Performance of sheep fed on annatto byproduct

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Abstract

This study aimed to evaluate intake, digestibility, and performance in sheep fed increasing levels of annatto byproduct (AB). A total of 32 male sheep without defined breed were used. Their initial weight was 23.17±1.45 kg. The animals were housed in individual pens and offered feed twice a day. Nutrient intake was quantified by the difference between the fractions present in the offered feed and the remains. The apparent digestibility was estimated with the aid of the external marker LIPE®. Weight gain was measured by the difference between the initial and final weight of the animals. The intake of dry matter (DM; g/day; g/kg BW; g/kg0.75), organic matter (g/day), crude protein (CP; g/day), and neutral detergent fibre (g/day) was not affected (P>0.05) by addition of AB. The intake of ether extract (EE; g/day) and non-fibre carbohydrates (g/day) was influenced by the inclusion of AB. The apparent digestibility of DM, organic matter, CP, and EE was not affected (P>0.05) by the addition of AB. The AB can be included in the diet at levels up 300 g/kg of total DM without affecting consumption, digestibility, and weight gain in sheep.

Introduction

The Brazilian sheep farm industry has been undergoing profound changes in its production chain facing the market demands. The request for meat with more palatable sensory characteristics has encouraged research in technologies that reduce the production cycle and improve the overall acceptability of sheep products (Ferraz and Felício, 2010; Costa et al., 2011). The production of confined sheep emerges as the main alternative to reduce the age at slaughter and improve the carcass characteristics to intensify the biological transformations of the animal through the constant supply of nutrients (Medeiros et al., 2007). Despite the advantages, the cost associated with confinement is often the main obstacle to its adoption. Alternatives to foods commonly used in intensive confinement systems have been researched, particularly due to the impact of this component on the cost of the system. In this context, agroindustrial residues have shown nutritional potential in the diet of ruminants, with satisfactory results on intake and animal performance (Azevêdo et al., 2011a, 2011b).

Brazil is the largest producer and exporter of seeds and extracts of annatto (Bixa orellana L.), which are used as a colourant in food, pharmaceutical, and cosmetic industries (De Rosso and Mercadante, 2009). Recent estimates quote in about 13 tons the domestic production (IBGE, 2010). Out of this total, between 94 and 98% are considered waste after extraction of the dye powder covering the seed pericarp (Preston and Rickard, 1980; Franco, 2001; Braz et al., 2007; Moraes, 2007). In the literature, the chemical composition of annatto byproduct (AB) showed mean values of 870.0 g/kg dry matter (DM), 148.0 g/kg crude protein (CP), 22.0 g/kg ether extract (EE), 569.0 g/kg neutral detergent fibre (NDF), 301.0 g/kg acid detergent fibre (ADF), 23.4 g/kg lignin (LIG), 766.0 g/kg total carbohydrates (TC), 296.0 g/kg non-fibrous carbohydrates (NPC), 3910.77 kcal/g gross energy, and 726.6 g/kg total digestible nutrients (TDN). In Cornell fractionation, 60% of rumen degradable protein, about 33% of the total protein, belonged to the highly soluble fraction A. The intestinal digestibility of the protein fraction not degraded in the rumen exceeded 41%. Regarding the carbohydrates, more than 40% of the total corresponded to the group of non-fibrous carbohydrates, while the fractionation indicated 52% of the carbohydrates in fraction A+B1, which was rapidly assimilated by ruminal microbes. The estimate for the TDN value was 64.60% of DM (Moraes, 2007; Clementino, 2008; Pereira et al., 2008, 2010a, 2010b).

Researches with AB addition in the diet of ruminant animals indicated potential for inclusion in elephant grass (Pennisetum purpureum Schum.) silages, with substantial improvements in the nutritional value of the silage for sheep (Gonçalves et al., 2006; Rêgo et al., 2010). Studies evaluating the replacement of Tifton 85 hay by AB reported improvements in intake and digestibility of nutrients in the diet of small ruminants (Moraes, 2007; Clementino, 2008). Therefore, this study evaluated intake, digestibility, and performance in sheep fed increasing levels of AB.

Materials and methods

Experimental site

The experiment was carried out at the Department of Animal Science of the Universidade Federal Rural de Pernambuco (UFRPE) in Recife, PE, Brazil. Humane animal care and handling procedures were followed according to the University’s animal care committee.

