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THE DIETARY NEUTRAL DETERGENT FIBER FOR FATTENING CROSSBRED CATTLE

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ABSTRACT

A review of neutral detergent fiber (NDF) levels in the beef cattle diets for improving the fodder utilizations and profitability. The structural change of NDF in plants is influenced by their varieties, ages, parts and the harvested time, which affects the dry matter and nutrient digestibility in ruminants. The changing of NDF structures of the roughages affected the dry matter (DM) and other nutrient digestibilities in ruminants. In in vitro experimental conditions showed that the soluble carbohydrate or nitrogen free extraction content of roughages had more affection on gas and CH4 production compared to the NDF one. When increasing NDF contents in the incubated mixtures from 35 to 65%, this gradually reduced the organic matter (OM) digestibility ($P<0.05$). Enhancing NDF percentage in the diets of the cattle from 47 to 59%, the DM and OM digestibilities were gradually reduced ($P<0.05$), however, there were no significant differences between the NDF47 and NDF55 treatment ($P>0.05$). In this research content, the NDF55 treatment revealed an expectation for the applied studies. At the level of 55% NDF in the diets, the Charolais crossbred cattle showed a superior trend on feed intake, DWG, FCR and economic return compared to the Black Angus and Wagyu crossbred ones. Therefore, the recommendation was that the dietary NDF level of 55% could be appropriate for the beef crossbred cattle.

1. INTRODUCTION

In tropical developing countries high-fiber diets are usually applied to beef cattle, due to the utilization of locally available low-cost forages. However, crossbred cattle have better meat performance than the local breeds and they require higher-quality diets (Favero et al., 2019; Mwangi et al., 2019). In Vietnam, the crossbred beef cattle are being developed from Zebu crossbred female with freeze sperm of high-producing cattle (Wagyu, Angus, and Charolais) by artificial insemination method (Vu et al., 2021).

The cattle can utilize locally available natural forages and agricultural by-products because their rumen microbes can effectively digest fibrous feeds into energy sources (McDonald et al., 2010; Dong and Thu, 2020). Neutral detergent fiber (NDF) or cell wall of plants such as hemicellulose, cellulose and lignin is a good source of fiber for animal feed (Mertens, 2014). The cell wall structure of plants used as feeds consists of the middle wall, the primary wall and the secondary wall. The difference among these walls is the chemical composition of cellulose, hemicellulose, lignin, pectin and protein molecules. Cellulose is a long-chain polysaccharide consisting of linear chains of several hundreds to several thousands of linked D-glucose units, which is an important structural component of the primary cell wall of plants. Hemicellulose is a short-chain polysaccharide, the main components are xylan, mannan and xyloglucan which are formed by pentose ($C_5H_{10}O_5$) and hexsose ($C_6H_{12}O_6$) molecules. Lignin is a phenylpropane polymer, a complex cross-linked structure from three hydroxyphenyl-lignin derivatives (H), guaiacyl-lignin (G) and syringyl-lignin (S) that form chemical bonds with attached hemicellulose stable with cellulose in cell walls. The ratio of the main components of the primary wall is cellulose, hemicellulose, pectin and proteins of cell walls but this ratio can be changed in the secondary wall. This change affects the primary link of the primary layer, which is the bond of xyloglucan with cellulose and pectin, but the increase of ligninization rate by age or the species of feed lead to an increase in these links in the cell wall. This can change the cell wall structure and percentage. The structural change of NDF in plants is influenced by their varieties, ages, parts and the harvested time, which affects the dry matter and nutrient digestibility in ruminants (Truong and Thu, 2019). According to Kodeš et al. (2015), NDF from the feed is important in the diet and provides metabolizable energy. Rahman et al. (2009) stated that the daily weight gain of fattening cattle was increased by the improvement of NDF digestibility. However, studies on dietary levels of NDF for crossbred cattle aiming to improve nutrition and beef performance have been still limited in Vietnam.

Therefore, a study of NDF levels in the diet on crossbred beef cattle is necessary for the sustainable development of beef cattle production.

