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Performance, feeding behavior, and fecal characteristics of Nellore bulls fed snaplage in finishing diets

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ABSTRACT - The objective of this study was to investigate the influence of snaplage on fecal characteristics, feeding behavior, and performance of finishing bulls. Seventy-two single-sourced Nellore bulls (initial body weight [BW] = 400 ± 27.4 kg; 2.4 years old) were randomly assigned to one of three treatments (three bulls/pen; eight pen replicates/treatment). Treatments consisted of finishing diets with the following sources of fiber and energy: corn silage, reconstituted corn grain silage, and dry-ground corn (control; inclusion of 22.9, 42.1, and 20.0% of dry matter (DM), respectively); snaplage (inclusion of 65% of DM) and dry-ground corn (SNAP65); and snaplage only (inclusion of 85% of DM; SNAP85). Bulls were adapted over a 15-d period and fed for a total of 86 d. Fecal samples were collected on days 42, 65, and 73. Feeding behavior was assessed on days 51 and 69. All data were analyzed as a completely randomized block design. No differences were obtained for initial BW, gain:feed ratio, hot carcass, and dressing. The SNAP85 diet had a greater intake, followed by SNAP65 and control diets ($P = 0.02$). There was a tendency of greater average daily gain and final BW ($P = 0.07$ and 0.08, respectively) for SNAP65 diet, followed by SNAP85 and control treatments. A tendency ($P = 0.07$) was also observed for greater ribeye area in bulls consuming SNAP65 (85 cm^2), followed by control (81 cm^2) and SNAP85 (80 cm^2). Bulls consuming SNAP65 and SNAP85 spent more time chewing (on average, 249 min/d) than those consuming control diet (177 min/d; $P = 0.01$). Fecal starch was lower, and pH was greater for SNAP85 ($P = 0.01$ for both variables). Overall, snaplage is a suitable ingredient in high-starch diets for providing energy and physically effective neutral detergent fiber. The inclusion of 65% of snaplage and 20% of dry-ground corn (DM basis) showed a slight superior performance in Nellore bulls.

Keywords: earlage, feedlot, high-starch diet

1. Introduction

In Brazil, high-moisture corn (HMC) has been the most common method for increasing starch digestibility in finishing diets (Bernardes et al., 2022). However, snaplage has gained wide acceptance, especially in the last decade (Bernardes et al., 2018; Gusmão et al., 2021). Snaplage allows harvesting and processing of the whole ear (cob, kernels, husk, and shank) in a single operation, with considerable logistic advantages, especially for beef feedlots (Stateler, 2018; Daniel et al., 2019). Advantages of snaplage over HMC include more dry matter (DM) yield per area, built-in roughage that can either provide all of the needed roughage or at least reduce the need for additional roughage (Hill et al., 1995). This processing method is also considered simpler and has faster fermentation due to availability of sugars from the cob (Hill et al., 1995; Stateler, 2018). Conversely, when HMC or reconstituted grain is fed, the feedlot must have a source of fiber (i.e., whole-plant corn silage), which requires the farm to conduct an additional harvest.

Although snaplage has been a staple in the feeding industry for a long time, there really has been very little research on its feeding value (Akins and Shaver, 2014; Stateler, 2018).

Therefore, we hypothesized that snaplage can replace the combination between corn silage and corn grain silage in finishing diets, maintaining or increasing animal performance. Thus, the objective of this study was to investigate the influence of snaplage on fecal characteristics, feeding behavior, and performance of finishing bulls.

2. Material and methods

2.1. Institutional animal care and use approval

The study was carried out on the Experimental Farm of the Universidade Federal de Lavras, in Lavras, MG, Brazil. (21°14' S, 44°59' W). The animal care and handling procedures used in this study were approved by the Committee of Animal Care and Use of the university (007/19).

2.2. Dietary treatments

Treatments consisted of finishing diets with the following sources of fiber and energy: corn silage, reconstituted corn grain silage, and dry-ground corn (control); snaplage (inclusion of 65% of DM; SNAP65) and dry-ground corn; and snaplage only (inclusion of 85% of DM; SNAP85).

