Research Article

Effect of Dietary Levels of Neutral Detergent Fiber on Feed Intake, Nutrient Digestibility, Rumen Parameters and Nitrogen Retention of Beef Cattle

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Abstract | The objective of this study was to evaluate effects of dietary levels of neutral detergent fiber (NDF) on feed intake, nutrients digestibility, rumen parameters and nitrogen retention of crossbred beef cattle (Black Angus × Zebu crossbred). Four male cattle at 17.5±1.78 (Mean±SD) months of age with an average live weight of 262±20.5 kg (Mean±SD) was allocated in a 4x4 Latin square design. The treatments were 47, 51, 55 and 59% NDF in diets corresponding to NDF47, NDF51, NDF55 and NDF59 treatments following the previous findings of the *in vitro* experiment. Each experimental period was two weeks including one week for adaptation and another one for sampling. The results showed that nutrient intakes (kg/animal/day) were similar (P>0.05) among treatments, however DM and OM intakes were numerically higher for the NDF55 treatment compared with the others. Digestibilities (%) of DM and OM were significantly different (P<0.05) among treatments and gradually decreased from the NDF47 to NDF59, however these values between NDF51 and NDF55 were not significantly different (P>0.05). Rumen pH, N-NH_3, and VFAs concentration values before (0h) and 3h after feeding were similar (P>0.05) among treatments. Nitrogen retention value was numerically higher in NDF47, NDF51 and NDF55 treatments compared with NDF59 treatment (P>0.05) and a similar trend of the observed daily weight gain was found in the treatments. It was concluded that increasing levels of NDF in cattle diets from 47 to 59% reduced DM and OM digestibility while nitrogen retention and daily weight gain decreased slightly. Content of 55% NDF in the diet could be properly recommended for further study in terms of available forage utilization and daily weight gain.

Keywords | Neutral detergent fiber, Beef production, Digestion, Rumen ecology, Ruminants

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INTRODUCTION

The crossbred beef cattle in Vietnam were produced from the artificial insemination projects between Zebu cattle groups and the improved breeds such as Angus, Charolais, Wagyu, etc. These crossbred cattle have higher beef performance compared to the local ones, but they require higher quality diets. Forage quality is important in the context of digestibility and the requirement for nutrients. However, high fiber diets are usually applied for beef cattle due to the utilization of locally available forages with low costs. Nha et al. (2008) stated that neutral detergent fiber (NDF) digestibility of cattle and buffaloes was 54.0 and 57.9, respectively. According to Truong and Thu (2019), the high NDF level in the diet reduced dry matter, crude protein, and metabolizable energy intakes for the beef cattle in villages of Vietnam. Moreover, Cuong et al. (2009) reported that increasing amount of NDF in the diets reduced the nutrient digestibility in ruminants. In another study, Truong and Thu (2020) concluded that increasing NDF level from 35.0%

to 65.0% in the mixture of grass and concentrate decreased gradually *in vitro* OM digestibility, and the dietary levels of NDF from 47 to 59% could be considered for further studies to apply for beef production. Promisingly, Rahman et al. (2009) stated that daily weight gain of fattening cattle was increased by the improvement of NDF digestibility. However, studies on dietary levels of NDF for cattle aiming to improve nutrition and beef performance have been still limited in Vietnam. Therefore, the objective of this *in vivo* study was to evaluate the feed utilization, rumen parameters and nitrogen retention of crossbred cattle affected by dietary NDF levels for further performance studies.

MATERIALS AND METHODS

Location and time

The experiment was carried out at Sau Duc cattle farm, which was located at Vinh Gia commune, Tri Ton district of An Giang province and the Laboratory E205 (Animal Anatomy and Physiology) of Department of Animal Sciences, College of Agriculture of Can Tho University from February 2020 to April 2020.

Experimental design, feeds and feeding

Four male cattle (Black Angus x Zebu crossbred) at 17.5±1.78 months of age with an average body weight of 262±20.5 kg (Mean±SD) was used in a 4x4 Latin square design. The treatments were NDF47, NDF51, NDF55 and NDF59 corresponding to 47, 51, 55 and 59% NDF in the diets (DM), which were based on the study results of Truong and Thu (2020). The dietary CP content (11.4 %) was calculated by the suggestion of Thu and Dong (2015). The experiment was conducted for four periods, and each period was 14 days including 7 days for adaptation and 7 days for samplings. The chemical compositions of feeds and diets are shown in Tables 1 and 2.