2. NEUTRAL DETERGENT FIBER

2.1 Effect of NDF sources on methane gas production and carbon dioxide by using an in vitro gas production

The experiment (Exp) 1 and 2 were a completely randomized design with 5 treatments and 3 replications. The treatment of Exp 1 were orange peel, cassava pulp, banana trunk, *Mucana pruriens*, Paspalum grass (*Paspalum atratum*). The treatments of Exp 2 were lemon and orange peels, corn cob, banana trunk, *Mucana pruriens* and *Paspalum atratum*.

Table 1. Multiple linear regression relationship between CH_4 gas production and nutrients at 72 hours of 2 experiments

Regression equation	R^2	SEM	P
(1) $CH_{4\text{-}72h}$ = 0.704 NFC + 0.421 NDF + 0.218 ADF + 0.128 EE+ 0.390 CP – 42.4	99.9	0.012	0.003
(2) $CH_{4\text{-}72h}$ = 1.04 NFE – 0.161 NDF + 1.49 ADF + 0.493 CP + 0.953 EE – 96.1	99.7	0.149	0.037

CP: crude protein, NDF: neutral detergent fiber, ADF: acid detergent fiber, EE: ether extract, NFE: nitrogen free extract.

The results the Exp 1 showed that the methane (CH4) production at 72h of orange peel treatment was significantly higher than Paspalum atratum, cassava pulp, Mucana pruriens and banana trunk corresponding to 72.6 vs 69.0, 55.4, 52.8 and 44.9 ml/g digestible organic matter (DOM). The organic matter digestibility (OMD) of Paspalum atratum treatment was about 60.4% and orange peel was about 95.6%. The results of the Exp 2 showed that the CH4 of Paspalum Atratum treatment was 88.9 ml/gDOM at 72h. This value was significantly higher ($P<0.05$) compared to corn cobs, lemon peel, orange peel and Mucana Pruriens for 77.9, 76.8, 71.0 and 68.4, respectively. The OMD values of 2nd experiment showed significantly various ($P<0.05$) among treatments with the highest value for the orange peel treatment (95.7%) and the lowest value for the Paspalum atratum (51.2%). In summary, the neutral detergent fiber sources from fiber feeds were variably effect to CH4 production and NFC or NFE was more influent than NDF for CH4 production, then ADF, CP and EE were followed.

2.2 Effect of dietary levels of NDF on in vitro organic matter and NDF digestibility with rumen fluid of beef cattle as an inoculum source

This experiment was arranged according to the complete randomized design with 6 treatments and 3 replications. The treatments were 35, 41, 47, 53, 59 and 65 % NDF corresponding to NDF35, NDF41, NDF47, NDF53, NDF59 and NDF65 treatment. The basal substrates (mixture) for the experiment included elephant grass (*Pennisetum purpureum*), *Operculia turpethum*, rice straw, broken rice, soybean extraction meal and urea with the fixed crude protein of 14.6 % (DM basis) for all the treatments. The *in vitro* DM and NDF digestibility were observed from 0 to 72 h by the method of Goering and Van Soest (1970).

Results showed that organic matter digestibility (OMD) was significantly different ($P<0.05$) among the treatments at 24, 48 and 72 h incubation. At 72 h the *in vitro* OMD values of NDF35 (85.1%) and NDF41 (82.7%) treatments were significantly higher ($P<0.05$) than those of other treatments. In Figure 2 confirmed that there was a close linear relationship between NDF (%) and the *in vitro* OMD with the function $y=-0.576x + 105$ and $R^2 = 0{,}954$ and when increasing the NDF (%) in the mixture the OMD was gradually reduced. Thus the reduction of OMD indicated that there was a great effect of the NDF increase (%) on the *in vitro* digestion for other nutrients of the mixture such as CP, EE, NFE, etc. The data also demonstrated that increasing the NDF levels in diets from 35 to 65% gradually reduced NDF digestibility (NDFD). The linear relationship between NDF levels (%) of the treatments and the NDFD was found with the function $y = -0.274x + 69.5$ and $R^2 = 0.683$, while this between NDF levels (%) and the *in vitro* OMD was the function $y=-0.576x + 105$ and $R^2 = 0{,}954$.

