Urea Treatment and Concentrate Supplementation on the Utilization of Sugarcane Top Pellets in Goats

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Abstract

Sugarcane tops (SCT) are agricultural crop residues commonly used as roughage in ruminant production. However, their utilization is limited due to low protein content and poor digestibility. Biological treatments of high-fiber have been shown to improve the feeding value of crop residues for ruminant production. An experiment was conducted to evaluate the intake and digestibility of SCT pellets treated with urea and supplemented with varying levels of concentrate and the interaction effect of these factors when fed to goats. The dietary treatments considered two factors: factor A (untreated and urea-treated SCT) and factor B (concentrate supplementation levels at 0.75%, 1.00%, and 1.25% body weight [BW]), on a dry matter [DM] basis). Data on intake and digestibility were analyzed using a two-way analysis of variance for a factorial experiment in a randomized complete block design (RCBD). The results indicated urea treatment significantly increased neutral detergent fiber (NDF) intake, with the most notable improvements in NDF digestibility. The intake and digestibility of SCT pellets were enhanced considerably when the pellets were urea-treated and supplemented with concentrates at 1.00% of BW (DM basis). In contrast, untreated SCT pellets showed the highest improvements in intake and digestibility when supplemented with concentrates at 1.25% of BW. Based on these findings, treating SCT with urea is recommended to improve digestibility further when fed to goats. Concentrate supplementation is also highly recommended to enhance the utilization of sugarcane top pellets, with suggested levels of 1.00% to 1.25% for untreated SCT and 0.75% to 1.00% for urea-treated SCT.

***Keywords**:* concentrate supplementation, digestibility, sugarcane top pellets, urea treatment

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1. Introduction

Sugarcane is an annual crop with a harvest cycle of 10-12 months. According to the Food and Agricultural Organization (Mekouar, 2013), the Philippines is the second largest sugar producer among the ASEAN nations and ranks ninth globally. The sugarcane industry, the primary commodity of Negros Island, contributed 66% of the total national sugar production during the 2017–2018 crop year, with an estimated annual production of sugarcane tops reaching approximately 2.13 million metric tons and an average yield of 57.83 tons of cane per hectare (SRA, 2018). Sugarcane tops account for about 20.55% of the total biomass of sugarcane plants (Tongol, 2018). Around 2.65 million metric tons of crop residues, including sugarcane tops, green leaves, leaf bundle sheaths, and immature cane (McKenzie, 2007) are generated after harvest. However, these residues are typically left in the field and often burned. Despite the abundance and availability of sugarcane tops, their use as ruminant feed remains underutilized and has yet to be optimized.

These crop residues are characterized by low levels of good-quality protein, limited fermentable carbohydrates, and poor digestibility due to their high fiber content (Diaz *et al.*, 1997; Wanapat, 2000; Ngamsaeng *et al.*, 2006). Feeding low-quality forage leads to slow growth, poor reproductive and milk production performance, reduced feed intake, and insufficient animal nutrient of animal’s nutrient requirements, mainly when used as the sole roughage (Alemu, 2008). Sugarcane tops present a potential feed source for ruminants, especially during the dry season when the grassland is insufficient (Suzuki *et al.*, 2010). Their inclusion in ruminant diets has been shown to positively influence the growth and carcass characteristics (Worku, 2015).

Urea treatment, introduced in 1970, is widely used to enhance fiber digestion in low-quality roughages. The primary principle of this method is to maximize cellulose digestion, as poor-quality roughages are slowly digested in the rumen (Naseeven, 1988). Ammonia produced from urea treatments weakens the lignified cell walls of forages, enabling rumen microorganisms to penetrate more effectively, resulting in improved fermentation and nutrient release. Urea is preferred over other treatments due to its availability, affordability, and ease of handling (Kiangi *et al.*, 1981; Sahnoune *et al.*, 1991). Pre-treating sugarcane tops with urea, particularly in silage preparation, has been shown to increase ruminants' digestibility (Sharifi *et al.*, 2016). Urea-treated sugarcane tops significantly improve voluntary consumption indices and live weight gain when fed to Zebu steers (Ferreiro and Preston, 1976). Similarly, ensiling sugarcane tops with urea enhances feed intake and nutrient digestibility in sheep (Reddy *et al*., 1996; Reddy and Prasad, 1983). Furthermore, ensiling chopped sugarcane tops with urea improves nutrient digestibility, although voluntary feed intake remains unaffected (Preston and Leng, 1987).

