates, g/kg DM | 500.05 | 65.08 | 500.05 | 230.10 |
| Total digestible nutrients, g/kg DMb | 624.8 | 588.9 | 600.0 | 600.0 |

| Substitution level, % DM | 0     | 33    | 66    | 100   |
|--------------------------|-------|-------|-------|-------|
| Tifton-85 hay, g/kg      | 500.0 | 500.0 | 500.0 | 500.0 |
| Ground corn, g/kg        | 349.0 | 347.0 | 345.0 | 343.0 |
| Soybean meal, g/kg       | 120.0 | 80.0  | 40.0  | 0.0   |
| Cottonseed cake, g/kg    | 0.0   | 40.0  | 80.0  | 120.0 |
| Urea + ammonia sulphate, g/kg | 16.0 | 18.0 | 20.0 | 22.0 |
| Mineral mixturea, g/kg   | 15.0  | 15.0  | 15.0  | 15.0  |
| Chemical composition     |       |       |       |       |
| Dry matter, g/kg DM      | 909.8 | 902.2 | 910.3 | 910.6 |
| Mineral matter, g/kg DM  | 57.3  | 57.4  | 57.4  | 57.4  |
| Crude protein, g/kg DM   | 147.7 | 141.7 | 135.6 | 129.6 |
| Ether extract, g/kg DM   | 23.2  | 28.6  | 32.5  | 36.8  |
| NDFap, g/kg DM           | 386.7 | 405.0 | 414.4 | 428.2 |
| Acid detergent fibre, g/kg DM | 212.5 | 221.0 | 229.4 | 237.9 |
| Lignin, g/kg DM          | 31.6  | 35.9  | 40.2  | 44.5  |
| Total carbohydrates, g/kg DM | 755.7 | 754.3 | 753.0 | 751.6 |
| Non-fibrous carbohydrates, g/kg DM | 425.5 | 412.5 | 399.4 | 386.4 |
| Total digestible nutrients, g/kg DMb | 624.8 | 588.9 | 600.0 | 600.0 |

**Table 2. Ingredients and chemical composition of experimental diets.**

| Ingredients                  | 0   | 33  | 66  | 100 |
|------------------------------|-----|-----|-----|-----|
| Tifton-85 hay, g/kg          | 500.0 | 500.0 | 500.0 | 500.0 |
| Ground corn, g/kg            | 349.0 | 347.0 | 345.0 | 343.0 |
| Soybean meal, g/kg           | 120.0 | 80.0  | 40.0  | 0.0   |
| Cottonseed cake, g/kg        | 0.0   | 40.0  | 80.0  | 120.0 |
| Urea + ammonia sulphate, g/kg | 16.0 | 18.0 | 20.0 | 22.0 |
| Mineral mixturea, g/kg       | 15.0  | 15.0  | 15.0  | 15.0  |
| Chemical composition        |     |     |     |     |
| Dry matter, g/kg DM          | 909.8 | 902.2 | 910.3 | 910.6 |
| Mineral matter, g/kg DM      | 57.3  | 57.4  | 57.4  | 57.4  |
| Crude protein, g/kg DM       | 147.7 | 141.7 | 135.6 | 129.6 |
| Ether extract, g/kg DM       | 23.2  | 28.6  | 32.5  | 36.8  |
| NDFap, g/kg DM               | 386.7 | 405.0 | 414.4 | 428.2 |
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| Total carbohydrates, g/kg DM | 755.7 | 754.3 | 753.0 | 751.6 |
| Non-fibrous carbohydrates, g/kg DM | 425.5 | 412.5 | 399.4 | 386.4 |
| Total digestible nutrients, g/kg DMb | 624.8 | 588.9 | 600.0 | 600.0 |

**g/kg: grams/kilogram; g/kd DM: grams/kilogram of dry matter; DM: dry matter.**

*aProvides per kg, in active ingredients: calcium 120.00 g; phosphorus 87.00 g; sodium 147.00 g; sulphur 18.00 g; copper 590.00 mg; cobalt 40.00 mg; chrome 20.00 mg; iron 1,800.00 mg; iodine 80.00 mg; manganese 1,300.00 mg; selenium 15.00 mg; zinc 3,800.00 mg; molybdenum 300.00 mg; maximum fluoride 870.00 mg; phosphorus (P) solubility in citric acid at 2% minimum (95%). NDFap: neutral detergent fibre corrected for ash and protein.*

*bValues estimated based on Detmann et al. (2006a, 2006b, 2006c, 2007) equations.*
the diets and their chemical composition are shown in Table 1 and the composition of the ingredients in Tables 1 and 2.