Corn hybrid (LG 3055, Limagrain seeds, Curitiba, PR, Brazil) was planted in a field of the research station of the Universidade Federal de Lavras. Half of the field was harvested as corn silage on February 19th, 2019, and half was harvested as snaplage on March 14th, 2019. A pull-type forage harvester (JF C120; JF Máquinas Agrícolas, Itapira, SP, Brazil) was used for harvesting corn silage at 38.2 ± 1.4% DM and a stubble height of ± 30 cm. The harvester was set for a 9-mm theoretical length of cut. Harvest of snaplage was done using a self-propelled forage harvester (John Deere Model 7350, Indaiatuba, SP, Brazil) fitted with an eight-row corn head (John Deere Model 600C; Indaiatuba, SP, Brazil) at 61.1 ± 1.9% DM. The harvester was set for a 14-mm theoretical length of cut with 1.5-mm processor gap spacing.

Corn grains to produce grain silage and ground corn were purchased at 86% DM and processed in a 10-mm screen in the hammer mill. To make reconstituted corn grain silage, after griding, water was added to reach 65% DM. Corn silage, snaplage, and reconstituted corn grain silage were stored in separate side-by-side bunker silos until the feeding trial was initiated. Times of conservation were 155, 139, and 108 d for corn silage, snaplage, and reconstituted corn grain silage, respectively. Diets were formulated using Valadares Filho et al. (2016) to provide an average daily gain (ADG) of 1.8 kg/d.

2.3. Animals, initial processing, and dietary management

Seventy-two single-sourced Nellore bulls (initial shrunk BW = 400 ± 27.4 kg; 2.4 years old) were randomly assigned to one of three treatments (three bulls per pen; eight pen replicates per treatment). To acclimate bulls to the facilities, all bulls were fed a common diet based on corn silage, dry-ground corn, soybean meal, and mineral mix for two weeks prior to experiment initiation. On the day of experiment initiation, bulls were identified, weighed, and treated against internal and external parasites (Solution® 3.5%, MSD Animal Health). Bulls were adapted over a 15-d period and fed finishing diets for 71 d (86 d on feed). Diets displayed in Table 1 are actual DM diet composition and nutrient concentrations. Diet formulation and composition were based on weekly DM analyses, actual nutrient values, and corresponding feed batching records.

Table 1 - Ingredients and nutrient composition of diets for finishing bulls[1]

Item	Dietary treatment[2]		
	Control	SNAP65	SNAP85
Ingredients (% of diet DM)			
Snaplage	-	65.0	85.0
Corn silage	22.9	-	-
Dry-ground corn	20.0	20.0	-
Reconstituted corn grain silage	42.1	-	-
Cottonseed meal	3.30	3.30	3.30
Soybean meal	7.60	7.60	7.60
Urea	0.90	0.90	0.90
Supplement premix[3]	3.20	3.20	3.20
Nutrients (% of DM; except DM)			
Dry matter (DM)	58.1	64.3	58.3
Ash	5.61	5.58	5.66
Crude protein	13.7	13.5	13.4
Neutral detergent fiber (NDF)	21.3	20.9	22.6
Ether extract	3.38	3.62	3.61
Starch	49.1	48.5	45.4
Starch origin (% of total)			
Snaplage	-	71.4	100
Corn silage	12.2	-	-
Dry-ground corn	28.3	28.6	-
Reconstituted corn grain silage	59.5	-	-
Particle size distribution (% as fed)			
> 19 mm	1.84	6.54	8.87
8–19 mm	16.2	20.4	26.5
4–8 mm	19.4	25.6	31.3
Bottom pan	62.6	47.4	33.4
Estimated peNDF (%)			
Top 2 sieves[4]	5.17	10.8	15.1
Top 3 sieves[5]	9.02	14.6	19.5