This study aimed to maximize the potential of sugarcane tops as feed for ruminants by utilizing urea treatment and concentrate supplementation in goats. The study aimed to determine the intake and digestibility of sugarcane top (SCT) pellets with urea treatment and varying levels of concentrate supplementation in goats.

2. Methodology

2.1 Ethical Approval

All the practices used in this study were approved by the South Western University- Matias H. Aznar Memorial College of Medicine Inc. Animal Care and Use Committee (Assignment Protocol No. MHAM-022018-20) at MHAM College of Medicine Redemptorist Plaza, Camputhaw Cebu City.

2.2 Preparation of Sugarcane tops-based Pellets

SCT pellets were prepared using the tops of the VMC 84-524 variety. The collected SCT was chopped into pieces approximately 3–4 inches long, shredded to achieve a finer particle size, and then air-dried. The dried SCT was manually mixed with other ingredients in the formulation for 15 minutes. Molasses, added at a rate of 5%, served as a binder for the pellets. The mixture was then processed into pellets using a pelleting machine and stored in sacks until needed for feeding.

2.3 Dietary Treatments and Experimental Set-up

The experiment utilizes a Repeated Measures Design within a Randomized Complete Block Design (RCBD) with four treatments and four blocks based on period/runs (Montgomery, 2017). The treatments were designed in a 2 x 3 factorial to examine the possible interaction between urea treatment and the level of concentrate supplementation. Factor A (Type of SCT): A1 – Untreated SCT and A2 – Urea-treated SCT; and Factor B (Level of concentrate supplementation): B1 – 0.75% Body Weight (BW), Dry Matter (DM) basis, B2 – 1.00% BW DM basis, and B3 – 1.25% BW DM basis.

2.4 Preparation of the Experimental Animals

The study used six heads of female goats aged 5–6 months and randomly assigned to six different treatments with a single block per run. Animals were dewormed using ivermectin prior to the experiment, and proper management was employed. The initial weight of the experimental animals was measured to determine the *ad-libitum* intake of the basal diet. Goats were confined in 2 x 4 ft open-top metabolism cages (Bestil and Espina, 1992) to allow the measurement of feed intake and refusal while separating feces from urine for digestibility measurements.

2.5 Feeding the Experimental Animals

In a three-day interval, the basal diet and experimental ration were gradually pre-fed, following the recommended ratio of 75:25, 50:50, and 25:75. This ratio was strictly adhered to prevent digestive upset as the microbial population adjusted to the new diet and to ensure enzyme production in the animals on the experimental ration during the adjustment period (Forbes, 2007).

The sugarcane top pellets were offered twice daily, at 8:00 A.M. and 4:00 P.M. At noon, the concentrate, at different percentages, was given to the animals. Drinking water was available at all times.

2.6 Intake and Digestibility Trial

The *in vivo* digestibility trial was conducted according to Bestil's procedures (2008). Days one to eight covered the adjustment period, during which the experimental animals were given the treatment diets *ad libitum*, with a 20% allowance based on the previous day's voluntary intake. The initial weights of the animals were measured, and their daily feed intake was recorded. Days 9 to 14 were the collection period. The daily feed given and refusals were recorded to calculate voluntary feed intake. Samples of feed offered and refused were collected daily for laboratory analysis. Daily fecal outputs were recorded, and representative samples were obtained, pooled, and sub-sampled for laboratory analysis of Dry Matter (DM), Crude Protein (CP), Organic Matter (OM), and Neutral Detergent Fiber (NDF) content. Days 15 to 19 served as the days to eliminate carry-over effects. The experimental animals were released into the grazing area with native grasses until the next feeding period.

