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Research Article

A Study of Dietary Neutral Detergent Fiber Levels on Nutrient Intake, Digestibility and Growth Performance of Charolais Crossbred Cattle in the Mekong Delta of Vietnam

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Abstract | Two experiments were implemented aiming to find out the appropriate neutral detergent fiber (NDF) levels in the crossbred beef cattle diets for improving the growth rate and roughage utilization. In the first experiment, four male Charolais crossbred cattle (Charolais x Zebu crossbred) with 17.6±1.49 months of age and 255±30.1 kg live weight (mean±SD) were used in a 4x4 Latin square design. Four treatments were 47, 51, 55, and 59% NDF in diets (DM basis) corresponding to NDF47, NDF51, NDF55 and NDF59 treatments. In the second experiment, a total of 30 crossbred beef cattle were assigned into three groups (Charolais, Black Angus and Wagyu) which each consisted of ten animals (5 males and 5 females). The experiment consisted of a 7 days adaptation period when crossbred cattle were introduced to the pens and experimental diets (from the result of experiment 1), followed by a 90-day experimental period. Results of the first experiment demonstrated that enhancing NDF percentage in the diets of the cattle from 47 to 59%, the dry matter and organic matter digestibility were gradually reduced ($P<0.05$), however, there was no significant differences between the NDF47 và NDF55 treatment ($P>0.05$). Before and 3 h after feeding the rumen pH values, $N\text{-}NH_3$ and total volatile fatty acids concentration of cattle were no differences and good for the rumen activities. In this research content, the NDF55 treatment revealed an expectation for the applied studies. Results of the second experiment indicated that with the NDF 55% in the diets, the Charolais crossbred cattle showed a superior trend on feed intake, daily weight gain and feed conversion ratio compared to the Black Angus and Wagyu crossbred ones. Therefore, the recommendation of this study was that the dietary NDF level of 55% could be appropriate for the crossbred beef cattle.

Keywords | Neutral detergent fiber, Beef production, Digestion, Growth performance, Ruminants

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INTRODUCTION

The low nutrient intake is the main problem for beef cattle (Zebu crossbred) production in the Mekong Delta, Vietnam, due to the higher neutral detergent fiber level in the diet reduced crude protein intake, metabolism energy and dry matter consumption per kg body weight. Recently, the crossbred beef cattle were produced from the artificial insemination between Zebu crossbred cows and the improved breeds of Angus, Charolais, Wagyu. These crossbred cattle have better beef performance compared to the local breeds and they require higher-quality diets. The NDF is considered as an indicator of quality assessment of ruminant feed (Mertens, 2014). In a previous study, Truong

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and Thu (2020) concluded that the dietary levels (%) of NDF from 47 to 59 promisingly gave the *in vitro* OM and NDF digestibility values, which could be used in further studies to apply for beef production. The objective of this study was to evaluate the dietary neutral detergent fiber levels on nutrient intake, digestibility, rumen environment, nitrogen retention and growth performance of crossbred beef cattle.

MATERIALS AND METHODS

This study included two experiments, the objective of the first experiment was to evaluate the effects of dietary levels of NDF on feed intake, nutrients digestibility, rumen parameters and nitrogen retention of crossbred beef cattle (Charolais × Zebu crossbred). The results of experiment 1 was applied to experiment 2. The aim of the second experiment was to determine feed intake, the daily weight gain and feed conversion ratio of three crossbred cattle groups (Black Angus × Zebu crossbred, Charolais × Zebu crossbred and Wagyu × Zebu crossbred) fix neutral detergent fiber.

Location and time

Both experiment 1 and 2 were carried out at Sau Duc cattle farm, which was located at Tri Ton district of A Giang province (10°29'33.6"N 104°49'05.4"E) and samples were analyzed at the laboratory E205 of the Department of Animal Science, College of Agriculture, Can Tho University. This study was conducted from February 2020 to April 2020 for the first experiment and May 2020 to August 2020 for the second experiment.