Over the experimental period, samples of both the ingredients provided and the surplus of each animal were collected weekly, which were conditioned in plastic bags properly identified and stored in a freezer at −20°C. After thawing, samples of roughage, concentrate and leftovers were pre-dried in a forced-air oven at 55°C for 72 h and then processed in a knife mill with a 1-mm sieve (Casali 2006). After the grinding process, a composite sample per animal was taken to determine the chemical composition.

Analysis were performed according to the analytical procedures of the Association of Analytical Communities (AOAC 1990), being determined the contents of dry matter (DM) (method 967.03), crude protein (CP) (method 981.05), ether extract (EE) (method 920.29), mineral matter (MM) (method 942.05). To determine the neutral detergent fibre (NDF) and acid detergent fibre (ADF), it was utilised the methodology proposed by Van Soest et al. (1991). The content of NDF was corrected for ashes and protein (NDFap), being the residue of neutral detergent fibre incinerated at 600°C for 4 h to the correction of the ashes. The correction of the protein was performed subtracting the protein content present in the residue of the NDF. The lignin determination was performed according to the method 973.18 (AOAC 2002), being utilised the ADF residue.

For the estimation of non-fibre carbohydrates (NFC), the following equation proposed by Hall (2000) was used: \( \text{NFC} = 100 - \text{MM} - \text{EE} - \text{NDFap} - (\text{CP} - \text{CPu} + \text{U}) \).

The determination of total digestible nutrients (TDN) of the ingredients and the experimental diets described in Tables 1 and 2 were estimated using the following equation:

\[
\text{TDN} = \text{NDFd} + \text{EEad} + \text{CPad} + \text{DNDFdLC}
\]

where the content of apparently digestible NFC was estimated using the following equation (Detmann et al. 2006a) for finishing cattle: \( \text{NFCad} = 0.9507 \times \text{NFCcp} - 5.11 \).

The content of apparently digestible EE (EEad%) was estimated using the following equation (Detmann et al. 2006b) for finishing cattle: \( \text{EEad} = 0.8596 \times \text{EE} - 0.21 \).

The content of apparently digestible CP (CPad%) was estimated using the following equation (Detmann et al. 2006c) for finishing cattle: \( \text{CPad} = 0.7845 \times \text{CP} - 0.97 \).

The contents of effectively digestible neutral detergent fibre corrected for ash and protein for lactating cows were estimated according to Detmann et al. (2007) as: \( \text{NDFdLC} = 0.67 \times (\text{NDFcp} - L) \times (1 - (L/\text{NDFcp})0.85) \).

For the nutrient intake determination, the surplus was collected and weighed daily, being the intake determined by means of total subtraction of each nutrient contained in the offered foods, and the total of each nutrient contained in the leftovers.

For the digestibility coefficient determination, it was performed a trial between the 45th and 52nd days of confinement, it was executed with 32 goat kids (8 animals per treatment), adopting the total faeces collect method. Hence, the first 3 d were destined to the adaptation of the goat kids to the collecting bags, followed five subsequent days of total faeces collection, between the 48th and 52nd days of confinement; it was performed the faeces collection directly from the collecting bags, twice a day (08:00 and 15:00 hours). Posteriorly, after being registered the total faeces production of each animal, were taken samples of approximately 10% of the total collected, which were individually conditioned in plastic bags and stored in freezer.

During the digestibility, trial samples were taken from the provided foods, which also were conditioned in plastic bags, where were submitted to pre-drying in forced ventilation dry oven at 55°C during 72 h. Then, it was performed the grinding in knife mill with a 1-mm sieve and composed samples were elaborated per animal, properly conditioned in identified plastic tubes for posterior laboratory analysis as described above for diets and leftovers.