2.7 Laboratory Analysis

The collected feed and feces samples were dried at 60°C for 72 hours and ground using a Wiley mill (Model 4 – Thomas Scientific, USA) with a 3mm screen. DM, CP, and ash were analyzed using the Association of Official Agricultural Chemists (AOAC) method (Helrich, 1990) while NDF was measured using Van Soest's method (1994). Dry Matter Intake (DMI), Organic Matter Intake (OMI), Crude Protein Intake (CPI) and Neutral Detergent Fiber Intake (NDFI) are calculated using Equations 1, 2, 3, and 4, respectively.

$$DMI = VFI \times \%DM \text{ of feed, DM basis} \quad (1)$$

where:

$$VFI = \text{Voluntary Feed Intake of SCT-based pellets}$$

DMI was measured for SCT pellets and total diet, as the amount of concentrate supplement was given fixed.

$$OMI, kg = DMI, kg \times \%\ OM \text{ of feed, DM basis} \quad (2)$$

$$CPI, kg = DMI, kg \times \%\ CP \text{ of feed, DM basis} \quad (3)$$

$$NDFI, kg = DMI, kg \times \%\ NDF \text{ of feed, DM Basis} \quad (4)$$

Dry Matter Digestibility (DMD), Organic Matter Digestibility (OMD), Crude Protein Digestibility (CPD), and Neutral Detergent Fiber Digestibility (NDFD) were computed using Equations 5, 6, 7, and 8, respectively.

$$DMD,\% = \frac{DM\ intake - DM\ excreted}{DM\ intake} \times 100 \quad (5)$$

where:

$$DM\ excreted = \text{Fecal output, kg} \times \%\ DM \text{ of feces, DM basis}$$

$$OMD,\% = \frac{OM\ intake - OM\ excreted}{OM\ intake} \times 100 \quad (6)$$

where:

$$OM\ excreted = DM\ excreted\ x\ \%\ OM\ of\ feces,\ DM\ basis$$

$$CPD, \% = \frac{CP\ intake\text{-}CP\ excreted}{CP\ intake}\ x\ 100 \tag{7}$$

where:

$$CP\ excreted = DM\ excreted\ x\ \%\ CP\ of\ feces,\ DM\ basis$$

$$NDFD, \% = \frac{NDF\ intake\text{-}NDF\ excreted}{NDF\ intake}\ x\ 100 \tag{8}$$

where:

$$NDF\ excreted = DM\ excreted\ x\ \%\ NDF\ of\ feces,\ DM\ basis$$

2.8 Data Analysis

The data on intake and digestibility were analyzed using a two-way analysis of variance for a factorial experiment in a randomized complete block design (RCBD) with SPSS (v.17). Pairwise mean comparisons were conducted using Tukey's Honestly Significant Difference Test.

3. Results and Discussion

3.1 Dry Matter Intake and Digestibility of SCT

Dry matter digestibility is the proportion of dry matter in the feed the animal is digesting. Table 1 shows no significant difference in DM intake for untreated and urea-treated SCT pellets supplemented with concentrates at varying levels. However, a significant difference ($p < 0.05$) was found in DM digestibility between untreated and urea-treated SCT pellets, with higher digestibility observed in untreated SCT pellets after concentrate supplementation.

Table 1. DM intake and digestibility of urea treatment and concentrate supplementation on the utilization of SCT pellets in goats

Treatments	DMI (g)	DMD (%)
Factor A (Urea) Treatment		
untreated	555.75	68.25^{a}
urea-treated	591.83	56.84^{b}
p-value	0.2840^{ns}	0.0540*
Factor B (Level of Concentrate)		
0.75% of BW, DM basis	528	59.71^{b}
1.00% of BW, DM basis	614	62.42^{a}
1.25% of BW, DM basis	572	65.50^{a}
p-value	0.1103^{ns}	0.0330*
Interaction (A x B)		
T1 (A1B1)	461 ^{b}	65.93 ^{ab}
T2 (A1B2)	578 ^{ab}	74.67 ^{a}
T3 (A1B3)	628 ^{ab}	74.43 ^{a}
T4 (A2B1)	596 ^{ab}	66.60 ^{ab}
T5 (A2B2)	659 ^{a}	73.71 ^{a}
T6 (A2B3)	521 ^{ab}	59.37 ^{b}
p-value	0.0208*	0.0363*
CV, %	13.90	8.67

Treatment means within columns with different superscript letters are statistically different

** - Significant @ p<0.05; ns- Not Significant*

DM intake was higher when urea-treated SCT was supplemented with concentrate at 1.00% of BW (DM basis), and untreated SCT was supplemented with concentrate at 1.25% BW (DM basis). Supplementation of concentrate at 1.00%-1.25% of BW to untreated SCT and 1.00% of BW to urea-treated SCT resulted in higher DM digestibility.

