EFFECT OF DIETARY NEUTRAL DETERGENT FIBER LEVELS ON NUTRIENT INTAKE, DIGESTIBILITY, RUMEN PARAMETERS AND NITROGEN RETENTION OF CROSSBRED WAGYU CATTLE

***Nguyen Binh Truong*[1,2,3] *and Nguyen Van Thu*[3]**

[1]Department of Animal husbandry and Veterinary Sciences, Faculty of Agriculture and Natural Resources, An Giang University, An Giang, Vietnam;
[2]Vietnam National University Ho Chi Minh City, Vietnam; [3]Can Tho University, Vietnam

Corresponding author: Nguyen Binh Truong; Mobile phone: 0983377424; Email: nbtruong@agu.edu.vn

ABSTRACT

The objective of the study was to determine the effect of neutral detergent fiber (NDF) on feed intake, nutrient digestibility, rumen parameters, and nitrogen retention of crossbred beef cattle. Four male F1 (Wagyu x Zebu crossbred) cattle were used 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. One experimental period lasted 14 days with 7 days for adaptation and 7 days for sampling. The results of experiment showed that dry matter (DM), organic matter (OM), crude protein intake were not different (P>0.05) among treatments. The metabolizable energy intake (MJ/animal/day) was reduced (P<0.05) from NDF47 to NDF59 treatments. The DM and OM digestibility were significantly different (P<0.05) among treatments with the highest value for NDF47 treatment (64.3% and 66.4%) and lowest for NDF59 treatment (55.7% and 58.5%), while NDF47 treatment was not different (P>0.05) compare to NDF55 treatment (59.1 and 61.4%). Rumen pH, N-NH_3 and total volatile fatty acids concentrations at 0h and 3h after feeding of experimental cattle were not different (P>0.05) among treatments. Nitrogen retention value was numerically higher in NDF47, NDF51 and NDF55 treatments compared to NDF59 treatment (P>0.05) and a similar trend of the observed daily weight gain was found in the treatments. The conclusion that NDF level was 55% in the diet was promising in the application.

Keywords:*crossbred beef cattle, digestibility, feed intake, and neutral detergent fiber*

INTRODUCTION

The crossbred beef cattle is produced from the artificial insemination between Zebu cattle groups and the improved breeds such as Wagyu, Angus, Charolais, etc. (Doan DucVu et al., 2021). These crossbred cattle have better beef performance compared to the local breeds, nevertheless, they require higher-quality diets, while in tropical developing countries high fiber diets are usually applied for beef cattle, due to the utilization of locally available low-cost forages (Favero et al., 2019; Mwangi et al., 2019). The neutral detergent fiber (NDF) is considered as an indicator of the quality assessment of ruminant feed (Mertens, 2014). The NDF content of roughage is often very variable and an increasing amount of NDF in the diet has reduced the nutrient digestibility in ruminants (Vu Chi Cuong et al., 2009). Nguyen Binh Truong and Nguyen Van Thu (2020) concluded that increasing the NDF level from 35.0% to 65.0% in the mixture gradually decreased *in vitro* OM and NDF digestibility, and the reasonable treatments from 47 to 59% NDF could be selected for the coming *in vivo* and performance studies. In Vietnam, studies on NDF levels in diets of beef cattle have been still limited. Therefore, the objective of this study was to evaluate the feed intakes, nutrient digestibility, rumen environment, and nitrogen retention of crossbred Wagyu cattle affected by dietary NDF levels for further studies and applications.

MATERIALS AND METHODS

Location and time

The experiment was carried out at Sau Duc cattle farm, which was located at Tri Ton district of An Giang province. The Animal Anatomy and Physiology laboratory (E205) of the Department of Animal Science, College of Agriculture of Can Tho University. This study was conducted from November 2019 to January 2020.