The digestibility coefficients (DC) of dry matter, crude protein, ethereal extract, neutral detergent fibre, non-fibrous carbohydrates and total digestible nutrients were determined by the ratio of what was consumed of each nutrient and its respective faecal excretion, utilising the following equation:

\[
\text{DC} = \left[ \frac{\text{kg of the ingested fraction} - \text{kg of fraction excreted}}{\text{kg of the ingested fraction}} \right] \times 100
\]

The total digestible nutrients concentration (%) (Table 4) was calculated based on the Weiss equations (1999): \( \text{TDN} = \text{DCP} + 2.25 \times \text{DEE} + \text{DNFC} + \text{DNDF} \); where DCP, DEE, DNFC and DNDF represent the digestibility of crude protein, ethereal extract, non-fibrous carbohydrates, and neutral detergent fibre, respectively.

The performance of the goat kids was determined based on their daily weight gain (DWG), total weight
gain (TWG) obtained by means of the individual weighing of the animals at the initial and at the end of the experiment, after 16 h of fasting and every 24 d without fasting. Based on the collected data, the daily weight gain (DWG), total weight gain (TWG) and feed conversion (FC) were calculated.

For 3 d, during the faeces-collection period in the digestibility trial, urine samples were collected from the animals, about 4 h after the morning feeding. By means of spontaneous urination, the urine was collected with the help of sterilised plastic cups, and at the end of each collection the samples were filtered with the aid of gauze, and a 10 mL aliquot of urine was removed. Subsequently, the samples were diluted in 40 mL of 0.036 N sulphuric acid solution (Valadares et al. 1999). Afterwards, samples were packaged in identified plastic tubes and stored at −20°C for the quantification of urinary creatinine concentrations.

Daily creatinine excretion (mg/d) was determined by multiplying the mean creatinine concentration (mg/kg of BW) by the mean body weight of each goat kid. It was considered that each animal excreted 16.33 mg of creatinine per kg of body weight (Carvalho et al. 2010), and the urinary volume (L/d) was estimated as presented below:

\[
UV (L/day) = \frac{DCE (mg/day)}{UCC (mg/L)}
\]

In what: UV = the average urinary volume estimated; DCE = daily creatinine excretion (mg/d), UCC = urinary creatinine concentration (mg/L).

Urinary creatinine concentrations were estimated utilising commercial kits (Biolab®).

The evaluation of the nitrogen content in the samples of the material consumed, faeces, and the urine was performed according to the methodology described by AOAC (1990). Nitrogen balance (g/d) was performed utilising the following formula:

Nitrogen balance = nitrogen intake (g) − faecal nitrogen (g) − urinary nitrogen (g)

**Ingestive behaviour**

In order to evaluate the intake behaviour, animals were submitted to visual observation during a period of 24 h on the 35th and 60th days of the experimental period, being the observations performed within five minutes for the evaluation of feeding, for the evaluation of the feeding, rumination, and idleness times according to Johnson and Combs (1991). During night evaluations, the environment was maintained with artificial lighting. Throughout the day, in the morning, afternoon and evening shifts, three observations of each animal were executed. During these periods, it was registered the numbers of chews per ruminal boli and the time spent for rumination of each boli. The data collection to determine the time spent in each activity was accomplished with the help of digital timers, handled by four observers, arranged in a manner to not interfere with the activities of the animals.

In order to estimate the behavioural feeding and rumination variables (min/kg DM and NDFap), feed efficiency (gDM and NDFap/h), and average intake of DM and NDFap per feeding period, it was utilised the values of voluntary intake of DM and NDF of the 35th and 60th days of the experimental period, being surplus computed. The data for the behaviour variables were obtained according to the methodology described by Bürger et al. (2000).

The number of ruminated boli was calculated daily by dividing the total rumination time (min) by the time spent with rumination of a boli. For the concentration of DM and NDFap in each ruminated boli (g), it was divided the quantity of DM and NDFap consumed (g/d) in 24 h by the number of ruminated boli in 1 d.