The concentrate was formulated (% in DM basis) from rice bran (51.7), broken rice (20.8), soybean meal (24.7), dicalcium phosphate (1.14), salt (1.14), premix vitamins and minerals (0.57). Urea and extra soybean meal were used to fix the dietary CP content of 11.4 %. The crossbred beef cattle were individually penned and water was available at all times.

Measurements taken

Feed, nutrient and energy intakes

Feeds and refusals were daily collected and the samples were analyzed for dry matter (DM), organic matter (OM), crude protein (CP), crude fiber (CF), ether extract (EE) following the procedures of AOAC (1990), neutral detergent fiber (NDF) and acid detergent fiber (ADF) according to Van Soest et al. (1991). Metabolizable energy (ME) content of feeds was estimated by the formula suggested by Abate and Mayer (1997), in which for the forages: ME (MJ/kgDM) = 20.27 – 0.1431CF – 0.1110NFE – 0.2200 Ash and for the concentrates: ME (MJ/kgDM)= – 4.80 + 0.6004CF - $0.0640CF^2$ + 1.1572NFE – $0.0236NFE^2$ + $0,00014NFE^3$. The metabolizable energy intake was calculated by the formula proposed by Bruinenberg et al. (2002), in which ME (MJ/animal/day) = 15.1 x DOM (with DOM/DCP>7.0; DOM is digestible organic matter and DCP is digestible crude protein) of the diets.

Apparent nutrient digestibility and nitrogen retention

Apparent digestibility of DM, OM, CP, NDF and ADF were determined following the method suggested by McDonald et al. (2010). The nitrogen (N) content of the feeds, refusals, feces, and urine was determined according to the Kjeldahl method (AOAC, 1990). By subtracting the amounts of N in the feed residue, feces, and urine from the N in the feed, N retention was calculated.

Rumen parameters

Rumen fluid was collected for determination of pH, total volatile fatty acids (VFAs) and ammonia ($N\text{-}NH_3$). The samples were taken before feeding (0h) and after feeding (3h) in the morning on the middle (on day 6) of each period by using a stomach tube. Rumen fluid was immediately measured for pH using a portable pH (EcoTestr pH2, Eutech – Singapore). Rumen VFAs was determined by the procedure of Barnet and Reid (1957). Rumen ammonia concentration was determined by distillation and titration with the Kjeldahl method (AOAC, 1990).

Table 1: Chemical composition (%DM) of feeds used in the experiment

Item	DM	OM	CP	NDF	ADF	CF	NFE	ME*, MJ/kgDM
Elephant grass	16.1	88.5	9.17	64.2	41.0	31.9	42.1	8.50
O. turpethum vines	13.5	87.9	13.8	37.5	30.8	24.4	44.2	9.22
Rice straw	85.2	89.3	5.27	69.0	40.8	30.5	49.5	8.07
Soybean meal	86.6	93.8	42.0	18.1	14.6	4.77	44.8	13.8
Concentrate	87.8	89.8	18.1	20.1	11.9	6.73	60.0	10.5
Rice bran	89.1	89.1	11.7	27.4	15.3	10.3	58.9	10.7
Broken rice	84.9	99.4	8.29	7.03	2.14	1.06	89.0	10.5
Urea	99.4	-	286	-	-	-	-	-

DM: dry matter; OM: organic matter; CP: crude protein; NDF: neutral detergent fiber; ADF: acid detergent fiber; CF: crude fiber; NFE: nitrogen free extract; NFE= OM – (CP + CF + EE), ME*: metabolizable energy (MJ/kg DM).

Table 2: Ingredient composition and chemical compositions of diets.

Item	Treatments			
	NDF47	NDF51	NDF55	NDF59
Ingredient composition, % DM				
Elephant grass	10.0	9.92	9.73	9.36
O. turpethum vines	38.0	25.0	12.2	-
Rice straw	33.0	46.0	59.1	72.1
Soybean meal	-	1.98	2.92	5.62
Concentrate	19.0	16.9	15.6	12.2
Urea	-	0.238	0.559	0.735
Total	100	100	100	100
Chemical compositions, % DM				
DM	24.7	30.6	40.1	57.2
OM	88.3	88.3	88.1	88.1
CP	11.4	11.4	11.4	11.4
NDF	47.0	51.0	55.0	59.0
ADF	30.8	31.9	33.0	34.1
CF	22.8	23.5	24.3	25.0
NFE	50.4	50.2	49.8	49.6
ME*, MJ/kgDM	8.86	8.71	8.51	8.38

DM: dry matter; OM: organic matter; CP: crude protein; NDF: neutral detergent fiber; ADF: acid detergent fiber; CF: crude fiber; NFE: nitrogen free extract; NFE = OM – (CP + CF + EE), ME: metabolizable energy (MJ/kg DM). NDF47, NDF51, NDF55 and NDF59 treatment contained neutral detergent fiber at 47, 51, 55 and 59% (DM basis).