Urea treatment enhances fiber digestion, which reduces the required concentrate supplementation to achieve higher digestibility. This aligns with the findings of Sharifi *et al.* (2016), who reported that pre-treatment of silage SCT with urea increases digestibility in ruminants. These results are consistent with the works of Preston and Leng (1987) and Wainman (1997), which suggested that significant production responses can be achieved when low-quality forages and grains are balanced at both the rumen and animal levels. Orden *et al*. (2014) demonstrated that a pelletized forage-based diet has high potential as an alternative feed ration for productive and sustainable goat farming, as evidenced by the increased duodenal nitrogen flow when supplemental protein was provided to ruminants consuming forage-based diets (Donaldson *et al*., 1991, as cited by Köster *et al*., 1996).

3.2 Nutrient Intake of SCT pellets in Goats

Organic matter, crude protein, and neutral detergent fiber intake of goats fed with untreated and urea-treated SCT pellets were measured. Table 2 shows that goats fed with urea-treated SCT pellets had higher OM, CP, and NDF intake than those fed with untreated SCT pellets. Among the supplementation levels, concentrate at 1.25% of BW resulted in the highest OM, CP, and NDF intake in goats fed with untreated SCT pellets. Similarly, goats fed with urea-treated SCT pellets with concentrate supplementation at 1.00% of BW had the highest OM, CP, and NDF intake.

A significant difference ($p < 0.05$) was found in the CP and NDF intake between untreated SCT pellets and urea-treated SCT pellets. On the other hand, there was no significant difference in the OM intake of SCT pellets fed to goats, regardless of urea treatment or levels of concentrate supplementation.

Furthermore, a significant interaction effect ($p < 0.05$) was observed between urea treatment and concentrate supplementation on OM, CP, and NDF intake. Urea-treated SCT pellets had higher organic matter, crude protein, and neutral detergent fiber intake when supplemented with 1.00% of BW on a DM basis. In contrast, untreated SCT pellets had higher OM, CP, and NDF intake when supplemented with concentrate at 1.25% of BW on a DM basis.

Urea treatment positively increases nutrient intake in high-fiber feedstuffs like sugarcane tops. The results are consistent with the study by Reddy and Prasad, as cited by Yuangklang *et al.* (2005), which found that ensiling sugarcane tops with urea increases feed intake and nutrient digestibility in sheep. Additionally, ensiling chopped sugarcane tops with urea improved nutrient digestibility, although voluntary feed intake was not affected, as stated by Preston and Leng (1987). Urea treatment also resulted in the highest crude protein digestibility, as Makkar and Becker (1996) concluded.

Table 2. Nutrient intake of urea treatment and concentrate supplementation on the utilization of SCT pellets in goats

Treatments	OMI, g	CPI, g	NDFI, g
Factor A (Urea) Treatment			
untreated	425	44^{b}	151^{b}
urea-treated	457	57^{a}	183^{a}
p-value	0.3384^{ns}	0.0001**	0.0001**
Factor B (Level of Concentrate)			
0.75% of BW	428	46^{b}	162^{b}
1.00% of BW	462	55^{a}	177^{a}
1.25% of BW	426	52^{a}	163^{b}
p-value	0.1190^{ns}	0.0034*	0.0122*
Interaction (A x B)			
T1 (A1B1)	352 ^{b}	36 ^{d}	140 ^{c}
T2 (A1B2)	442 ^{ab}	45 ^{cd}	176 ^{c}
T3 (A1B3)	482 ^{ab}	53 ^{bc}	190 ^{c}
T4 (A2B1)	453 ^{ab}	56 ^{ab}	532 ^{ab}
T5 (A2B2)	498 ^{a}	65 ^{a}	604 ^{a}
T6 (A2B3)	399 ^{ab}	50 ^{bc}	424 ^{b}
p-value	0.0222*	0.0001**	0.0027*
CV, %	13.87	8.80	14.12

Treatment means within columns with different superscript letters are statistically different
** - Significant @ p<0.05; **-Highly Significant @p<0.05; ns- not Significant*

3.3 Nutrient Digestibility of SCT pellets in Goats

Digestibility of nutrients shows that untreated SCT pellets had higher OM and CP digestibility than urea-treated SCT pellets, as shown in Table 3. However, NDF digestibility was higher in urea-treated SCT pellets. Supplementation of concentrates at 1.25% of BW resulted in higher OM and NDF digestibility, while supplementation at 1.00% of BW gave higher CP digestibility in untreated SCT pellets. On the other hand, supplementation with concentrate at 1.00% of BW resulted in the highest OM and CP digestibility, while concentrate at 1.25% of BW resulted in higher NDF digestibility.