The feeding and rumination efficiency was obtained by means of the following equations:

\[
FE_{DM} = \frac{DC_{DM}}{FT}; \quad FE_{NDF} = \frac{DC_{NDF}}{FT};
\]

In what: \(FE_{DM}\) (gDM consumed/h) = feeding efficiency of dry matter; \(FENDF\) (g NDF consumed/h) = feeding efficiency of neutral detergent fibre; \(DC_{DM}\) = daily intake of dry matter; \(DC_{NDF}\) = daily intake of neutral detergent fibre; \(FT\) = time spent feeding daily;

\[
RE_{DM} = \frac{DC_{DM}}{FT} \quad \text{and} \quad RE_{NDF} = \frac{DC_{NDF}}{FT}
\]

In what: \(RE_{DM}\) (gDM ruminated/h) = rumination efficiency of dry matter; \(FT\) = time spent in rumination per day; \(RE_{NDF}\) = rumination efficiency of neutral detergent fibre.

\[
TCT = FT + RT
\]

In what: \(TCT\) = Total Chewing Time; \(RT\) (h/d) = rumination time.

The number of feeding, rumination and idleness periods were accounted by observing the sequential number of activities in the annotation worksheet. The average daily time spent during these periods was calculated by dividing the total duration of each activity (feeding, rumination and idleness) by their respective number of periods.

At the end of the intake behaviour evaluations, samples of roughage, concentrate, and surplus from each animal were conditioned in plastic bags, properly
identified and stored in a freezer at −20 °C, for further laboratory analysis.

**Statistical analysis**

The data were submitted to variance analysis and regression at 5% of probability, calculated by the software Statistical Analysis System – SAS version 9.2 (SAS 2009), utilising a completely randomised design using the following statistical model:

$$Y_{ij} = \mu + s_i + e_{ij}$$

Where $Y_{ij}$ = observed value; $\mu$ = overall mean; $s_i$ = effect of the levels of cottonseed cake and $e_{ij}$ = effect of the experimental error on plots.

**Results and discussion**

**Nutrients intake**

Substitution of soybean meal by cottonseed cake did not influence ($p > 0.05$) the daily intake of dry matter and other nutritional components by goat kids (Table 3). The reduction of dry matter intake according to Choi and Palmquist (1996) can be attributed to the increase of lipid intake by means of the activation of physiological satiety mechanisms, which are not related to the reduction of ruminal fibre degradation. Hence, the physiological mechanisms are related to the increase of the fatty acids oxidised in the liver, which, through reflection of the vagus nerve, stimulates satiety (Scharrer 1999; Leonhardt and Langhans 2004). However, in the present study, the increasing levels of ether extract from cottonseed cake did not influence the intake of the animals. This could be due to the maximum level of EE in the diet 36.8 g/kg of DM (Table 2), which was lower than 50 g/kg of EE considered the maximum level accepted for use in ruminant diets without negative affecting their dry matter intake.

There was no difference in the intake of organic matter and crude protein ($p > 0.05$) with the replacement of soybean meal for the cottonseed cake, presenting averages of 0.732 and 0.154 kg d$^{-1}$, respectively, being explained by the similarity of the dry matter content between treatments (Table 2), and the similarity between crude protein contents (Table 3), since the diets were formulated to be isoproteic.

According to Van Soest (1994), diets presenting crude protein contents lower than 7% alter the ruminal environment making it inadequate for the ruminal microbiota, thus, compromising microbial maintenance and growth, altering the use of fibrous carbohydrates.

### Table 3. Daily intake of nutritional components by crossbred Boer goat kids fed diets containing cottonseed cake substituting soybean meal.

| Substitution level, % DM | Intake, kg/day |
|--------------------------|---------------|
|                          | DM            | OM            | CP            | EE            | NDGap | NFC  | TDN |
| 0                        | 64.32         | 58.04         | 59.14         | 59.19         | 1.811 | 0.358 | 0.393 |
| 33                       | 66.30         | 59.70         | 61.27         | 60.65         | 1.773 | 0.315 | 0.404 |
| 66                       | 70.19         | 72.33         | 74.93         | 73.16         | 1.402 | 0.352 | 0.507 |
| 100                      | 65.81         | 57.04         | 63.27         | 65.20         | 1.583 | 0.929 | 1.142 |

### Table 4. Digestibility of dry matter and nutrients (%) in diets containing cottonseed cake substituting soybean meal for crossbred Boer goat kids.

| Item | Substitution level, % DM | $p$ value $^{ab}$ |
|------|--------------------------|------------------|
| DM   |                          |                  |
| OM   | 58.04                    |                  |
| CP   | 59.70                    |                  |
| EE   | 57.04                    |                  |
| NDFap| 54.04                    |                  |
| NFC  | 50.22                    |                  |
| TDN  | 52.71                    |                  |

However, regardless of the treatment, the animals effectively consumed at least 165 g crude protein per kg of dry matter, which was enough to meet their minimum protein requirements.