Animals, housing, and feeding

A total of 32 sheep with no defined breed were used. They were intact males with an initial weight of 23.17±1.45 kg and a mean age of 8 months. The animals were divided into blocks according to their weight in the four treatments, totalling eight replicates per treatment. The experimental period lasted 78 days, with 20 days of adaptation and 58 days of data collection. At the beginning of the adaptation period, the animals were treated against ectoparasites and endoparasites and vaccinated against clostridial diseases. Throughout the period of confinement, animals were kept in...
and EE were performed according to the 2007). Obtained for each animal, which was milled with leftover corresponding to water
inclusion of AB (0, 100, 200, and 300 g/kg) in individual pens with dimensions of 1.0 m×2.8 m and provided with feeders and drinkers, with water ad libitum.

The treatments consisted of four levels of inclusion of AB (0, 100, 200, and 300 g/kg) in the DM of diet (Tables 1 and 2). The control diet (0 g/kg of AB in DM) was formulated to meet the requirements of male sheep with an average weight of 25 kg for maintenance and gain of 200 g/day (National Research Council, 2007).

**Chemical analysis, intake, and digestibility**

Diets were offered as total mixed rations ad libitum given in two meals daily (08:00 and 16:00). The food supply was adjusted every 3 days based on the weight of daily remains. Ad libitum intake was ensured, with leftover corresponding to 10% of the total DM offered.

Analyses of DM, mineral matter (MM), CP, and EE were performed according to the methodology described by Silva and Queiroz (2002). To determine the NDF and ADF, methodologies described by Van Soest et al. (1991) were used, with the modifications of the use of polypropylene bags (non-woven fabric, weight 100 g/m²) and an autoclave. For estimation of TC and NFC, the equations proposed by Sniffen et al. (1992). The intake of TDN was estimated as described by Weiss (1999). To estimate faecal DM production, the external marker enriched and purified lignin (LIPE®) was used. The manufacturer’s specifications consisted of a capsule of 250 mg/day for 7 days, 2 days for adaptation, and 5 days for faeces collection. Faeces were collected directly from the rectum once a day, at different times (08:00, 10:00, 12:00, 14:00, and 16:00). The faeces collected during the digestibility assay were dried in a forced circulation oven (55°C) for 72 h. After drying, a sample was obtained for each animal, which was milled using a Willey type mill and passed through sieves with a mesh of 1 mm. Subsequently, aliquots of 10 g were sent to the laboratory of the Company P2S2® for analysis. According to the manufacturer, LIPE® in faeces was analysed in an infrared spectrophotometer with Fourier transform, and the equipment used was Varian 800. The concentration of LIPE® in faeces was determined based on a standard curve of LIPE®.

The digestibility coefficients (DC) of nutrients were calculated using the following formula: DC=[(g of nutrient intake–g of nutrient in the faeces)/(g of nutrient intake)].

**Growth performance**

The weight gain of animals was checked by fortnightly weighing. The animals were fasted from food for 16 hours before weighing. The total weight gain (TWG) was obtained by the difference between the initial and final body weight (BW), while the average daily gain (ADG) was obtained by dividing TWG by the period of confinement. The feed was obtained by dividing DM intake (DMI; g/day) by ADG (g/day). At the same time, feed efficiency was obtained by dividing ADG (g/day) by DMI (g/day).

**Statistical analysis**

The experimental design was a randomised block (initial BW), with four treatments, according to the following mathematical model:

\[ y_{ij} = \mu + \alpha i + \beta j + e_{ij} \]

where: \( y_{ij} \) is the value observed in the plot that received treatment \( i \) in block \( j \); \( \mu \) is the general average of the population; \( \alpha i \) is the effect of treatment \( i \); \( \beta j \) is the effect of block \( j \) (1, 2, 3, or 4); \( e_{ij} \) is the random error.