Daily weight gains (DWG)

The cattle were weighed by an electronic scale (Model TPSDH, YAOHUA, Taiwan) and calculated by using cattle live weights, which were weighed for 3 consecutive days in early morning before feedings at the beginning and at the end of each experimental period.

Statistical analysis

The data were analyzed variance using the ANOVA of General Linear Model of Minitab Reference Manual Release 16.1 (Minitab, 2010). Tukey's pairwise comparisons (α= 0.05) were applied to determine differences between dietary treatments. Data were analyzed using the model $y_{ijk} = \mu + T_i + A_j + P_k + e_{ijk}$; where y_{ijk}: = the dependent variable, μ: the overall mean, T_i = the effect of treatment (i = 1 to 4), A_j: the effect of animal (j = 1 to 4), P_k= the effect of period (j = 1 to 4), and e_{ijk} = the random error.

RESULTS AND DISCUSSION

Feed, nutrient and ME intakes

The results presented in Table 3 indicated that DM, OM, CP and NFE intakes were not different (P>0.05) among the treatments. Neutral detergent fiber and ADF intakes were augmented (P < 0.05) while the ME was gradually reduced from NDF47 to NDF59 treatments (P= 0.065).

Table 3: Daily feed, nutrient and metabolism energy intake of experimental cattle

Item	Treatments				P	SEM
	NDF47	NDF51	NDF55	NDF59		
Feed intake, kgDM/animal						
Elephant grass	0.659	0.664	0.660	0.665	0.498	0.003
O. turpethum vines	2.10^{a}	1.41^{b}	0.69^{c}	-	0.000	0.036
Rice straw	1.91^{d}	2.57^{c}	3.33^{b}	3.92^{a}	0.000	0.020
Soybean meal	-	0.117^{c}	0.174^{b}	0.351^{a}	0.000	0.005
Concentrate	1.09^{a}	0.99^{b}	0.92^{c}	0.75^{d}	0.000	0.008
Urea	-	0.012	0.029	0.036	-	-
Nutrient intake, kg/animal						
DM	5.76	5.75	5.81	5.73	0.782	0.057
OM	5.12	5.11	5.16	5.10	0.834	0.051
CP	0.649	0.654	0.656	0.658	0.502	0.004
NDF	2.75^{d}	2.96^{c}	3.21^{b}	3.38^{a}	0.000	0.022
ADF	1.83^{b}	1.89^{b}	1.98^{a}	2.02^{a}	0.001	0.018
NFE	2.81	2.81	2.86	2.83	0.543	0.028
ME**, MJ	49.2	47.4	46.9	44.4	0.065	0.960
DM/LW, %	2.05	2.03	2.06	2.02	0.400	0.016
CP/100 kg LW, kg	0.231	0.231	0.232	0.231	0.668	0.001
NDF/100 kg LW, kg	0.98^{d}	1.05^{c}	1.14^{b}	1.19^{a}	0.000	0.009
Water, kg/day	21.8^{b}	24.1^{ab}	25.9^{ab}	29.4^{a}	0.044	1.429

DM: dry matter; OM: organic matter; CP: crude protein; NDF: neutral detergent fiber; ADF: acid detergent fiber; CF: crude fiber; NFE: nitrogen free extract; ME: metabolizable energy (MJ/kg DM); **Bruinenberg *et al.* (2002); LW: live weight. NDF47, NDF51, NDF55 and NDF59 treatment contained neutral detergent fiber at 47, 51, 55 and 59% based on dry matter. ^{a,b,c} Means within rows with different letters were differ (P<0.05).

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Table 4: Feed and nutrient digestibility (%) of experimental cattle in treatments.

Item	Treatments				P	SEM
	NDF47	NDF51	NDF55	NDF59		
Nutrient digestibility, %						
DM	62.4[a]	60.1[ab]	58.7[ab]	56.2[b]	0.034	1.094
OM	63.8[a]	61.4[ab]	60.2[ab]	57.8[b]	0.034	1.045
CP	68.0	64.1	65.0	64.9	0.596	2.077
NDF	59.5	58.7	58.3	56.7	0.751	1.847
ADF	51.8	48.2	46.9	45.0	0.066	1.418
Output						
Feces, kgDM/animal/d	2.17[b]	2.30[ab]	2.40[ab]	2.51[a]	0.037	0.062
Urine, kg/animal/d	15.5[a]	15.0[ab]	11.0[ab]	9.76[b]	0.027	1.142

DM: dry matter; OM: organic matter; CP: crude protein; NDF: neutral detergent fiber; ADF: acid detergent fiber. NDF47, NDF51, NDF55 and NDF59 treatment contained neutral detergent fiber at 47, 51, 55 and 59% based on dry matter. [a, b, c] Means within rows with different letters were differ (P<0.05).