Crossbred cattle used in the experiments of this study were produced from Zebu crossbred cows inseminated by frozen semen of Black Angus, Charolais, and Wagyu cattle.

Experiment 1

Experimental design, feeds and feeding

Four male cattle (Charolais x Zebu crossbred) at 17.6±1.49 months of age with an average body weight of 255±30.1 kg (Mean±SD) were used in a (4x4) Latin square design. Four treatments were different levels of NDF in the diets including 47, 51, 55 and 59% (DM basis) corresponding to NDF47, NDF51, NDF55 and NDF59 treatments. They were recommended by Truong and Thu (2020) and nutrient requirements of ruminants in developing countries were standardized by Kearl (1982). The dietary CP content (11.4%) was calculated by the suggestion of Thu and Dong (2015). The chemical composition of feeds is shown in Table 1.

The elephant grass was grown on the farm. Rice straw and *O. turpethum* vines were purchased from local farmers. The concentrate was formulated (%DM) from broken rice (20.8), soybean meal (24.7), rice bran (51.7), salt (1.14), dicalcium phosphate (1.14), premix vitamins and minerals (0.57). Both soybean meal and urea were used to fix the dietary CP content of 11.4 %. The animals were individually penned and water was available at all times. The ingredients and chemical compositions of diets are given in Tables 2 and 3.

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

Feed	DM	OM	CP	NDF	ADF	CF	NFE	ME*, MJ
Elephant grass	16.8	88.4	8.92	64.6	39.9	32.6	42.2	8.38
O. turpethum vines	13.7	88.2	13.4	37.0	31.2	24.4	45.5	9.13
Rice straw	85.1	89.3	5.24	68.9	40.5	30.4	49.8	8.05
Soybean meal	86.6	93.8	42.0	18.1	14.6	4.77	44.8	13.8
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
Concentrate	87.8	89.8	18.1	20.1	11.9	6.73	60.0	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, ME: metabolizable energy (MJ/kg DM), *: Abate and Mayer (1997).

Table 2: Dietary formula (% DM) in different treatments of the experiment.

Ingredient, %DM	NDF47	NDF51	NDF55	NDF59
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

NDF47, NDF51, NDF55 and NDF59 treatment contained neutral detergent fiber at 47, 51, 55 and 59% (DM basis).

Table 3: Dietary chemical compositions (% DM) of the experiment

Treat-ments	DM	OM	CP	NDF	ADF	CF	NFE	ME*, MJ
NDF47	24.7	88.3	11.4	47.0	30.8	22.8	50.4	8.86
NDF51	30.6	88.3	11.4	51.0	31.9	23.5	50.2	8.71
NDF55	40.1	88.1	11.4	55.0	33.0	24.3	49.8	8.51
NDF59	57.2	88.1	11.4	59.0	34.1	25.0	49.6	8.38

DM: dry matter, OM: organic matter, CP: crude protein, NDF: neutral detergent fiber, ADF: acid detergent fiber, NFE: nitrogen free extract. NDF47, NDF51, NDF55 and NDF59 treatment contained neutral detergent fiber at 47, 51, 55 and 59% (DM basis), *: Abate and Mayer (1997).

The cattle were fed in the individual cages with facilities for collecting feces and urine advantageously during the experiment. The fixed quantities of concentrate, soybean meal, and urea were daily offered to the animals 2 times at 7:00 am and 1:00 pm, then *O. turpethum* vines, Elephant grass, and rice straw were given at 8:00 am, 10:00 am, 3:00 pm, 6:00 pm and 10:00 pm.