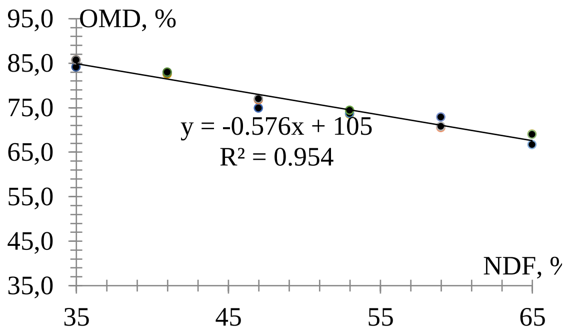

Figure 2. Relationship between NDF levels and OM digestibility

In conclusion, 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.

3. A STUDY OF DIETARY NDF LEVELS ON NUTRIENT INTAKE, DIGESTIBILITY AND GROWTH PERFORMANCE OF CROSSBRED CATTLE

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.

3.1 Black Angus crossbred cattle

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.

Table 2. Nutrient, metabolism energy intake and digestibility of experimental cattle

Item	Treatments				P	SEM
	NDF47	NDF51	NDF55	NDF59		
Nutrient intake						
ME*, MJ	49.2	47.4	46.9	44.4	0.065	0.960
DM/BW, %	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
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

*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), BW: 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).*

The results presented in Table 2 indicated that 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/kgW$^{0.75}$) 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 is reduced. The DM/BW in this study agreed with the findings of Valero et al. (2015) ranged from 1.87 to 2.07%. 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. 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 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).

In summary, 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.

3.2 Charolais crossbred cattle

Four male F_1(Charolais x Zebu cross) cattle at 17.6±1.49 (mean±SD) months of age and average body weight at 255±30.1 kg were used in a Latin square design.

Table 3. Nutrient digestibility of experimental cattle in treatments

Nutrient digestibility, %	Treatments				P	SEM
	NDF47	NDF51	NDF55	NDF59		
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]	56.5[b]	0.014	1.135
CP	71.6	69.1	68.8	67.3	0.235	1.310
NDF	60.5	59.7	59.7	58.6	0.732	1.165
ADF	51.7	48.7	46.6	44.4	0.101	1.697

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 different ($P<0.05$).

The results showed that nutrient intakes were not significantly different ($P>0.05$) among treatments. However, neutral detergent fiber (NDF) and acid detergent fiber (ADF) were highest for NDF59 treatment and lowest for NDF47 treatment. Metabolizable energy (MJ/animal/day) consumption decreased ($P=0.052$) by increasing NDF levels with the highest value for the NDF47 treatment (49.8 MJ) and lowest value for NDF59 treatment (44.5 MJ).

The DM digestibility was significantly different ($P<0.05$) among treatments with the highest value for NDF47 treatment (63.2%) and lower value for NDF59 treatment (55.6%), but NDF55 treatment (59.1%) was not significantly different ($P>0,05$) compared 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%. Similarly, the OM digestibility of NDF47 treatment (64.6%) was higher than NDF59 (56.5%) treatments (P<0.05). However, It was not significantly different (P>0.05) with NDF51 and NDF55 (61.0 and 60.7%, respectively). This finding was similar to the results of Kongphitee et al. (2018) being 51.9-67.4%. Besides these evaluations, 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%. Moreover, Sari et al. (2018) reported 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.

The conclusion was that levels of NDF in cattle diets from 47 to 59% tended to reduce DM and OM digestibility while nitrogen retention and daily weight gain decreased slightly.

3.3 Wagyu crossbred cattle

Four male F1 (Wagyu x Zebu crossbred) cattle were used in a 4x4 Latin square design.