Experimental design and feeds and feeding

Four male F_1 (Wagyu x Zebu crossbred) cattle at 21.9±1.75 months of age with an average body weight of 314±21.3 kg (Mean±SD) were arranged in a Latin square design with 4 treatments and 4 periods (14 days for each period). The four treatments were 47, 51, 55 and 59 % NDF in the diets (DM) corresponding to NDF47, NDF51, NDF55 and NDF59 treatments, which were based on the studies of Nguyen BinhTruong and Nguyen Van Thu (2020). The dietary CP content was calculated by the suggestion of Nguyen Van Thu and Nguyen Thi Kim Dong (2015), nutrient requirements of ruminants in developing countries by Kearl (1982). The chemical compositions of feeds and diets are shown in Tables 1 and 2.

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

Item	DM	OM	CP	NDF	ADF	CF	EE	NFE	ME*, MJ/kgDM
Elephant grass	16.9	89.4	9.26	64.5	39.3	33.2	4.03	43.0	8.43
O. turpethum vines	13.4	88.4	14.4	35.7	31.3	24.0	4.19	45.8	9.20
Rice straw	84.2	89.5	5.16	69.3	40.1	29.5	2.41	52.4	7.92
Soybean meal	86.7	93.5	42.4	18.9	16.5	4.85	2.19	44.0	13.9
Rice bran	87.4	88.5	9.87	28.2	16.1	11.0	7.90	59.8	10.8
Broken rice	86.4	99.6	7.99	6.40	1.96	1.13	1.00	89.5	10.7
Concentrate	87.3	89.6	17.3	20.4	12.7	7.05	4.79	60.5	11.4
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), *: Abate and Mayer (1997).*

Table 2. Composition and chemical analysis (%DM) of the diet in experiment

Item	Treatments			
	NDF47	***NDF51***	***NDF55***	***NDF59***
Ingredient composition, % DM				
Elephant grass	10.0	9.98	9.93	9.94
*O. turpethum*vines	38.8	25.9	12.9	-
Rice straw	32.2	44.9	57.7	70.5
Soybean meal	-	2.00	2.98	5.96
Concentrate	19.0	17.0	15.9	12.9
Urea	-	0.250	0.570	0.735
Total	100	100	100	100

Item	Treatments			
	NDF47	***NDF51***	***NDF55***	***NDF59***
Dietary chemical compositions, % DM				
DM	24.9	30.7	40.1	57.8
OM	88.2	88.2	88.0	88.0
CP	11.3	11.3	11.3	11.3
NDF	47.0	51.0	55.0	59.0
ADF	31.0	32.1	33.1	34.3
CF	23.6	24.2	24.8	25.4
NFE	49.4	49.3	49.1	49.2
ME*, MJ/kgDM	9.08	8.89	8.68	8.51

*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/kgDM), *: Abate and Mayer (1997). NDF47, NDF51, NDF55 and NDF59 treatment contained neutral detergent fiber at 47, 51, 55 and 59% (DM basis).*

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). While urea and extra soybean meal were used to fix the dietary CP content of 11.3 %.

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 givenat 8:00 am, 10:00 am, 3:00 pm, 6:00 pm, and 10:00 pm.

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 – 0.2200Ash and for the concentrates: ME (MJ/kgDM) = − 4.80 + 0.6004CF – $0.0640CF^2$ + $0.0015CF^3$ + 1.1572NFE – $0.0236NFE^2$ + $0.00014NFE^3$. 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. Water intake was weighed before feeding in the morning of each day.

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). 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. Rumen fluid was immediately measured for pH using a portable pH (EcoTestr pH2, Eutech – Singapore).

The sample was filtrated through a clean double layer of cotton cloth, the liquid fraction was centrifuged for analyses of VFA and $N\text{-}NH_3$ concentrations.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).

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 by using the ANOVA of General Linear Model (GLM) of Minitab Reference Manual Release 16.1 (Minitab, 2010). Then for the paired comparison of two treatments, the Tukey test of the Minitab was used. 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 the animal (j = 1 to 4), P_k= the effect of period (j = 1 to 4), e_{ijk} = the random error.

RESULTS AND DISCUSSION

Feed, nutrient and ME intakes of experiment

The feed, nutrient and ME intakes in the present study are presented in Table 3.