No difference was observed for the intake of NDFap in the different forms of presentation ($p > 0.05$). According to Van Soest (1994), the intake of NDF varies from 0.8% to 1.2% of body weight, values close to those found in the present study, 1.02% in the diet containing 100% soybean meal, and 1.22% in the highest level of inclusion of the cottonseed cake. However, it is worth mentioning that this limit can be exceeded when the energy density of the diet is low.

Despite the higher content of NDFap in the diets with cottonseed cake, these values were still below the maximum limit recommended by Mertens (1997), which according to this author, NDF values above 60% present a negative correlation with dry matter intake.

Regarding ether extract intake, it presented a quadratic effect with the substitution of soybean meal for...
the cottonseed cake (p < .05), with a minimum verified intake level of 37.5%. Values contrary to those observed in this study were corroborated by Silva et al. (2016b), who reported a linear increase in the intake of ether extract in diets for sheep, relating this result to the ether extract content present in the cottonseed cake. In addition, despite the quadratic effect of the cottonseed cake inclusion level on EE intake, it is important to emphasize that, in practical terms, EE intake ranged from 10 to 13 g/d only.

The intake of non-fibrous carbohydrates and total digestible nutrients were not influenced by the substitution of soybean meal for the cottonseed cake (Table 3). However, the values are below those recommended by the NRC (2007), where it mentions that the general average intake of TDN specified should contain values of 510 g of TDN, for goats with gains of 150 g d⁻¹. In the present study, overall average intake of TDN observed was 0.467 kg d⁻¹, which can be explained by the negative associative effect being frequently correlated with reduced energy values of the diet, due to lack of synchrony in the release of substrates for fermentation, reducing the fermentative efficiency of the diet and unbalance in fermentation ratios in the rumen.

**Nutrients digestibility**

Similarly to nutrient intake, it was not verified effect of diets (p > .05) on the digestibility of nutritional fractions (Table 4). Even with the increase in the lipid content of the diets (Tables 1 and 2), the levels of guarantee of fat intake in ruminants were respected, in what their inclusion of lipids is maximum five per-cent preserving the ruminal flora (Bomfim et al. 2011).

In the present study, there was no effect on the carbohydrates digestibility, which according to Maia et al. (2006), usually is compromised with this increment. Possibly, the absence of effect on the digestibility of nutritional fractions, may have been provided in all diets with a 50:50 roughage:concentrate ratio. In addition, prior milling of both the roughage and the concentrate prior to providing to the animals. A similar response was described by Silva et al. (2016b), who fed diets with increasing levels of cottonseed cake replacing soybean meal to lambs.

As evidenced by Van Soest (1994) the food digestibility is related to the rate of degradation and the time of exposure of the substrate to the microorganisms of the rumen. Therefore, even with the change of the protein sources in the diets, there was a similar passage rate and permanence in the rumen, justifying the absence of difference between treatments.

### Table 5. Production performance of crossbred Boer goat kids fed diets containing cottonseed cake substituting soybean meal.

| Variable                  | Substitution level, % DM | p value | SEMa | Linear | Quadratic |
|---------------------------|-------------------------|---------|------|--------|-----------|
| Initial weight, g         | 16.600                  | .996    | .992 |        |           |
| Final weight, kg          | 24.510                  | .410    | .660 |        |           |
| TWG, kg                   | 6.966                   | .389    | .756 |        |           |
| DWG, kg/day               | 0.110                   | .389    | .756 |        |           |
| FC                        | 9.560                   | .094    | .612 |        |           |