peNDF - physically effective NDF.
[1] Diet and nutrient formulation based on weekly DM determination (diet formulation) and monthly composite nutrient determination.
[2] Control = corn silage, reconstituted corn grain silage, and dry-ground corn; SNAP65 = snaplage (inclusion of 65% of DM) and dry-ground corn; SNAP85 = snaplage (inclusion of 85% of DM).
[3] Calcium, 36 g/kg; phosphorus, 12 g/kg; sodium, 16 g/kg; potassium, 22 g/kg; magnesium, 16 g/kg; sulfur, 7 mg/kg; zinc, 279 mg/kg; cooper, 74 mg/kg; fluor, 65 mg/kg; manganese, 234 mg/kg; cobalt, 6.5 mg/kg; iodine, 4.5 mg/kg; selenium, 1.2 mg/kg; folic acid, 6.4 mg/kg; biotin, 20.2 mg/kg; pantothenic acid, 250 mg/kg; vitamin A, 12,870 IU/kg; vitamin B12, 523 µg/kg; vitamin B6, 37 mg/kg; vitamin D3, 1,788 IU/kg; vitamin E, 193 IU/kg; monensin 650 mg/kg.
[4] Percent peNDF was estimated by multiplying the percentage of sample larger than 8 mm in particle size (top 2 sieves) by the percent NDF of those particle sizes.
[5] Percent peNDF was estimated by multiplying the percentage of sample larger than 4 mm in particle size (top 3 sieves) by the percent NDF of those particle sizes.

Samples from each week were stored in a freezer at −20 °C until nutrient analyses were completed. After DM determination (AOAC, 2023), samples from each ingredient were composited by month and analyzed for total nitrogen (crude protein [CP] = N × 6.25; AOAC, 2023), ash (AOAC, 2023), starch, (Hall, 2015), neutral detergent fiber [NDF] (Mertens, 2002), and ether extract (AOAC, 2023). Samples of mixed diets were separated using the Pen State Particle Separator as described by Heinrichs and Jones (2013). Percent physically effective fiber (peNDF) was estimated by multiplying the percentage of sample larger than 8 mm (top 2 sieves) or 4 mm in particle size (top 3 sieves) by the percent NDF (as a decimal) of those particle sizes.

Particle size of dry-ground corn and reconstituted corn grain silage was measured as follows (Table 2): duplicate dried samples of each processed grain (100 g) were placed on the top screen (6.7 mm mesh size) of an R-Tap testing sieve shaker (Marconi MA750, Piracicaba, Brazil) and vigorously agitated for 5 min. The amount of grain held on each screen was collected, weighed, and used for particle size comparisons.

Table 2 - Particle size distribution (% of total grain) of dry-ground corn and reconstituted corn grain silage and grains presented in corn silage and snaplage

Item	Corn silage	Snaplage	Dry-ground corn	Reconstituted corn grain
Screen mesh size				
6.7 mm	16.3	1.44	0.00	0.00
4.75 mm	14.3	9.13	5.45	6.11
3.35 mm	11.9	23.0	9.48	9.60
2.36 mm	8.89	20.0	14.7	14.1
1.7 mm	8.60	15.2	21.2	20.9
1.18 mm	7.64	9.27	18.1	18.8
0.59 mm	11.7	10.6	22.4	21.7
Bottom pan	20.7	11.4	8.60	9.1
Particle size (mm)	2.33	1.68	1.13	1.15

To measure particle size of grains presented in corn silage and snaplage, samples of these feeds were dried, and grains were separated from fiber components. Afterwards, the same protocol was used, as described above. The mean particle size was calculated as reported by Yu et al. (1998).

Throughout the experimental period, diets were provided twice a day (at 08:00 and 15:00 h) in equal proportions, as a total feed mixture. The DM intake (DMI) was calculated as the total kg of DM delivered to each pen after subtracting the weight of dry orts.

2.4. Fecal characteristics

Fecal samples (~20 g) were collected at 12:00 h on days 42, 65, and 73. On each day, three fresh and undisturbed piles were chosen and scored by each member of a three-person panel during sampling. The three people on the panel were the same for all sampling. The following fecal consistency scale was developed for visual scoring: 1 = liquid consistency; 2 = loose; 3 = soft; 4 = firm but not dry; and 5 = dry. A composite aliquot of fresh feces was used to measure pH immediately after sampling (Edge HI 11310; Hanna Instruments, Woonsocket, RI). The second subsample was stored in a freezer at −20 °C until the analyses were completed.

2.5. Feeding behavior

Feeding behavior was assessed by 12 trained people (two pens/person) on d 51 and 69. Bulls were observed every 5 min for 24 h to determine time spent eating, chewing, and resting (Johnson and Combs, 1991). Frequency of meals was calculated as the number of feeding visits per day. The meal duration was calculated as the sum of the length of all visits within a meal, according to Moya et al. (2011).