Measurements taken

Feed, nutrient and energy intakes

All feeds offered were weighed and recorded daily for each cattle. The refusals were collected and weighed daily in the morning before feeding. Chemical analyses of the feeds, refusals and feces were determined according to standard methods of AOAC (1990). The samples were analyzed for dry matter (DM), organic matter (OM), crude protein (CP), crude fiber (CF) and ether extract (EE). Neutral detergent fiber and acid detergent fiber (ADF) were analyzed following the methods of Van Soest *et al* (1991). The metabolizable energy (ME) 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 done following the method of McDonald *et al.* (2010). Each experimental period lasted for 14 days including 7 days for adjustment and 7 days for sampling. The nitrogen (N) content of the feeds, refusals, feces and urine was analyzed using the Kjeldahl methods (AOAC, 1990). Nitrogen retention was employed with the animal feces and urine daily collected: $N_{Retention} = N_{Intake} - (N_{Feces} + N_{urine})$.

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 day (on day 6) of each period by using a stomach tube. The rumen fluid was immediately determined by a pH meter (EcoTestr pH2, Eutech – Singapore). Rumen fluid was cryopreserved and transferred to the laboratory. Rumen VFAs was determined by the procedure of Barnet and Reid (1957). Rumen ammonia concentration was analyzed using the Kjeldahl methods (AOAC, 1990).

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.

Experiment 2

Experimental design, feeds and feeding

A total of 30 cattle were assigned into three breeds groups (Black Angus × Zebu crossbred, Charolais × Zebu crossbred and Wagyu × Zebu crossbred) in which each group consisted of ten animals (balanced in sex). The dietary NDF content was 55% (from the results of experiment 1), while the dietary CP content (11%) was calculated by the instruction of Thu and Dong (2015). The experimental design is presented in Table 4.

Table 4: Design of experiment 2 for growth performance of the cattle.

Item	Charolais × Zebu crossbred	Black angus × Zebu crossbred	Wagyu × Zebu crossbred
Male	5	5	5
Months of age	18.3±3.39	18.7±2.10	18.1±3.86
Average body weight	291±38.6	289±35.1	286±57.5
Female	5	5	5
Months of age	16.5±2.61	16.6±1.40	16.3±1.11
Average body weight	239±28.0	236±18.1	234±17.8

Mean±SD

Crossbred cattle were kept in individual pens and had free access to fresh drinking water at all times. The experiment consisted of a 7-day adaptation to the diets then followed by a 90-days of the experiment. Nutrient composition and ME values of feeds in experiment 2 are displayed in Table 5.

Table 5: Nutrient composition (%DM) and ME of feeds in the experiment 2.

Feed	DM	OM	CP	NDF	ADF	CF	NFE	ME*, MJ
Elephant grass	14.8	90.8	9.54	63.2	39.4	32.0	47.5	8.41
O. turpethum vines	12.5	87.0	14.7	36.3	30.2	27.8	41.7	8.80
Rice straw	84.8	89.6	6.47	69.3	41.0	33.5	48.1	7.84
Concentrate	87.6	89.7	18.6	19.4	11.1	6.24	60.5	11.5
Rice bran	89.1	89.2	11.4	28.0	15.1	9.54	60.9	10.9
Broken rice	84.8	98.6	8.22	7.76	2.56	1.19	88.4	10.4
Soybean meal	85.8	93.4	44.9	13.5	11.2	4.27	42.8	13.9
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, ME: metabolizable energy (MJ/kgDM), *: Abate and Mayer (1997).

The ingredient composition of the experimental diets was formulated (%DM) from concentrate (19.9%), *O. turpethum* vines (3.98%), Elephant grass (39.8%), rice straw (35.8%)

and urea (0.567%). The chemical composition (%DM) of the experimental diets was 26% DM, 55% NDF, 11.0% CP and ME was 8.83 MJ/kgDM. The chemical composition of concentrate in this experiment was similar to experiment 1. Total feed intake was adjusted weekly by results of the previous week's DM intake plus 1.5%.

Measurements taken

Feed, nutrient and energy intakes

All feeds, refusals and chemical analyses were similar to experiment 1. However, metabolizable energy 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 – $0.0640CF^2$ + $0.0015CF^3$ + 1.1572NFE – $0.0236NFE^2$ + $0,00014NFE^3$.

Daily weight gains

The animals were weighed by an electronic scale (Model TPSDH, YAOHUA, Taiwan). Feed conversion ratio (FCR) was calculated as the weight of DM intake required for 1 kg of live weight gain.