### Table 1. Chemical composition of the ingredients used in diets.

| Ingredient          | DM, g/kg | MM, g/kg DM | EE, g/kg DM | CP, g/kg DM | NDF, g/kg DM | ADF, g/kg DM | TC, g/kg DM | NFC, g/kg DM |
|---------------------|----------|-------------|-------------|-------------|--------------|--------------|-------------|--------------|
| Tifton 85 hay       | 874.6    | 60.6        | 17.2        | 71.5        | 765.6        | 422.2        | 850.7       | 85.1         |
| AB                  | 858.0    | 63.2        | 81.2        | 145.5       | 451.0        | 201.8        | 710.1       | 259.1        |
| Soybeans meal       | 887.9    | 61.6        | 18.2        | 478.1       | 161.2        | 41.3         | 424.1       | 280.9        |
| Corn, grain         | 874.6    | 16.5        | 109.0       | 87.8        | 144.0        | 41.3         | 786.7       | 642.7        |
| Urea                | 99.9     | -           | -           | -           | 432.0        | -            | -           | -            |
| Mineral mixture°    | 99.9     | 99.9        | -           | -           | -            | -            | -           | -            |

DM, dry matter; MM, mineral matter; EE, ether extract; CP, crude protein; NDF, neutral detergent fibre; ADF, acid detergent fibre; TC, total carbohydrates; NFC, non-fibrous carbohydrates; AB, annatto byproduct. °Mineral mixture provided the following guaranty levels/kg: vitamin A, 135,000 U; vitamin D3, 68,000 U; vitamin E, 450 mg; Ca, 240 g; P, 71 g; K, 28.2 g; S, 20 g; Mg, 20 g; Co, 30 mg; Cu, 400 mg; Cr, 10 mg; Fe, 2500 mg; I, 40 mg; Mn, 1550 mg; Se, 15 mg; Zn, 1700 mg; P (max.), 710 mg.

### Table 2. Proportion of ingredients and chemical composition of the experimental diets.

| Ingredients, %          | 0 | 100 | 200 | 300 |
|-------------------------|---|-----|-----|-----|
| Tifton 85 hay           | 55 | 55  | 55  | 55  |
| Corn, grain             | 30 | 22.2| 12.8| 4.1 |
| Soybeans meal           | 13 | 10.8| 10.2| 8.9 |
| AB                      | 0  | 10  | 20  | 30  |
| Urea                    | 1  | 1   | 1   | 1   |
| Mineral salt            | 1  | 1   | 1   | 1   |
| Total                   | 100| 100 | 100 | 100 |

Chemical composition

| Ingredient          | 0    | 100  | 200  | 300  |
|---------------------|------|------|------|------|
| DM, g/kg            | 878.5| 876.5| 874.7| 872.8|
| OM, g/kg DM         | 943.7| 940.0| 935.3| 931.5|
| CP, g/kg DM         | 154.0| 151.2| 154.6| 155.3|
| EE, g/kg DM         | 44.5 | 43.7 | 41.5 | 39.9 |
| NDF, g/kg DM        | 485.2| 515.5| 546.1| 576.6|
| ADF, g/kg DM        | 249.9| 266.0| 282.0| 298.1|
| TC, g/kg DM         | 745.3| 745.2| 739.3| 736.4|
| NFC, g/kg DM        | 260.1| 229.7| 193.7| 158.8|
| TDN, g/kg           | 729.5| 727.3| 703.0| 710.2|
| ME, Mca/ADg°        | 2.64 | 2.63 | 2.54 | 2.56 |

AB, annatto byproduct; DM, dry matter; OM, organic matter; CP, crude protein; EE, ether extract; NDF, neutral detergent fibre; ADF, acid detergent fibre; TC, total carbohydrates; NFC, non-fibrous carbohydrates; TDN, total digestible nutrients; ME, metabolisable energy. °Obtained from TDN (Weiss, 1999) and the ratios 1 kg NDT equals to 4409 Mcal digestible energy (DE) and ME=82% DE.
The statistical analyses were performed using PROC GLM of SAS ver. 9.0 (SAS, 2003). An orthogonal partition of the sum of the square of treatments into linear, quadratic, and cubic degree effects was obtained by analysis of variance. Regression equation was adjusted when significance (P<0.05) was observed for intake, digestibility and growth performance, using PROC REG of SAS ver. 9.0.

Results and discussion

Intake and digestibility

Annatto byproduct inclusion had no effect (P>0.05) on DMI (kg/day g/kg BW or g/kg^{0.75}; organic matter intake (OMI), kg/day; CP intake, kg/day; NDF intake (NDFI) kg/day; and TDN intake (TNDI, kg/day; Table 3).