2.6. Carcass traits

Ultrasound images (Aloka 500-V machine, equipped with a 3.5-MHz, 17.2-cm linear array transducer; Corometrics Medical Systems, Wallingford, CT, USA) were obtained for rib eye area and 12th-rib fat thickness on the day of shipping to slaughter. Following this procedure, final BW was recorded, and bulls were shipped and harvested the next day at a commercial beef processor. Hot carcass weight (HCW) was assessed immediately following the harvest procedure, and dressing was calculated as HCW/SBW, in which SBW is the shrunk body weight.

2.7. Statistical analysis

Statistical analysis of experimental data was performed using the MIXED procedure of SAS (Statistical Analysis System, version 9.4). All data were analyzed as a completely randomized block design (blocked by pen location within the feedyard). Initial BW was used as a covariate for feedlot performance and carcass traits. Pen served as the experimental unit for all analysis. An α of 0.05 determined significance and an α of 0.06 to 0.10 was considered a tendency. The generalized linear model can be expressed as follows:

$$Y_{ij} = \mu + D_i + B_j + E_{ij},$$

in which Y_{ij} = dependent variable, μ = overall mean of all observations, D_i = effect of diet of order i, B_j = effect of a block of order j, and E_{ij} = random residual effect.

3. Results

3.1. Performance

No differences were obtained for gain:feed ratio, hot carcass, and dressing. Treament SNAP85 had greater intake (2.16% of BW), followed by SNAP65 (2.05% of BW) and control (1.95% of BW; P = 0.02) treatments (Table 3). There was a tendency (P = 0.07) of greater ADG for bulls fed SNAP65 diet (2.01 kg/d), followed by SNAP85 and control treatments (1.95 and 1.85 kg/d, respectively.). Bulls fed SNAP65 diet tended (P = 0.08) to have a 5-kg increase in final BW compared with bulls fed SNAP85 and a 14-kg increase in final BW compared with bulls fed control diet.

A tendency (P = 0.07) was also observed for greater ribeye area in bulls consuming SNAP65 (85.0 cm^2), followed by control (80.9 cm^2) and SNAP85 (79.6 cm^2). Bulls fed SNAP85 tended to have greater 12th-rib fat (5.12 mm) compared with bulls fed SNAP65 (4.23 mm) and control diet (3.80 mm).

Table 3 - Performance and carcass traits of finishing bulls fed different sources of energy and fiber

Item	Dietary treatment[1]			SEM	P-value
	Control	SNAP65	SNAP85		
FBW (kg)	558b	572a	567ab	4.19	0.08
DMI (% of BW)	1.95b	2.05ab	2.16a	0.05	0.02
ADG (kg/d)	1.85b	2.01a	1.95ab	0.05	0.07
ADG/DMI (G:F)	0.16	0.16	0.16	0.02	0.70
HCW (kg)	301	302	305	7.22	0.68
Dressing (%)	55.7	54.5	55.6	0.25	0.56
Ribeye area (cm^2)	80.9ab	85.0a	79.6b	0.54	0.07
12th-rib fat (mm)	3.80b	4.23ab	5.12a	0.11	0.06

FBW - final body weight; DMI - dry matter intake; ADG - average daily gain; G:F - gain:feed ratio; HCW - hot carcass weight; SEM - standard error of the mean.
[1] Control = corn silage, reconstituted corn grain silage, and dry-ground corn; SNAP65 = snaplage (inclusion of 65% of DM) and dry-ground corn; SNAP85 = snaplage (inclusion of 85% of DM).
a-b - For each row, mean values with different letters are significant at P<005.

3.2. Feeding behavior

No differences were obtained for time spent eating, number of meals per day, and meal length (Table 4). Bulls consuming SNAP65 and SNAP85 spent more time chewing (on average, 249 min/d) than those consuming control diet (177 min/d; P<0.01). Time spent resting was longer for bulls fed control diet (816 min/d), followed by SNAP85 (758 min/d) and SNAP65 (705 min/d).