**Table 6. Nitrogen balance in crossbred Boer goat kids fed diets containing cottonseed cake substituting soybean meal.**

| Variable                  | Substitution level, % DM | p value | SEMa | Linear | Quadratic |
|---------------------------|-------------------------|---------|------|--------|-----------|
| N intake                  | 14.55                   | .289    | .055 |        |           |
| N faeces                  | 3.89                    | .001    | .251 |        |           |
| N urine                   | 6.47                    | .001    | .696 |        |           |
| Retained N                | 10.66                   | .738    | .449 |        |           |
| Non retained N            | 4.70                    | .096    | .147 |        |           |

### Productive performance

Total and daily weight gains, as well as feed conversion, and final weight were not influenced (p > .05) by the diets (Table 5). This result may possibly be attributed to the fact that there was no effect of diets on the intake of nutrients by the goat kids. Thus, the diets containing cottonseed cake provided a productive performance similar to those fed with diets containing only soybean meal, and it can be concluded that cottonseed cake can be used as a source of alternative proteic food to the goat kids.

A similar result was observed by Silva et al. (2016b) when evaluating the effect of substitution of soybean meal for cottonseed cake on diet for lambs, in regard to productive performance. As observed, the diets evaluated also did not affect the final body weight, daily weight gain, and total weight gain of the goat kids. According to the authors, the similarity in the productive performance can be attributed to the absence of a significant effect of the diets on the dry matter intake, which is the nutritional factor with the greatest influence on weight gain.

### Nitrogen balance

There was no effect of the diets (p > .05) on the ingested, digested, and retained nitrogen contents. Additionally, the amount of nitrogen excreted in urine
and faeces increased and decreased linearly as the levels of substitution of soybean meal for cottonseed cake were elevated, respectively (Table 6).

Urinary nitrogen excretion decreased linearly as soybean meal was replaced by cottonseed cake, even when the amount of ingested nitrogen was equal among diets. This could be due to the difference between the ruminal protein degradability of these sources, corroborating Van Soest (1994), who declared that this factor may influence the urinary nitrogen excretion. Therefore, the amount of ruminal ammonia produced could be greater in the soybean meal diet, resulting in a higher synthesis of urea in the liver and, consequently, higher excretion thereof in urine.

On the other hand, an increasing linear effect \((p < .05)\) of the diets was observed on the levels of nitrogen excreted in the faeces. Although no difference was observed for nitrogen digestibility, it is possible that goat kids fed the diets containing the highest level of replacement had a higher faecal nitrogen content due to a higher concentration of neutral or acid detergent indigestible protein in this byproduct, thus making nitrogen unavailable to the animals. Another factor that could influence faecal nitrogen excretion may be associated with fractionation of the food protein, which is less digestible in the cottonseed cake compared to soybean meal.

In contrast to the present study, Silva et al. (2016a) fed increasing levels of cottonseed cake to lambs and did not observe an effect of the diets on nitrogen balance or changes in the routes of nitrogen excretion via urine and faeces in response to the substitution of soybean meal for cottonseed cake.

According to the authors mentioned above, the positive and statistically similar concentrations in the nitrogen balance indicate that there was a balance between protein and energy levels. Therefore, the absence of effect on retained nitrogen indicates that even with the addition of urea to the diets, the substitution of soybean meal for cottonseed cake did not cause changes in the balance between non-proteic nitrogen and true nitrogen.

**Ingestive behaviour**

Among feeding, ruminating, chewing and idleness activities, only feeding time in min/d, kilogram of NDF ruminated in min/d and number of chews per day differed between treatments \((p < .05)\) (Table 7).

The feeding time in min/d and the chewing number/d of the animals presented an increasing linear effect with the substitution of soybean meal for cottonseed cake (Table 8). These results may be justified by the high capacity of food selection and, consequently, spend longer feeding and chewing due the time spent with the selection.