Table 3. Nutrient digestibility of urea treatment and concentrate supplementation on the utilization of SCT pellets in goats

Treatments	OMD (%)	CPD (%)	NDFD (%)
Factor A (Urea Treatment)			
untreated	77.60^{a}	85.35	31.80^{b}
urea-treated	72.94^{b}	84.43	73.73^{a}
p-value	0.0329*	0.5805^{ns}	0.0001**
Factor B (Level of Concentrate)			
0.75% of BW, DM basis	73.02^{b}	83.36^{b}	55.34
1.00% of BW, DM basis	79.45^{a}	88.06^{a}	51.29
1.25% of BW, DM basis	73.32^{b}	83.00^{b}	62.85
p-value	0.0375*	0.0443*	0.2452^{ns}
Interaction (A x B)			
T1 (A1B1)	72.98 ^{ab}	81.83^{ab}	60.25
T2 (A1B2)	79.79 ^{a}	87.37^{ab}	63.86
T3 (A1B3)	80.02 ^{a}	86.85^{ab}	72.90
T4 (A2B1)	73.07 ^{ab}	85.37^{ab}	50.41
T5 (A2B2)	79.11 ^{a}	88.76^{a}	38.72
T6 (A2B3)	66.62 ^{b}	79.16^{b}	52.79
p-value	0.0297*	0.0296*	0.1566^{ns}
CV, %	6.72	4.69	20.68

Treatment means within columns with dissimilar superscript letters are statistically different
*** - Highly significant @ p<0.01; * - Significant @ p<0.05; ns- Not Significant*

Data showed a significant difference ($p < 0.05$) in OM digestibility and a highly significant difference ($p < 0.01$) in NDF digestibility between urea-treated and untreated SCT pellets in goats. Concentrate supplementation levels also showed significant differences ($p < 0.05$) in OM and CP digestibility, but no significant difference was found in NDF digestibility.

Nutrient digestibility shows a significant interaction ($p < 0.05$) on OM and CP digestibility between urea treatment and levels of concentrate supplementation, but no significant effect on NDF digestibility. Untreated SCT pellets supplemented with concentrate at 1.00% of BW and 1.25% of BW (DM basis) showed comparable results to urea-treated SCT pellets supplemented with 0.75% of BW and 1.00% of BW (DM basis) in terms of OM and CP digestibility. These results concur with the findings of Getachew *et al*. (2000), which indicated that urea treatment increases digestibility in ruminants. Pre-treatment of silage sugarcane tops resulted in the highest crude protein digestibility (Sharifi *et al*., 2016). Maximum cellulose digestion occurred when ammonia nitrogen (NH3N) concentrations reached approximately 43 mg/dl, according to Kiangi *et al.* (1981).

4. Conclusion and Recommendation

The study demonstrates that urea treatment of sugarcane tops (SCT) pellets significantly enhances neutral detergent fiber digestibility, making it a valuable technique to improve the nutritional quality of low-quality forages. While both untreated and urea-treated SCT pellets show potential as feed for goats, the urea-treated pellets, when supplemented with concentrates at 1.00% of body weight (BW) on a dry matter (DM) basis, offer superior digestibility and intake. Conversely, untreated SCT pellets achieve optimal intake and digestibility when supplemented with concentrates at 1.25% of BW. These findings underscore the importance of urea treatment and appropriate concentrate supplementation in maximizing the utilization of SCT pellets in goat diets.

For optimal goat nutrition, treating SCT pellets with urea is recommended to enhance fiber digestion, thereby reducing the need for higher levels of concentrate supplementation. Concentrate supplementation should be tailored to the type of SCT pellet used: for untreated pellets, a supplementation level of 1.00% to 1.25% of BW on a DM basis is advised, while for urea-treated pellets, 0.75% to 1.00% of BW is sufficient. Further research could explore the long-term effects of these feeding strategies on goat health and production, and the economic feasibility and environmental impact of implementing urea treatment on a larger scale.

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