Statistical analysis

The data of experiment 1 were analyzed as Latin square design using the General Linear Model procedure of Minitab Reference Manual Release 16.1 (Minitab, 2010) according to 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 (k = 1 to 4), e_{ijk} = the random error. Then for the comparison of two treatments, the Tukey test of the Minitab was used, while the Two-Sample T-test of the Minitab was used in experiment 2 for three breeds groups.

RESULTS AND DISCUSSION

Experiment 1

Feed, nutrient and ME intakes

In Table 6 showed that the DM intake (kgDM/animal/day) was not different (P<0.05) among treatments and from 5.77 to 5.87 kg. It was similar to that of 275 kg crossbred beef cattle reported by Kearl (1982) being 5.65-6.60 kg. The NDF intake (kg/animal/day) was different (P<0.05) among treatments, the highest value for NDF59 treatment (3.43 kg) and lowest value for NDF47 treatment (2.74 kg). The NDF intake of crossbred cattle in this study was similar to the results on Charolais x Nellore of Porsch *et al.* (2018) which reported 2.92-3.38 kg.

The ME intake decreased (P=0.052) when increasing NDF in the diets. It was 49.8, 47.4, 47.6, and 44.5 MJ/animal/day for the NDF47, NDF51, NDF55 and NDF59 treatments, respectively. The ME intake of experimental cattle was lower than the result of Kearl (1982) which reported that the ME intake of crossbred cattle (275 kg) was 52.4 MJ/animal/day. In short, increasing NDF levels in diets could reduce metabolizable energy for crossbred beef cattle.

Table 6: Daily feed, nutrient and metabolism energy intake of experimental cattle.

Item	Treatments				P	SEM
	NDF47	NDF51	NDF55	NDF59		
Feed intake, kgDM/animal/day						
Elephant grass	0.684	0.680	0.690	0.691	0.372	0.004
O. turpethum vines	2.12[a]	1.40[b]	0.70[c]	-	0.000	0.059
Rice straw	1.89[c]	2.66[b]	3.35[a]	4.02[a]	0.000	0.137
Soybean meal	-	0.115[c]	0.175[b]	0.350[a]	0.000	0.011
Concentrate	1.089[a]	0.969[b]	0.925[c]	0.752[d]	0.000	0.006
Urea	-	0.012[c]	0.030[b]	0.037[a]	0.000	0.001
Nutrient intake, kg/animal/day						
DM	5.77	5.83	5.87	5.85	0.901	0.095
OM	5.13	5.18	5.22	5.20	0.905	0.085
CP	0.640	0.646	0.657	0.661	0.240	0.007
NDF	2.74[c]	3.00[bc]	3.23[ab]	3.43[a]	0.003	0.077
ADF	1.83[b]	1.92[ab]	1.99[ab]	2.04[a]	0.043	0.041
NFE	2.84	2.88	2.91	2.90	0.780	0.049
DM/BW, %	2.16	2.18	2.17	2.16	0.963	0.033
CP/100 kg BW, kg	0.240	0.242	0.243	0.245	0.414	0.002
NDF/100 kgBW, kg	1.03[c]	1.12[bc]	1.19[ab]	1.27[a]	0.001	0.021
ME**, MJ	49.8	47.4	47.6	44.5	0.052	1.016
Water, kg	22.4[b]	22.7[b]	28.4[ab]	30.3[a]	0.012	1.311

DM: dry matter, OM: organic matter, CP: crude protein, NDF: neutral detergent fiber, ADF: acid detergent fiber, NFE: nitrogen free extract, ME: metabolizable energy (MJ/kg DM), **: Bruinenberg *et al.* (2002), BW: body 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).