Table 3. Feed, nutrient, and metabolism energy intake of experimental cattle

Item	Treatments				P	SE
	NDF47	NDF51	NDF55	NDF59		
Feed intake, kgDM/animal						
Elephant grass	0.819	0.828	0.827	0.841	0.156	0.006
*O. turpethum*vines	2.47[a]	1.65[b]	0.82[c]	-	0.000	0.059
Rice straw	2.24[d]	3.12[c]	3.86[b]	4.60[a]	0.000	0.090
Soybean meal	-	0.139[c]	0.209[b]	0.425[a]	0.000	0.008
Concentrate	1.29[a]	1.17[b]	1.10[b]	0.91[c]	0.000	0.015
Urea	-	0.015[c]	0.036[b]	0.046[a]	0.000	0.001
Nutrient intake, kg/animal						
DM	6.82	6.92	6.85	6.82	0.787	0.080
OM	6.08	6.17	6.10	6.08	0.786	0.072
CP	0.769	0.779	0.775	0.784	0.388	0.006
NDF	3.23[c]	3.55[b]	3.77[ab]	4.01[a]	0.000	0.052
ADF	2.16[b]	2.26[ab]	2.31[ab]	2.36[a]	0.015	0.030
NFE	3.44	3.52	3.51	3.51	0.505	0.041
ME**, MJ	60.8[a]	59.1[ab]	56.8[ab]	53.7[b]	0.046	1.381
DM/BW, %	2.07	2.08	2.06	2.03	0.654	0.027
CP/100 kg BW, kg	0.233	0.234	0.233	0.233	0.992	0.002
NDF/100 kg BW, kg	0.98[c]	1.07[b]	1.13a[b]	1.19[a]	0.001	0.017
Water, kg/day	29.5	33.1	33.8	38.1	0.211	2.476

*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), **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 differ (P<0.05).*

In Table 3 showed that total DM intake was not different (P>0.05) among treatments and ranged 6.82-6.92 kg/animal/day. The CP consumption of cattle in this study was from 0.769 to 0.784 kg/animal/day. It was higher than the findings of Rattakorn (2017), who reported that CP intake of Wagyu cattle in Thailand was 0.600 kg/animal/day. However, It was also in agreement with the results of crossbred beef cattle presented by Kearl (1982) which ranged from 0.612-0.780 kg/animal/day.

The neutral detergent fiber intake (kg/animal/day) was significantly different (P<0.05) among treatments with the highest value for the NDF59 treatment (4.01 kg) and the lowest value for NDF47 treatment (3.23 kg). According to Tham and Udén (2013), the primary component of the feed regulating intake was NDF. Similarly, the ADF intake (kg/animal/day) was different (P<0.05) among treatments and lowest value in NDF47 treatment (2.16 kg) and highest value in NDF59 treatments (2.36 kg). The ME intake (MJ/animal/day) of NDF47 treatment (60.8 MJ) was slightly higher (P>0.05) than that of NDF51 and NDF55 treatments (59.1 and 56.8 MJ, respectively) but it was higher (P<0.05) than NDF59 treatment (53.7 MJ). According to Kearl (1982), the ME consumption of crossbred beef cattle was 59.4-66.2 MJ/animal for a daily weight gain of 0.750 kg/animal/day.

The nutrient intake ratio (DM/BW) of NDF51 (2.08%) was numerically higher (P>0.05) than that of NDF47, NDF55, and NDF59 treatments (2.07, 2.06, and 2.03%, respectively). The CP intake per 100 kgBW in this experiment was from 0.233 to 0.234 kg (P>0.05) and it was higher than the findings of Mirattanaphra and Suksombat (2020), who reported that CP intake of Wagyu cattle was 0.195-0.196 kg/100 kg BW. Water intake (kg/animal/day) tended to be lower in NDF47 treatment (29.5 kg) than NDF59 treatments (38.1 kg). 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 of experiment

The apparent nutrient digestibility of cattle in the treatments was shown in Table 4.