The average DMI was 1.11 kg/day, 40.00 g/kg of BW, and 91.17 g/kg^{0.75}. These values are within the range established by the National Research Council (2007) for sheep with a mean weight around 30 kg. Moraes (2007) and Clementino (2008) observed that increased levels of AB promoted a linear increase in DMI (kg/day; %BW; g/kg^{0.75}) by goats and sheep. In a study evaluating the nutritive value of elephant grass silages added to AB, Rêgo et al. (2010) also observed a linear increase in DMI (g/day) with increased levels of AB silage. In the three studies mentioned, AB replaced bulky diets, thus influencing positively the nutritive value of experimental diets and increasing the nutrient density. In the present study, the CP and ME levels in the experimental diets were similar, which partly explains the lack of difference in DMI among the treatments. The apparent digestibility of DM (DMD) was not influenced by AB (Table 4). The physical and chemical characteristics of AB can probably explain this result. AB has a high degree of hydration (Anselmo et al., 2008) that favours microbial colonisation (Queiroz et al., 2010) and subsequent fermentation. Another factor contributing to the high DMD, even at high levels of AB inclusion, is the presence of starch as the main reserve carbohydrate in the annatto grain (Amaral et al., 2001), which probably replaced the corn starch without major changes in microbial dynamics.

From the organic matter intake (OMI) and digestibility (OMD) (Tables 3 and 4), it can be inferred that the animals ingested 0.80 kg/day, 0.80 kg/day, 0.69 kg/day, and 0.76 kg/day of digestible organic matter, which has high and positive correlation such as energy content of diets (Agricultural and Food Research Council, 1993). The presence of carbohydrate fractions and highly digestible protein (A+B1) confirmed by studies of Pereira et al. (2008, 2010a, 2010b) for carbohydrates and AB proteins may explain the relatively high OMD values even with the inclusion of 300 g/kg of alternative food in the diet. The CP digestibility (CPD) was not influenced by AB inclusion (P>0.05) and showed values of 0.17, 0.16, 0.15, and 0.16 kg/day for increasing levels of AB. The lack of treatment effects (P>0.05) was also found for other expression units of consumption, with values of 5 kg of BW and 13.31 g/kg^{0.75}. The similarity of the CP content of the experimental diets and the lack of difference in DMI of the experimental diets may explain these results. The apparent CPD was not affected (P>0.05) by AB inclusion and had a mean of 0.79 g/kg, resulting in 127 g/day of mean digestible protein. The lack of influence of AB on protein digestibility was also reported by Moraes (2007) and Rêgo et al. (2010).

Table 3. Nutrient intake depending on the increasing levels of the annatto byproduct.

| AB levels, g/kg | 0    | 100  | 200  | Mean  | L  | Q  | CV, % |
|----------------|------|------|------|-------|----|----|-------|
| DMI, kg/day    | 1.15±0.21 | 1.15±0.19 | 1.02±0.13 | 1.10±0.14 | 1.10±0.18 | ns  | ns  | 17.28 |
| DMI, g/kg BW   | 40.00±0.007 | 40.00±0.005 | 40.00±0.004 | 40.00±0.000 | 40.00±0.01 | ns  | ns  | 14.01 |
| DMI, g/kg^{0.75} | 93.82±16.11 | 93.65±10.41 | 85.74±8.64 | 91.48±10.74 | 86.17±32.63 | ns  | ns  | 14.08 |
| OMI, kg/day    | 1.01±0.18 | 1.01±0.16 | 0.89±0.11 | 0.96±0.12 | 0.97±0.16 | ns  | ns  | 17.33 |
| CPI, kg/day    | 0.17±0.03 | 0.16±0.02 | 0.15±0.03 | 0.16±0.02 | 0.16±0.03 | ns  | ns  | 17.29 |
| NDFI, kg/day   | 0.50±0.09 | 0.54±0.09 | 0.51±0.06 | 0.58±0.07 | 0.53±0.09 | ns  | ns  | 16.83 |
| ADFI, kg/day   | 0.25±0.04 | 0.27±0.04 | 0.25±0.06 | 0.29±0.04 | 0.26±0.04 | ns  | ns  | 17.10 |
| EEI, kg/day    | 0.05±0.009 | 0.05±0.008 | 0.04±0.005 | 0.04±0.006 | 0.04±0.01 | 0.05° | ns  | 17.79 |
| NFCI, kg/day   | 0.29±0.05 | 0.26±0.04 | 0.19±0.02 | 0.17±0.02 | 0.23±0.06 | <0.001° | ns  | 18.78 |
| TDNI, kg/day   | 0.84±19.43 | 0.84±17.54 | 0.72±11.69 | 0.79±13.16 | 0.80±16.78 | ns  | ns  | 22.15 |