Table 5: Rumen pH, N-NH_3 and total volatile fatty acids (VFAs) concentrations of experimental cattle in different treatments.

Item	Treatments				P	SE
	NDF47	NDF51	NDF55	NDF59		
pH						
0 h	7.14	7.11	7.09	7.03	0.509	0.049
3 h after feeding	6.98	7.02	7.01	6.93	0.313	0.034
N-NH_3, mg/100ml						
0 h	19.7	18.8	17.5	17.9	0.653	1.282
3 h after feeding	24.5	21.4	21.0	22.3	0.231	1.130
VFAs, mM/L						
0 h	65.8	68.8	67.1	72.3	0.400	2.614
3 h after feeding	77.8	80.2	76.6	76.9	0.326	1.358

NDF47, NDF51, NDF55 and NDF59 treatment contained neutral detergent fiber at 47, 51, 55 and 59% based on dry matter. [a, b, c] Means within rows with different letters were differ (P<0.05).

Table 6: Daily nitrogen retention and weight gain of cattle in different treatments.

Item	Treatments				P	SE
	NDF47	NDF51	NDF55	NDF59		
Nitrogen (N) balance, g/animal/day						
Nitrogen intake (Ni)	103.9	104.6	105.0	105.2	0.502	0.608
Fecal N excretion	33.5	37.2	36.8	36.9	0.625	2.203
Urinary N excretion	28.5	32.4	34.7	38.0	0.330	3.375
Nitrogen retention (Nret)	41.9	35.0	33.4	30.3	0.328	4.127
Nret, g/kg$W^{0.75}$	0.614	0.509	0.482	0.440	0.338	0.063
Body weight, kg/animal						
Initial	276	278	278	280	0.209	1.040
Final	288	290	288	289	0.761	1.260
Daily weight gain, g/day	822	847	774	651	0.580	103.3

NDF47, NDF51, NDF55 and NDF59 treatment contained neutral detergent fiber at 47, 51, 55 and 59% based on dry matter. [a, b, c] Means within rows with different letters were differ (P<0.05).

The DM intake of cattle in this experiment was similar (P > 0.05) among treatments and ranged from 5.73 to 5.81 kg/animal/day. It was similar to that of crossbred beef cattle (250-300 kg) reported by Kearl (1982) being 5.65-6.60

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kgDM/animal/day. Similarly, Truong and Thu (2019) also reported that DM intake of crossbred Zebu cattle with an average live weight of 295 kg was 5.87 kg/head/day. In our study, the daily CP intake (kg/animal) was similar (P>0.05) among treatments and ranged 0.649-0.658 kg. It was also in agreement with the results of crossbred beef cattle presented by Kearl (1982) being 0.651 kg/animal/day.

The NDF consumption (kg/animal/day) was different (P<0.05) and observed to be lowest for NDF47 (2.75 kg) and highest for NDF59 (3.38 kg). The daily NDF intake in the present study was consistent with the findings of Porsch et al. (2018) being from 2.92 to 3.38 kg/animal for the crossbred cattle (312 kg). ME intake (MJ/animal/day) was gradually reduced (P=0.065) from NDF47 to NDF59 treatments (y = -0.3725x + 66.718 and R^2= 0.943). The proportion of ME intake decreased for the NDF51 (-3.66%), NDF55 (-4.67%), and NDF59 treatments (-9.76%) as compared to the NDF47 treatment. The ME intake of experimental cattle was similar to the result of Kearl (1982), who reported that the ME intake of crossbred cattle (275 kg) was 52.4 MJ/animal/day. In another study, ME intake was decreased (from 0.886 to 0.616 MJ/kg$W^{0.75}$) by increasing levels of NDF (45.2 - 63.2%) in the diets (Kongphitee et al., 2018).

The DM intake per kg live weight (%) was not different (P>0.05) among treatments and ranged from 2.02% to 2.06%. Tham and Udén (2013) reported that the primary component of the feed regulating intake was NDF. When the NDF content of a forage increases, the digestion rate decreases, and intake was reduced. Our results agreed with the findings of Valero et al. (2015) ranged from 1.87 to 2.07%. In this study, it was found that the water consumption was gradually increased (P<0.05) by increasing NDF in diets. It was 21.8, 24.1, 25.9, and 29.4 kg/animal/day corresponding to NDF47, NDF51, NDF55 and NDF59 treatment. Increased water intake could be explained by reduced *O. turpethum* vines intake with high moisture and the increased rice straw in the diets.