Table 4 - Feeding behavior of finishing bulls fed different sources of energy and fiber

Item	Dietary treatment[1]			SEM	P-value
	Control	SNAP65	SNAP85		
Eating (min/d)	170	149	151	10.9	0.39
Chewing (min/d)	177b	243a	254a	14.7	<0.01
Resting (min/d)	816a	705b	758ab	20.0	<0.01
Meals per day (no.)	14.1	11.5	13.6	0.21	0.10
Meal length (min)	12.0	13.1	11.3	0.21	0.17

SEM - standard error of the mean.
[1] Control = corn silage, reconstituted corn grain silage, and dry-ground corn; SNAP65 = snaplage (inclusion of 65% of DM) and dry-ground corn; SNAP85 = snaplage (inclusion of 85% of DM).
a-b - For each row, mean values with different letters are significant at P<005.

3.3. Fecal characteristics

The DM concentration, fecal score, and nitrogen concentration were not affected by diets (Table 5). Bulls consuming control and SNAP65 diets had greater starch concentrations than those fed SNAP85 diet (P<0.01). Fecal pH was lower for bulls fed control and SNAP65 diets compared with those consuming SNAP85 diet.

Table 5 - Fecal characteristics of finishing bulls fed different sources of energy and fiber

Item	Dietary treatment[1]			SEM	P-value
	Control	SNAP65	SNAP85		
Dry matter (DM; %)	20.2	21.5	21.6	0.62	0.56
Fecal score	2.62	2.64	2.70	0.06	0.65
Nitrogen (% DM)	2.52	2.24	2.54	0.23	0.58
Starch (% DM)	5.33a	5.03a	3.13b	0.23	<0.01
pH	6.22b	6.22b	6.52a	0.06	<0.01

SEM - standard error of the mean.
[1] Control = corn silage, reconstituted corn grain silage, and dry-ground corn; SNAP65 = snaplage (inclusion of 65% of DM) and dry-ground corn; SNAP85 = snaplage (inclusion of 85% of DM).
a-b - For each row, mean values with different letters are significant at P<005.

4. Discussion

Over the past two decades, dry corn, processed by hammer or roller mills, has been the main energy source in Brazilian finishing diets (Millen et al., 2009; Silvestre and Millen, 2021). However, when dry-ground corn is offered to cattle, starch digestibility is lower compared with other processing methods (e.g., steam-flaking; early-harvest; Owens et al., 1997; Jacovaci et al., 2021). Thus, to increase starch availability and the energy content of finishing diets, feedlot owners started adopting different grain processing methods, based mainly on ensiling (Silvestre and Millen, 2021; Bernardes et al., 2022). Currently, 43% of feedlots have adopted grain silage in the diets (Bernardes et al., 2022). High-moisture corn, snaplage, reconstituted grain corn, and reconstituted grain sorghum were used by 21, 12, 6.7, 4% of feedlots, respectively (Bernardes et al., 2022). Hence, snaplage accounted for almost one-third of operations that have been using grain silages.

As snaplage is high in energy (82% of total digestible nutrients; NASEM, 2016) and has a certain concentration of fiber (15–25% of NDF; Akins and Shaver, 2014; NASEM, 2016; Gusmão et al., 2021), we investigated two inclusions of this feed in the diet, combined or not with ground corn (65 and 85% of inclusion, respectively). The control treatment was a diet commonly practiced by Brazilian feedlots, based on corn silage, corn grain silage, and dry-ground corn. Bulls consuming SNAP65 tended to have a greater performance, followed by SNAP85 and control treatments (Table 3). Our results also showed that bulls fed SNAP65 and SNAP85 spent more time chewing than those consuming the control diet. Differences in chewing could explain why cattle fed snaplage (greater peNDF in the diets; Table 1) outperformed cattle fed corn silage (lower peNDF). Bulls consuming SNAP65 and SNAP85 chewed, on average, 70 min/d more compared with cattle fed the control diet. Mertens (1997) reported that fiber particle size can promote chewing and rumination, which are important in maintaining a desirable rumen pH. It is commonly assumed that low rumen pH (< 5.8), especially for more than 3 h, reduces mean DMI and performance (Owens et al., 1997; Schwartzkopf-Genswein et al., 2003). Although we did not measure ruminal pH profile, we speculated that bulls consuming the control diet had more unfavorable rumen environment, promoted by lower pH, than bulls fed snaplage in the diets. In our study, this fact may have affected the intake in bulls fed the control diet (Table 3). Thus, a lower nutrient intake may have led to lower performance in those bulls.