Regarding ruminating time per kg of NDF of \(d^{-1}\), it presented a linear decreasing effect, being justified by the higher NDF content in the diets with cottonseed cake and by the similarity on NDF intake in the diets. The observed behaviour corroborates with what was described by Van Soest (1994), who mentioned that the time spent by the animal in the ruminating activity is influenced by the nature of the diet, physical form of the diet, and the amount of NDF. Hence, the highest NDF content in the diets is justified by the higher NDF content in cottonseed cake (419.2 g kg DM\(^{-1}\), Table 1), in comparison with soybean meal (68.4 g kg DM\(^{-1}\), Table 1), however, the physical effectiveness of the fibre of cottonseed cake is low due to the previous processing applied for the reduction of particle size, and this fact associated to the similar intake explains the shorter time spent per kg of \(d^{-1}\) of ruminated NDF.

There was no difference to ruminating and idleness frequency, however, feeding frequency presented influence \((p < .05)\) by the substitution of soybean meal for cottonseed cake, with increasing linear effect (Table 9).

Animals fed with cottonseed cake presented a lower efficiency in obtaining food, probably by the fact that these animals presented more time with the feeding due to the selection capacity, since the dry matter intake was similar between the treatments, which hypothetically led animals to feed more often on the diets containing cottonseed cake.

There was no difference in feed efficiency of dry matter and NDF \((p > .05)\). According to Agy et al.
most of the time, food and rumination efficiencies are altered mainly by DM and NDF intake, in the present study there was no difference for these variables (Table 8). In addition, despite the longer time spent with feeding (Table 7) in the cottonseed cake diets, this fact was not enough to express differences on feed efficiency in the two forms presented.

The substitution of soybean meal by cottonseed cake did not influence rumination efficiency in gDM/h, gNDF/boli and number of ruminated boli per day (p > .05) (Table 10), however, it altered rumination efficiency in gNDF/h and in gDM/boli (p > .05) (Table 10). The NDF contents of the diets interfere directly in rumination and its parameters, being proportional to the NDF content in the diets (Carvalho et al. 2006), this way, although the DCDM and DCNDF (Table 3) have no effect with the substitution of the soybean meal by cottonseed cake, rumination efficiency to gNDF/h and gDM/boli presented a linear increasing effect according to the substitution, attributed to the higher NDF content in cottonseed cake diets, however, with lower physical effectiveness induced by the reducing on particle size (Agy et al. 2012).

As mentioned, particle size may have influenced in this study on the intake behaviour of goat kids. Consequently, this behaviour corroborates with what has been described by Van Soest (1994) that particle size may be an important factor that influences the nutritional value of food, since it affects dry matter.

| Table 8. Intakes of dry matter (DMI) and neutral detergent fibre (NDFI) and feeding, rumination, chewing and idle times by crossbred Boer goat kids fed diets containing cottonseed cake substituting soybean meal. |
|-----------------|-----------------|-----------------|-----------------|-----------------|-----------------|-----------------|
| Item            | Substitution level, % DM | p value        |
|-----------------|-----------------|-----------------|-----------------|-----------------|-----------------|-----------------|
| Substitution level, % DM |                      | p value        |
|-----------------|-----------------|-----------------|-----------------|-----------------|-----------------|-----------------|
| Intake in 24 h, g/d |                      |                |
| DMI             | 748.80          | 898.24         | 803.45          | 811.86          | 39.56           | .476            |
| NDFI            | 366.07          | 456.33         | 429.87          | 492.53          | 27.22           | .919            |
| Feeding         | 200.00          | 248.75         | 245.00          | 271.87          | 11.15           | .034            |
| min/d           | 329.39          | 295.37         | 306.27          | 387.37          | 22.67           | .376            |
| min/kg DM       | 686.35          | 585.33         | 572.10          | 671.72          | 45.95           | .000            |
| Rumination      | 200.00          | 248.75         | 245.00          | 271.87          | 11.15           | .034            |
| min/d           | 329.39          | 295.37         | 306.27          | 387.37          | 22.67           | .376            |
| min/kg NDF      | 686.35          | 585.33         | 572.10          | 671.72          | 45.95           | .000            |
| Chewing         | 52.31           | 57.51          | 59.24           | 56.38           | 2.23            | .512            |
| seconds/boli    | 124.23          | 151.22         | 153.11          | 50.84           | 1.61            | .120            |
| hour/day        | 22,661.90       | 37254.70       | 33,845.10       | 36,217.00       | 1827.00         | .013            |
| min/kg DM       | 913.14          | 819.44         | 812.76          | 959.76          | 33.24           | .644            |
| min/kg NDF      | 1917.81         | 1631.85        | 1520.07         | 1637.60         | 78.23           | .182            |
| Idle            | 812.50          | 699.37         | 779.37          | 765.00          | 23.99           | .775            |

h: hours; DM: dry matter; NDF: neutral detergent fiber; g/d: grams/day; min/d: minutes/day; min/kg: minutes/kilogram; g DM/h: grams of dry matter/hour; g NDF/hour: grams of neutral detergent fiber/hour; SEM: standard error of the mean