Table 4. Nutrient digestibility (%) of experimental cattle in the treatments

Item	Treatments				P	SE
	NDF47	***NDF51***	***NDF55***	***NDF59***		
Nutrient digestibility, %						
DM	64.3^{a}	61.3^{ab}	59.1^{ab}	55.7^{b}	0.032	1.486
OM	66.4^{a}	63.4^{ab}	61.4^{ab}	58.5^{b}	0.031	1.349
CP	69.2	68.5	68.8	67.9	0.946	1.533
NDF	61.0	60.5	58.1	55.8	0.195	1.628
ADF	53.3	52.5	51.2	50.7	0.644	1.540
Output						
Feces, kgDM/animal/day	2.55	2.68	2.79	2.89	0.225	0.107
Urine, kg/animal/day	22.9	19.7	17.0	17.2	0.107	1.562

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 differ (P<0.05).*

The result of Table 4 showed that DM and OM digestibility (%) were different (P<0.05) among treatments. The DM and OM digestibility of NDF47 treatment (64.3 and 66.4%) were higher (P<0.05) than NDF59 (55.7 and 58.5%) but they were not different (P>0.05) compare to NDF51 (61.3 and 63.4%) and NDF 55 treatments (59.1 and 61.4%). According to Pimpaet al. (2019), the DM and OM digestibility of crossbred Wagyu in Thailand were 58.5-62.7% and 60.3-66.0%.

The CP digestibility was not different (P>0.05) among treatments and ranged 67.9-69.2%. The NDF digestibility in this study was from 55.8 to 61.0%. It was similar to the finding of Seankamsorn and Cherdthong (2020), who reported that the NDF digestibility on crossbred Wagyu cattle in Thailand was 55.8-61.0%. According to Nguyen Binh Truong and Nguyen Van Thu (2020), increasing the NDF level from 35.0% to 65.0% in the mixture gradually decreased *in vitro* OM and NDF digestibility. Brandao and Faciola (2019) found that diets containing 58% NDF may not be adequate for high-producing animals. The results showed that the feces excretion of cattle tended to be lower in NDF47 treatment (2.55 kg/animal/day) than in other treatments (P>0.05).

In short, the DM and OM digestibilities (%) were reduced in this study, the digestible 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 parameters of experiment

Rumen parameters of crossbred beef cattle in the present study are presented in Table 5.

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	6.96	6.96	6.98	6.84	0.146	0.039
3 h after feeding	6.85	6.90	6.88	6.71	0.361	0.076
N-NH_3, mg/100ml						
0 h	15.8	15.3	14.4	17.1	0.286	0.866
3 h after feeding	17.9	17.1	18.8	21.0	0.141	1.034
VFAs, mM/L						
0 h	61.5	56.0	74.3	68.8	0.091	4.319
3 h after feeding	97.4	91.2	96.1	93.9	0.171	1.761

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 differ (P<0.05).*

In general, rumen pH, N-NH_3 and VFAs concentrations at 0h and 3h after feeding of experimental cattle were not different (P>0.05) among treatments (Table 5). Our results agree with those of Cherdthonget al. (2019), who found that the rumen pH of crossbred Wagyu cattle at 0h in Thailand was 6.83-6.89. The pH values at 3h after feeding was lower than those of pH at 0h. Both N-NH_3 and VFAs concentrations at 3h after feeding were higher than those of N-NH_3 and VFAs 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 of experiment

The results of the nitrogen balance daily weight gain are presented in Table 6.

Table 6. Daily nitrogen (N) retention and weight gain of cattle in different treatments.

Item	Treatments				P	SE
	NDF47	***NDF51***	***NDF55***	***NDF59***		
Nitrogen balance, g/animal/day						
Nitrogen intake	123	125	124	125	0.388	0.915
Fecal N excretion	38.0	39.2	38.6	40.4	0.834	1.936
Urinary N excretion	33.1	35.8	44.8	48.0	0.051	3.269
Nitrogen retention (Nret)	52.0	49.7	40.7	37.0	0.071	3.582
Nret, g/kg$W^{0.75}$	0.672	0.642	0.524	0.482	0.062	0.044
Body weight, kg/animal						
Initial	324	328	327	333	0.134	2.237
Final	335	339	338	341	0.510	2.372
Daily weight gain, g/animal/day	835	810	749	566	0.840	230.7

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 differ (P<0.05).