Apparent nutrient digestibility

The DM digestibility was significantly different (P<0.05) among treatments (Table 7) with the highest value for NDF47 treatment (63.2%) and lower value for NDF59 treatment (55.6%), but NDF55 treatment (59.1%) was not different (P>0,05) compare to NDF51 (59.6%) and NDF47 treatments. Konka *et al.* (2015) observed that increasing NDF from 55.4 to 66.2% in the diets, which reduced DM digestibility from 57.8% to 55.5%. The OM digestibility of NDF47 treatment (64.6%) was found significantly higher than NDF59 (56.5%) treatments (P<0.05). However, It was not different (P>0.05) with NDF51 and NDF55 (61.0 and 60.7%, respectively). In a previous report, Truong and Thu (2020) reported that OM digestibility decreased by increasing NDF in diet from 47 to 65%.

Table 7: Nutrient digestibility of experimental cattle in treatments.

Item	Treatments				P	SEM
	NDF47	NDF51	NDF55	NDF59		
Nutrient digestibility, %						
DM	63.2[a]	59.6[ab]	59.1[ab]	55.6[b]	0.004	0.845
OM	64.6[a]	61.0[ab]	60.7[ab]	57.4[b]	0.008	0.894
CP	71.6	69.1	68.8	67.3	0.235	1.310
NDF	60.5	59.7	59.7	56.8	0.201	0.107
ADF	51.7	48.7	46.6	44.4	0.101	1.697
Output						
Feces, kgDM/animal/day	2.12[b]	2.37[ab]	2.40[ab]	2.64[a]	0.019	0.078
Urine, kg/animal/day	13.7[a]	10.8[b]	9.90[b]	8.94[b]	0.003	0.517

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).

The NDF digestibility decreased (P>0.05) by increasing the dietary neutral detergent fiber levels. This finding was similar to the results of Kongphitee *et al.* (2018) being 51.9-67.4%. The ADF digestibility tended to be lower in NDF59 than in other treatments. This above results explained that the digestibility of animals can be affected by the structural components of plant feed material such as low NDF will increase the nutrient digestibility of feed (Sari *et al.*, 2018).

In short, increasing NDF levels in the cattle diets led to reducing DM and OM digestibility (P<0.05); however, NDF55 treatment was not different (P>0.05) with NDF47 and NDF51 treatments.

Rumen environment

In this study, rumen pH, N-NH_3 and VFAs concentration at 0h and 3h after feeding were not different (P>0.05) among treatments (Table 8). The rumen pH values of Charolais crossbred at 0h was similar to those stated by Packer *et al.* (2011) being 7.08-7.13. The VFAs at 3h after feeding was higher than those of VFAs at 0h. Similarly, the value at 3h after the feeding of N-NH_3 was higher than those of N-NH_3 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.

Table 8: Rumen pH, N-NH_3 and total volatile fatty acids (VFAs) concentrations of experimental cattle.

Item	Treatments				P	SEM
	NDF47	NDF51	NDF55	NDF59		
pH						
0 h	7.10	7.06	6.99	6.98	0.053	0.026
3 h after feeding	6.83	6.93	6.84	6.89	0.367	0.038
N-NH_3, mg/100ml						
0 h	15.3	18.4	14.4	15.8	0.351	1.473
3 h after feeding	20.0	21.0	18.7	18.4	0.675	1.662
VFA, mM/L						
0 h	82.7	78.9	81.6	91.6	0.205	3.802
3 h after feeding	90.4	88.6	93.2	99.7	0.232	3.531

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).

Nitrogen retention and daily weight gain

In Table 9 indicated that nitrogen intake was similar to (P>0.05) among treatments. However, the nitrogen excretion of feces and urinary tended to be lower in the NDF47 treatment than in other treatments. The differences were not found (P>0.05) for the nitrogen retention among the four treatments but tended to decrease from NDF47 to NDF51, NDF55 and lowest value for NDF59 treatments (49.3, 45.8, 43.6 and 38.9 g/animal/day, respectively). Daily weight gain was not different (P>0.05) among treatments and ranged from 579 to 712 g/animal/day. However, Brandao and Faciola (2019) concluded that diets containing 58% NDF may not be adequate for high-producing animals.