Snaplage has lower peNDF than corn silage (NASEM, 2016). However, the proportions of snaplage used in SNAP65 and SNAP85 diets were greater than corn silage in the control diet (22.9% of DM), which led to greater peNDF values. Stock and Erickson (2006) reported that feeding combinations of corn grain silage with more slowly digested grains (e.g., dry-rolled corn) resulted in a positive complementary effect in performance and feed efficiency in the feedlot cattle. According to these authors, these improvements can be explained partially by a reduction in subacute acidosis as compared with feeding corn grain silage alone. Therefore, the strategy of feeding grain blends, as recommended by Stock and Erickson (2006) and adopted by us in the control and SNAP65 diets may work when a minimum of peNDF is offered, i.e., this method had positive effects in bulls fed SNAP65 diet.

Another fact that may explain the unfavorable rumen environment in bulls consuming the control diet was the particle size of the energy sources used in this diet (Table 2). Dry-ground corn and reconstituted corn grain silage had a mean particle size of 1.13 mm (Table 2) and accounted for 87.8% of starch origin (Table 1). Conversely, grains presented in the snaplage had a particle size of 1.68 mm and represented 71.4 and 100% of starch origin in SNAP65 and SNAP85, respectively. It has been established in the literature that finer particles of cereal grains have higher chances of causing metabolic disorders (Beauchemin et al., 2001; NASEM, 2021).

Regarding the starch utilization by the animals, bulls consuming SNAP85 had lower fecal starch. This diet had highly fermentable starch from snaplage and no inclusion of dry-ground corn, while control and SNAP65 diets had an inclusion of 20% of ground corn in the diet (~28% of starch origin; Table 1). Several papers reported that griding and rolling are not the most suitable methods to process corn, once steam-flaking and ensiling have greater starch digestibility (Owens et al., 1997; Jacovaci et al., 2021). Hence, this fact may explain a greater fecal starch in the control and SNAP65 diets. Another factor related to a lower concentration of starch in feces of bulls consuming SNAP85 is the greater retention time of particles in the rumen. Among the processing methods, ensiling has greater ruminal retention time compared with others, and it allows greater starch digestibility, decreasing fecal starch (Owens et al., 1986; Owens and Zinn, 2005). Feces of bulls consuming the control and SNAP65 diets had lower fecal pH. This corroborated the fact that the starch presented in those diets was less degradable in the rumen and, consequently, more starch entered in the hindgut due to the presence of dry-ground corn. When greater concentrations of starch reach the hindgut, the fecal pH can get lower (Wheeler and Noller, 1977; Gressley et al., 2011). That occurs because the hindgut is a fermentation compartment with less buffering capacity than the rumen (Gressley et al., 2011).

5. Conclusions

Overall, snaplage is a suitable ingredient for high-starch diets for providing energy and physically effective fiber. The inclusion of 65% of snaplage and 20% of dry-ground corn (DM basis) showed a slight superior performance in Nellore bulls.

Data availability

All data are available in the manuscript.

Author contributions

Conceptualization: Bernardes, T. F.; Gionbelli, M. P.; Casagrande, D. R. and Ladeira, M. M. **Data curation:** Bernardes, T. F. **Formal analysis:** Bernardes, T. F.; Justino, T. G. and Casagrande, D. R. **Funding acquisition:** Bernardes, T. F. and Ladeira, M. M. **Investigation:** Bernardes, T. F.; Justino, T. G.; Domingues, E. H. R.; Gionbelli, M. P. and Casagrande, D. R. **Methodology:** Bernardes, T. F.; Domingues, E. H. R.; Gionbelli, M. P. and Casagrande, D. R. **Project administration:** Bernardes, T. F. **Supervision:** Bernardes, T. F. **Validation:** Bernardes, T. F. and Casagrande, D. R. **Visualization:** Bernardes, T. F.; Justino, T. G.; Gionbelli, M. P. and Casagrande, D. R. **Writing – original draft:** Bernardes, T. F. **Writing – review & editing:** Bernardes, T. F.

Conflict of interest

The authors declare no conflict of interest.

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