Table 4. Apparent digestibility of nutrients depending on the increasing levels of annatto byproduct.

| AB levels, g/kg | 0    | 100  | 200  | 300  | Mean  | L  | Q  | CV, % |
|----------------|------|------|------|------|-------|----|----|-------|
| DMD, g/kg      | 0.7±0.37 | 0.78±0.28 | 0.76±0.28 | 0.77±0.29 | 0.77±0.33 | ns  | ns  | 4.56 |
| OMD, g/kg      | 0.79±0.36 | 0.79±0.25 | 0.77±0.35 | 0.78±0.26 | 0.78±0.30 | ns  | ns  | 4.08 |
| CPD, g/kg      | 0.7±0.30 | 0.80±0.34 | 0.78±0.25 | 0.80±0.25 | 0.79±0.31 | ns  | ns  | 4.11 |
| NDFD, g/kg     | 0.7±0.49 | 0.72±0.27 | 0.74±0.31 | 0.78±0.26 | 0.76±0.38 | ns  | ns  | 5.00 |
| EED, g/kg      | 0.82±0.75 | 0.72±1.10 | 0.83±0.29 | 0.81±0.50 | 0.81±0.77 | ns  | ns  | 9.35 |
| NFCD, g/kg     | 0.79±0.37 | 0.79±0.39 | 0.75±0.45 | 0.68±0.65 | 0.75±0.68 | <0.001° | ns  | 6.95 |
According to Pereira et al. (2010a), the main site of AB protein digestion in the rumen, the food has 60% of rumen degradable protein. The timing between the rate of degradation of protein and carbohydrates in the rumen is primarily responsible for the synthesis of microbial protein (Van Soest, 1994). Annatto byproduct is balanced in levels of carbohydrates and proteins that are degradable in the rumen (Pereira et al., 2010b), resulting in an elevated soluble fraction of DM (Gonçalves et al., 2004). The intakes of NDF (NDFI) and ADF (ADFI) did not differ between diets. However, the treatments had an effect (P<0.05) on the NDFI (g/kg BW) and ADFI (g/kg BW). Average values of 17.70, 18.90, 18.50, and 21.10 g/kg of BW (Y=17.50+0.01X, R^2=0.76) and 40.89, 43.67, 42.51, and 48.41 g/kg^0.75 (Y=40.66+0.21X, R^2=0.73) were obtained. It can be inferred that the increased fibre fraction of the experimental diets (Table 2) contributed to this increase in NDFI and ADFI. Cardoso et al. (2006) studied the effect of different NDF levels on intake of sheep. They also found increased NDFI as the content of NDF was increased in the diet. Digestibility of NDF was not influenced (P>0.05) by AB inclusion in the diets. A likely NDF replacement effect probably from forage by NDF coming from AB was expected in this study, with increases in NDF digestibility. Regadas Filho et al. (2011) highlighted the heterogeneity of the fibre present in agroindustry byproducts. Despite a high fibre content (451.0 g/kg), the NDF of AB has low effectiveness according to Clementino (2008), indicating the differentiated nature of the fibre in the byproduct. In addition, the lignin concentration of AB is low (Pereira et al., 2008). Regarding the use of EE, it was recorded effect (P<0.05) AB levels. The reduced levels of EE in the experimental diets (44.5, 43.7, 41.5, and 39.9 g/kg) due to corn grain removal may partly explain these results. Annatto byproduct levels had no effect (P>0.05) on the apparent digestibility of the diets, with values of 0.82, 0.77, 0.83, and 0.81 g/kg for the four levels of AB inclusion. The fraction of EE is quite heterogeneous and variable regarding its digestibility. Fatty acids have digestibility close to 100% and are used as an energy source by the body, while carotenoids do not provide energy to the animal (Van Soest, 1994). The composition of the lipid fraction of AB was dependent on the method used for bixin extraction (Preston and Rickard, 1980; Cardarelli et al., 2008). In this study, the alternative food showed high levels of EE (81.2 g/kg) due to bixin extraction by heated vegetable oil. Furthermore, the presence of carotenoids in the AB, although energetically inert, makes the lipid fraction of this material potentially antioxidant, with effects on the quality and shelf life of meat (Dunne et al., 2009; Castro et al., 2011, Oliveira et al., 2012). Regarding the use of NFC there was a negative linear behaviour (P<0.05) with consumption. For every 1% AB inclusion in the diet, there was a 10 g decrease in non-fibrous carbohydrates intake (NFCI; g/day). It can be inferred that the NFC reduction in the experimental diet adversely affected the intake of this fraction by animals. The opposite effect was documented by Clementino (2008), who reported increased NFCI (g/day, %BW, and g/kg^0.75) with increased levels of Tifton 85 hay replacement by AB, due precisely to the increased NFC fraction in the experimental diets. The apparent DC of NFC was linearly reduced (P<0.05) with AB inclusion, with mean values of 0.79, 0.80, 0.75, and 0.68% for increasing levels of alternative food. The reduction in NFC digestibility was due to modification of the source of this fraction in the experimental diets, changing corn grain for annatto seed. Corn is rich in amylopectin (72%), which has greater ruminal digestibility than amylose, while matured annatto grain has more amylose, besides protein bodies surrounding the starch granule (Amaral et al., 2001). Thus, the reduction in digestibility of NFC can be partly explained by the change in the profile of digestible carbohydrates. Annatto byproduct inclusion had no effect (P>0.05) on TDNI (kg), which was 0.84, 0.84, 0.72, and 0.79 kg/day for increasing levels of byproducts. The dietetic TDN (%) had mean values of 0.72, 0.72, 0.70, and 0.71 g/kg for increasing levels of AB. It can be inferred that the negative linear effect (P<0.05) on the consumption of NFC and lipids resulted in decreased energy density of the diet.