The result of experiment 1 showed that the content of 55% NDF in the diet could be properly recommended for further study in terms of available forage utilization and daily weight gain.

Experiment 2

Feed and nutrient intakes

The daily DM intake in experiment 2 was 5.87±1.11, 5.47±0.10 and 5.35±0.10 kg/animal/day corresponding to Charolais crossbred, Black Angus crossbred and Wagyu crossbred cattle (Table 10). Although, Subepang *et al.* (2019) found that DM intake of growing Charolais crossbred was 6.10 kg/animal/day. However, the proportion of forage in this study (80.1%) was higher than in the

Table 9: Daily nitrogen retention and weight gain of cattle in different treatments.

Item	Treatments				P	SEM
	NDF47	NDF51	NDF55	NDF59		
Nitrogen (N) balance, g/animal/day						
Nitrogen intake	102	103	105	106	0.240	1.128
Fecal N excretion	29.0	32.6	32.7	34.7	0.194	1.597
Urinary N excretion	24.1	24.9	28.9	32.2	0.299	3.015
Nitrogen retention (Nret)	49.3	45.8	43.6	38.9	0.075	2.225
Nret, g/kg$W^{0.75}$	0.738	0.691	0.653	0.583	0.106	0.037
Body weight, kg/animal						
Initial	263	262	266	265	0.291	1.505
Final	273	272	274	273	0.726	1.563
Daily weight gain, g/day	712	710	616	579	0.896	152.1

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 10: The feed and nutrient intakes of crossbred cattle in experiment 2.

Item	Crossbreeds cattle			P		
	Charolais × Zebu crossbred (n=10)	Black Angus × Zebu crossbred (n=10)	Wagyu × Zebu crossbred (n=10)	Cha-Black	Cha-Wag	Black-Wag
Feed intake, kgDM/animal/day						
O. turpethum vines	0.260±0.05	0.241±0.03	0.236±0.04	0.304	0.250	0.731
Elephant grass	2.29±0.33	2.21±0.24	2.17±0.36	0.564	0.460	0.770
Rice straw	2.03±0.51	1.82±0.27	1.77± 0.41	0.277	0.235	0.762
Concentrate	1.25±0.24	1.16±0.13	1.13±0.20	0.306	0.251	0.730
Urea, g	47.5± 9.19	44.0± 5.01	42.8±7.48	0.314	0.233	0.687
Nutrient intake, kgDM						
DM	5.87±1.11	5.47±0.10	5.35±0.10	0.333	0.286	0.744
OM	5.24±0.99	4.89±0.89	4.78±0.89	0.334	0.287	0.745
CP	0.758±0.14	0.706±0.08	0.690±0.12	0.330	0.274	0.731
NDF	3.24±0.61	3.03±0.32	2.96±0.55	0.337	0.290	0.746
ADF	1.95±0.36	1.82±0.19	1.78±0.33	0.350	0.303	0.749
NFE	2.92±0.56	2.71±0.29	2.65±0.50	0.325	0.280	0.744
ME*, MJ	51.8±9.78	48.3±5.12	47.2±8.73	0.331	0.283	0.743

Mean±SD, DM: dry matter, OM: organic matter, CP: crude protein, NDF: neutral detergent fiber, ADF: acid detergent fiber, NFE: nitrogen free extract, ME: metabolizable energy (MJ/kgDM), *: Abate and Mayer (1997), Cha: Charolais x Zebu crossbred, Black: Black Angus x Zebu crossbred, Wag: Wagyu x Zebu crossbred.

experiment of Subepang *et al*. (2019). The CP intake (kg/animal/day) of beef cattle was 0.758±0.14, 0.706±0.08 and 0.690±0.12 (P>0.05) for Charolais crossbred, Black Angus crossbred and Wagyu crossbred, respectively. The CP consumption in this experiment was similar to the results of the study by Mota *et al*. (2015) being 0.62-0.65 kg for crossbred cattle. Moreover, the CP intake of steers and heifer in this study were similar to results reported by Kearl (1982) being 0.679-0.753 kgCP and 0.564-0.644 kgCP, respectively.