The nitrogen intake was not different among treatments (P>0.05) and was from 123-125 g/animal/day (Table 6). Nitrogen retention tended to decrease gradually with increasing dietary NDF content, however it was not different (P>0.05). Therefore, the daily weight gain (g/animal/day) had a trend to be gradually reduced (P>0.05) from the treatment NDF47 to NDF59 and it was 835, 810, 749 and 566 g for the NDF47, NDF51, NDF55, and NDF59 treatments, respectively.

CONCLUSION

It was concluded that nutrient digestibility, nitrogen retention, and daily weight gain of crossbred Wagyu cattle had a decreased tendency by incremental NDF in the diets from 47.0 to 59.0%. 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.

REFERENCES

Abate, A. L. and Mayer, M. 1997. Prediction of the useful energy in tropical feeds from proximate composition and *in vivo* derived energetic contents: 1. Metabolisable energy. Small Ruminant Research, 25:51-59.

AOAC. 1990. Official methods of analysis (15th edition). Washington. DC. Volume 1: 69-90.

Barnet, A. J. G. and Reid, R. L. 1957. Studies on the production of volatile fatty acids from grass by rumen liquor in an artificial rumen: The volatile fatty acid production from grass. Journal of Agricultural Science, 48:315-321.

Brandao, V. L. and Faciola, A. P. 2019. Unveiling the relationships between diet composition and fermentation parameters response in dual-flow continuous culture system: a meta-analytical approach. Translational Animal Science, 3(3), 1064-1075. DOI: 10.1093/tas/txz019

Bruinenberg, M. H., Valk, H., Korevaar, H. and Struik, P. C. 2002. Factors affecting digestibility of temperate forages from semi-natural grasslands. Grass and Forage Science, 57 (3):292 - 301. DOI: https://doi.org/10.1046/j.1365-2494.2002.00327.x

Cherdthong, A., Prachumchai, R., Dagaew, G., Wachirapakorn, C., Lakham, P., and Saising, T. 2019. Comparative study cassava chip and cassava meal in concentrate diet on feed intake, rumen ecology and growth performance in Thai native beef cattle and Wagyu crossbred cattle. Kaen Kaset Khon Kaen Agriculture Journal, 47 (Suppl. 1), 117-122.

Doan DucVu, Pham Van Quyen, Hoang ThiNgan, Dau Van Hai, Nguyen Thanh Van and Nguyen Thi Be Tho. 2021. Appearance and growth performance of F1 crossbreds between Red Angus, BBB and Black Wagyu bulls with Zebu crossbred cows at Ho Chi Minh city. Journal of Animal Science and Technology, 125:13-21. Link: https://vcn.org.vn/xuat-ban/tap-chi-khoa-hoc-cong-nghe-chan-nuoi-so-125-thang-7-2021-

Favero, R., Menezes, G. D. O., Torres, R. A. A., Silva, L. O. C, Bonin, M. N., Feijó, G. L. D. and Gomes, R. D. C. 2019. Crossbreeding applied to systems of beef cattle production to improve performance traits and carcass quality. Animal, 13(11): 2679-2686. DOI:https://doi.org/10.1017/s1751731119000855

Kearl, L. C. 1982. Nutrient requirements of ruminants in development countries, International feedstuffs institute Utah Agricultural experiment station. Utah State University. Loga, Utah, USA. Google Scholar; CAB Direct

McDonald, P., Edwards, R. A, Greenhalgh, J. F. D., Morgan, C. A., Sinclair, L. A. and Wilkinson, R. G. 2010. Animal Nutrition (7th edition), Longman Scientific and Technical, N. Y. USA.