Table 9. Frequency of feeding, rumination and idle activities by crossbred Boer goat kids correlated with the cottonseed cake substitution levels in the diets.

| Item            | Substitution level, % DM |
|-----------------|--------------------------|
| Feeding         | 13.91                     |
| Rumination      | 29.59                     |
| Idleness        | 56.48                     |
| SEM: standard error of the mean. |                      |
| aStandard error of the mean. |                      |
| b p value significant probability at the 5%. |                      |

(2012), most of the time, food and rumination efficiencies are altered mainly by DM and NDF intake, in the present study there was no difference for these variables (Table 8). In addition, despite the longer time spent with feeding (Table 7) in the cottonseed cake diets, this fact was not enough to express differences on feed efficiency in the two forms presented.

The substitution of soybean meal by cottonseed cake did not influence rumination efficiency in gDM/h, gNDF/boli and number of ruminated boli per day (p > .05) (Table 10), however, it altered rumination efficiency in gNDF/h and in gDM/boli (p > .05) (Table 10). The NDF contents of the diets interfere directly in rumination and its parameters, being proportional to the NDF content in the diets (Carvalho et al. 2006), this way, although the DCDM and DCNDF (Table 3) have no effect with the substitution of the soybean meal by cottonseed cake, rumination efficiency to gNDF/h and gDM/boli presented a linear increasing effect according to the substitution, attributed to the higher NDF content in cottonseed cake diets, however, with lower physical effectiveness induced by the reducing on particle size (Agy et al. 2012).

As mentioned, particle size may have influenced in this study on the intake behaviour of goat kids. Consequently, this behaviour corroborates with what has been described by Van Soest (1994) that particle size may be an important factor that influences the nutritional value of food, since it affects dry matter.

| Table 10. Feeding and rumination efficiencies of dry matter (DM) and neutral detergent fibre (NDF) in crossbred Boer goat kids fed diets containing cottonseed cake substituting soybean meal. |
|-----------------|-----------------|-----------------|-----------------|-----------------|-----------------|-----------------|
| Item            | Substitution level, % DM | p value        |
|-----------------|-----------------|-----------------|-----------------|-----------------|-----------------|-----------------|
| Substitution level, % DM |                      | p value        |
| Feeding         | 13.91           | 17.51           | 17.01           | 18.88           | 0.78            | .039            |
| Rumination      | 29.59           | 33.42           | 28.86           | 27.99           | 1.23            | .401            |
| Idleness        | 56.48           | 49.05           | 54.12           | 53.12           | 1.62            | .735            |

SEM: standard error of the mean. |                      |
| aStandard error of the mean. |                      |
| b p value significant probability at the 5%. |                      |
intake, ruminal retention (Van Soest 1994), and rumin-ation and chewing activities (Saenz 2005).

**Conclusions**

Substitution of 100% of the soybean meal for cotton-seed cake in diet of confined crossbred Boer goat kids, in termination, does not alter the productive performance, intake and digestibility of nutritional com-ponents and nitrogen balance of the animals. In addition, it does not promote changes in ingestive behaviour. In areas in which there is availability of cot-tonseed cake, this coproduct can be a viable alter-na-tive as source of protein in diet for goat.

**Disclosure statement**

No potential conflict of interest was reported by the authors.

**Ethical Approval**

This study was performed according with the recommenda-tions on the Guide of the National Council of Animal Experimentation Control (CONCEA). The protocol was approved by the Committee on the Ethics of Animal Experiments of the Federal University of Bahia, Bahia State, Brazil ( Permit Number: 08/2013).

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