The NDF intake was not different (P>0.05) among breeds and it was lower for the Wagyu crossbred (2.96±0.55 kg) than Black Angus crossbred (3.03±0.32 kg) and Charolais crossbred cattle (3.24±0.61 kg). Subepang *et al*. (2019) found that NDF intake of Charolais crossbred fed 51.9% NDF in the diet being 3.4 kg/animal/day. However, Valero *et al*. (2015) reported that 2.95-3.27 kg for Black Angus crossbred cattle was similar to in this study. The ME consumption of crossbred cattle had a trend to be reduced (P>0.05) from 51.8±9.78 to 48.3±5.12 and 47.2±8.73 MJ/animal/day (Charolais, Black Angus and Wagyu crossbred cattle, respectively).

Table 11: Daily weight gain and feed conversion ratio of experiment 2.

Item	Crossbreeds cattle			P		
	Charolais × Zebu crossbred (n=10)	Black angus × Zebu crossbred (n=10)	Wagyu × Zebu crossbred (n=10)	Cha-black	Cha-wag	Black-wag
Initial body weight, kg	265±41.9	262±38.2	260±48.4	0.869	0.798	0.909
Final body weight, kg	328±55.8	314±48.2	308±58.0	0.575	0.458	0.804
DWG, kg	0.693±0.17	0.578±0.16	0.537±0.14	0.130	0.035	0.536
FCR. kgDM	8.60± 0.83	9.83±1.60	10.2±1.42	0.050	0.008	0.572

Mean±SD, DWG: Daily weight gain, FCR: feed conversion ratio, Cha: Charolais × Zebu crossbred, Black: Black Angus × Zebu crossbred, Wag: Wagyu × Zebu crossbred.

In short, the feed and nutrient intakes of crossbred cattle were numberly reduced from Charolais to Black Angus, and Wagyu breeds.

Daily weight gain and feed conversion ratio

In Table 11 showed that the DWG (kg) of Charolais crossbred cattle (0.693±0.17 kg) was not different (P>0.05) with Black Angus crossbred (0.578±0.16 kg), but it was higher (P<0.05) than Wagyu crossbred (0.537±0.14 kg). While DWG of Black Angus crossbred was similar to Wagyu crossbred cattle (P>0.05). Rahman *et al.* (2009) stated that the daily weight gain of fattening cattle was increased by the improvement of NDF digestibility. In another study, Subepang *et al.* (2019) reported that the DWG of male Charolais was 0.80 kg/animal/day in the 51.9% NDF diet.

The feed conversion ratio (kgDM/kgDWG) of Charolais crossbred cattle (8.60±0.83 kg) was different (P=0.050) with Black Angus crossbred (9.83±1.60 kg) and it was significantly different (P<0.05) with Wagyu crossbred cattle (10.2±1.42 kg). The FCR in this study was higher than the experiment of Subepang *et al.* (2019) being 7.63 kgDM on crossbred Charolais cattle. However, Cherdthong *et al.* (2019) reported that FCR of Wagyu crossbred cattle was around 8.98-9.18 kgDM. In this case, FCR could be explained by concentrate intake in the experiment was 19.9% in the diet. It was lower than the study of Cherdthong *et al.* (2019) being 66.5-66.7%.

CONCLUSIONS AND RECOMMENDATIONS

It was concluded that nutrient digestibility, nitrogen retention and daily weight gain of Charolais x Zebu crossbred cattle had a decreased tendency by incremental NDF in the diets from 47.0 to 59.0%. The NDF 55% in the diets, the Charolais crossbred cattle showed a superior trend on forage utilization and daily weight gain compared to the Black Angus and Wagyu crossbred ones.

NOVELTY STATEMENT

The crossbreed beef cattle are developing from female Zebu crossbred with freeze sperm of high-producing beef cattle (Black Angus, Charolais and Wagyu) 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, performed the experiments, analyzed the data, 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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