Mertens, D. R. 2014. Measuring fiber and its effectiveness in ruminant diets. Link:http://blogs.cornell.edu/cncps/files/2014/06/MertensPNC2002-280goex.pdf.

Minitab. 2010. Minitab Reference Manual. Release 16 for Windows, Minitab Inc, USA.

Mirattanaphra, M. and Suksombat, W. 2020. Effect of rumen-protected rice bran oil on carcass quality and fatty acid profile of beef from crossbred Wagyu steers. Songklanakarin J. Sci. Technol, 42, pp.123-131.

Mwangi, F. W., Charmley, E., Gardiner, C. P., Malau-Aduli, B. S., Kinobe, R. T. and Malau-Aduli, A. 2019. Diet and Genetics Influence Beef Cattle Performance and Meat Quality Characteristics. Foods, 8(12):648. DOI:https://doi.org/10.3390/foods8120648

Nguyen Binh Truong and Nguyen Van Thu. 2020. Effect of dietary levels of neutral detergent fiber (NDF) on *in vitro* organic matter and NDF digestibility with rumen fluid of beef cattle as an inoculum source. Journal of Animal Science and Technology, ISSN 1859-0802, 116 (10.20): 34-41. Link: https://vcn.org.vn/xuat-ban/journal-of-animal-science-and-technology-vol-116-october-2020-tap-chi-khoa-hoc-cong-nghe-chan-nuoi-so-116-thang-10-2020-

Nguyen Van Thu and Nguyen Thi Kim Dong. 2015. Effect of dietary crude protein levels supplemented by multi-nutrient cakes on feed intake, rumen parameters and nitrogen retention of Lai Sind cattle. Journal of Science Can Tho University, 37 (2015)(1): 11-17. Link: https://sj.ctu.edu.vn/ql/docgia/tacgia-1137/baibao-8121/doi-ctu.jvn.2015.077.html

Pimpa, O., Khwankaew, S., Pimpa, B., Khamseekhiew, B.and Pastsart, U. 2019. The effect of liquid fermented herb on feed intake and digestibility of Wagyu crossbred cattle. Kaen Kaset= Khon Kaen Agriculture Journal, 47(Suppl. 1), pp. 127-130.

Rattakorn, M. 2017. Effects of rumen protected fat containing oleic acid supplementation on carcass and beef quality, and beef fatty acids profile in wagyu crossbred cattle (Doctoral dissertation, School of Animal Production Technology Institute of Agricultural Technology Suranaree University of Technology).Link:http://sutir.sut.ac.th:8080/jspui/handle/123456789/7806

Seankamsorn, A. and Cherdthong, A. 2020. Dried Rumen Digesta Pellet Can Enhance Nitrogen Utilization in Thai Native, Wagyu-Crossbred Cattle Fed Rice Straw Based Diets. Animals, 10(1), 56.DOI:10.3390/ani10010056

Tham, H. T. And Udén, P. 2013. Effect of water hyacinth (*Eichhorniacrassipes*) silage on intake and nutrient digestibility in cattle fed rice straw and cottonseed cake. Asian-Australasian Journal of Animal Sciences, 26 (5), 646. Link: http://dx.doi.org/10.5713/ajas.2012.12498

Van Soest, P. J., Robertson, J. B. and Lewis, B. A. 1991. Methods for dietary fiber, neutral detergent fiber and non-starch polysaccharides in relation to animal nutrition. Journal of Dairy Science, 74: 3583-3598. DOI:https://doi.org/10.3168/jds.S0022-0302(91)78551-2

Vu Chi Cuong, Nguyen Thien Truong Giang and Nguyen Van Quan. 2009. Effect of length of re-growth in the dry season on productivity, chemical composition, potential intake, digestibility and nutritive value of Elephant grass (*pennisetum purpureum*). Journal of Animal Science and Technology – NIAS, ISSN 1859-0802, Vol 16 (February, 2009), 01-08.

Received date: 24/12/2021

Submitted date: 03/01/2022

Acceptance date: 25/02/2022

Opponent: Assoc. Prof. Bui Quang Tuan