Apparent nutrient digestibility

The DM and OM digestibility (%) were different (P<0.05) among treatments, while the CP, ADF, and ADF digestibility were similar (P>0.05) among treatments (Table 4). The DM digestibility for NDF47 treatment (62.4%) was not significantly different (P>0.05) compared to NDF51 and NDF55 treatments (60.1% and 58.7%, respectively). The DM digestibility of cattle in this experiment was similar to that reported by Konka et al. (2015), who observed that increasing NDF from 55.4 to 66.2% in the diets, which reduced DM digestibility from 57.8% to 55.5%. Similarly, the OM digestibility (%) was not different among NDF47 (63.8), NDF51 (61.4) and NDF55 treatment (60.2). The data also demonstrated that increasing the NDF levels in diets from 47 to 59% gradually reduced OM digestibility (y= -0.48x + 86.24 and R^2= 0.9846). Truong and Thu (2020) concluded that increasing the NDF level from 35.0% to 65.0% in a mixture gradually decreased *in vitro* OM digestibility (y = -0.576x + 105 and R^2 = 0.954). CP digestibility of cattle in this experiment was similar among treatments and ranged 64.1 - 68.0%. This result could explain by CP consumptions, which were similar among treatments (0.649-0.658 g/head/day).

The NDF digestibility (%) of cattle was not different (P>0.05) among the treatments, however this gradually decreased from the NDF47 (59.5) to NDF59 (56.7) treatments (y = -0.22x + 69.96; R^2 = 0.931). Konka et al. (2015) stated that NDF digestibility (%) was decreased from 57.8 to 55.5 by increasing levels of NDF in the diets from 55.4% to 66.2%. ADF digestibility (%) was also not different (P>0.05) among the treatments and ranged from 51.8 (NDF47) to 45.0 (NDF59). The results showed that the feces excretion of cattle was increased (P<0.05) from the NDF47 to NDF59 treatment.

In short, the DM and OM digestibilities (%) were reduced in the present study, the digestibility of CP, NDF, and ADF (%) tended to be reduced by the incremental NDF in diets from NDF47 to NDF59. However, these were similar for the NDF47, NDF51, and NDF55 treatment (P>0.05).

Rumen environment

In general, rumen pH values, N-NH_3, and VFAs concentrations at 0h and 3h after feeding of the cattle were not different (P>0.05) among treatments (Table 5). The pH values at 3h after feeding were lower than those at 0h, while the concentrations of N-NH_3 and VFAs at 3h after feeding were higher than those at 0h. The results indicated that there was no significant effect of dietary NDF increment (%) from 47.0 to 59.0 on the rumen parameters of cattle.

Nitrogen retention and daily weight gain

Nitrogen intake of cattle was similar (P>0.05) among treatments and ranged 103.9 - 105.2 g/animal/day. The nitrogen retention (g/animal/day) had a trend of decrease by increasing dietary NDF and it was 41.9, 35.0, 33.4 and 30.3 g/animal/day for the NDF47, NDF51, NDF55 and NDF59 treatments (Table 6). There was a linear relationship between the N retention and dietary NDF levels with the function y = -0.885x + 82.2 (R^2 = 0.914). The daily weight gain (g/animal) of experimental cattle was similar (P>0.05) among the treatments. Vu et al. (2018) reported that daily weight gain of growing crossbred beef cattle being 699 - 842 g/animal/day.

CONCLUSIONS AND RECOMMENDATIONS

It was concluded that increasing NDF content in the diets from 47.0 to 59.0% showed the similar DM and OM intakes among the treatments, while the ME intakes, nutrient digestibilities, nitrogen retention and daily weight gain had a decreased tendency. A level of 55% NDF in the diet could be properly recommended to implement performance studies in beef cattle for applications in terms of better forages utilization and reasonable growth rate.

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NOVELTY STATEMENT

The crossbreed beef cattle are developing from female Zebu crossbred with freeze sperm of high-producing beef cattle (Black Angus) by artificial insemination method. Both crossbred and the results of an experiment are new.

AUTHOR'S CONTRIBUTION

NBT and NVT conceived and designed the experiments. NBT performed the experiments. NBT and NVT analyzed the data. NBT and NVT wrote the paper. All authors reviewed and approved the final manuscript.

Conflict of interest

The authors have declared no conflict of interest.

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