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

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

Nutrient digestibility, %	Treatments				P	SEM
	NDF47	NDF51	NDF55	NDF59		
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

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 different (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 & 66.4%) were higher (P<0.05) than NDF59 (55.7 & 58.5%) but they were not different (P>0.05) compared to NDF51 (61.3 & 63.4%) and NDF 55 treatments (59.1 & 61.4%). According to Pimpa et 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 from 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%. Brandao and Faciola (2019) found that diets containing 58% NDF may not be adequate for high-producing animals.

In short, the DM and OM digestibilities (%) were reduced in this study, the digestibilities 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 treatments (P>0.05).

3.4 A study of dietary NDF levels on nutrient intake and growth performance of crossbred beef cattle

A total of 30 cattle were assigned into three breed groups (Black Angus x Zebu crossbred, Charolais x Zebu crossbred and Wagyu x Zebu crossbred) in which each group consisted of ten animals (balanced in sex). The study was conducted on individual crossbred cattle of 3 breed groups. The dietary NDF content was 55% in this study. The experimental design is presented in Tables 5.

Table 5. Design of experiment for growth performance of the cattle

Item	**Charolais x Zebu crossbred** (n=10)	**Black Angus x Zebu crossbred** (n=10)	**Wagyu x Zebu crossbred** (n=10)
Male	5	5	5
Months of age	18.3±3.39	18.7±2.10	18.1±3.86
Average body weight, kg	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, kg	239±28.0	236±18.1	234±17.8

The experiment consisted of a 7-day adaptation to the diets then followed by a 90-days of the experiment.

Table 6. The feed and nutrient intakes of crossbred cattle in experiment 2

Item	**Crossbreeds cattle**			**P**		
	Charolais x Zebu crossbred	**Black Angus x Zebu crossbred**	**Wagyu x Zebu crossbred**	**Cha-Black**	**Cha-Wag**	**Black-Wag**
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
Daily weight gain and feed conversion ratio						
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, DM: dry matter, OM: organic matter, CP: crude protein, NDF: neutral detergent fiber, ADF: acid detergent fiber. ME: metabolizable energy (MJ/kgDM), **: according to method of Abate and Mayer (1997), DWG: Daily weight gain, FCR: feed conversion ratio, Cha: Charolais x Zebu crossbred, Black: Black Angus x Zebu crossbred, Wag: Wagyu x Zebu crossbred.*

The daily DM intake in this experiment was 5.87±1.11, 5.47±0.10 and 5.35±0.10 kg/animal/day corresponding to Cha, Black and Wagcattle (Table 6). 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 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 Cha, Black and Wag, 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 was 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 Wag (2.96±0.55 kg) than Black (3.03±0.32 kg) and Cha cattle (3.24±0.61 kg). Subepang et al. (2019) found that NDF intake of Charolais crossbred fed 51.9% NDF in diets 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 (Cha, Black and Wag, respectively). In short, the feed and nutrient intakes of crossbred cattle were numerically reduced from Cha to Black and Wag breeds.

Table 6 showed that the DWG (kg) of Cha cattle (0.693±0.17 kg) was not different (P>0.05) with Black (0.578±0.16 kg), but it was higher (P<0.05) than Wag (0.537±0.14 kg). While DWG of Black was similar to Wag 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 Char cattle (8.60±0.83 kg) was different (P=0.050) with Black (9.83±1.60 kg) and it was significantly different (P<0.05) with Wag 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 concentrated 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%.

4. CONCLUSION

The structural change of NDF in plants is influenced by their varieties, ages, parts and the harvested time, which affects the dry matter and nutrient digestibility in ruminants. the NDF sources from fiber feeds had a variably effect to CH_4 production and NFC or NFE had a greater influent than NDF for CH_4 production, then ADF, CP and EE were followed.

It was concluded that increasing NDF content in the diets from 47.0 to 59.0% showed similar DM and OM intakes among the treatments, while the ME intakes and nutrient digestibilities had a decreased tendency. The NDF 55% in the diets, the Charolais crossbred cattle showed a superior trend in forage utilization and daily weight gain compared to the Black Angus and Wagyu crossbred ones.

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