**Table 5. Performance depending on the increasing levels of annatto byproduct.**

| AB levels, g/kg | 0      | 100    | 200    | 300    | Mean   | L      | Q      | CV, % |
|----------------|--------|--------|--------|--------|--------|--------|--------|-------|
| BW, kg         | 23.16±1.27 | 23.49±1.96 | 22.95±1.18 | 23.09±1.07 | 23.17±1.42 | ns     | ns     | 2.78  |
| FW, kg         | 34.38±2.28 | 34.56±2.22 | 32.52±2.37 | 32.85±1.43 | 33.58±2.61 | ns     | ns     | 7.08  |
| TWG, kg        | 11.22±2.36 | 11.07±1.49 | 8.57±1.24  | 9.46±1.75  | 10.33±2.13 | ns     | ns     | 18.76 |
| ADG, g         | 103.4±0.04 | 180.7±0.02 | 165.0±0.04 | 162.1±0.03 | 178.1±0.04 | ns     | ns     | 19.76 |
| FC ratio       | 5.9±0.70   | 6.02±0.41  | 6.18±0.71  | 6.74±1.14  | 6.22±0.88  | ns     | ns     | 22.54 |
| FE, %          | 18.82±1.73 | 16.59±1.19 | 16.19±2.00 | 14.83±2.60 | 16.11±2.08 | ns     | ns     | 21.31 |

AB, annatto byproduct; FW, initial weight; FW, final weight; TWG, total weight gain; ADG, average daily gain; FE, feed conversion; FC, feed efficiency; L, linear effect; Q, quadratic effect; CV, coefficient of variance; ns, not significant.

**Growth performance**

The AB inclusion had no effect (P>0.05) on the final weight (FW; kg), TWG (kg), ADG (kg), feed conversion (FC), or feed efficiency (Table 5). The lack of effect (P>0.05) of treatments on the FW (kg), TWG (kg), and ADG (kg/day) can be explained by the similarity among the intake of TDN. According to Van Soest (1994), consumption is related to the supply of nutrients and meeting the nutritional requirements of animals, and is considered the main determinant of animal performance.

The mean TWG was 10.40 kg and the mean ADG was 179.39 g/day and were not affected by AB inclusion. Specifically for AB, Clementino (2008) noted that 40% inclusion of byproduct resulted in gains in total weight and ADG of 10.02 kg and 179.00 g/day, respectively.

**Conclusions**

The AB can be included in the diet at levels up to 300 g/kg of total DM without affecting intake, digestibility, and weight gain in sheep. Thus, the inclusion of this byproduct in the diet may be performed whenever light into account the cost of ingredients.

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