Research Article

# The Proportion of Non-Fiber Carbohydrates to Neutral Detergent Fiber on Feed Intake, Nutrient Digestibility and Nitrogen Retention in Boer Crossbred Goats

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**Abstract** | The objective of this study was to determine the effect of the ratio of non-fiber carbohydrates (NFC) to neutral detergent fiber (NDF) on feed intake, nutrient digestibility, and nitrogen retention in Boer crossbred goats. The present study employed a 4×4 Latin square design using four male Boer crossbred goats (average body weight: 23.4 ± 1.91 kg). The proportion of NFC/NDF was 0.8, 1.0, 1.2 and 1.4 from maize, O. *turpethum* vines, elephant grass and urea (NFC0.8, NFC1.0, NFC1.2 and NFC1.4 treatments, respectively). Observed dry matter (DM) consumption per body weight was not different (P>0.05) such as 2.42, 2.51, 2.66 and 2.46% (NFC0.8, NFC1.0, NFC1.2 and NFC1.4 treatments, respectively). However, the metabolism energy intake was not various (P>0.05). It was 4.72 to 5.31, 5.66, and 5.50 MJ/goat/day corresponding to NFC0.8, NFC1.0, NFC1.2, and NFC1.4 treatments. The DM, organic matter and crude protein digestibility were lower for NFC0.8 treatment and higher for NFCl.4 treatment (P<0.05). The nitrogen retention was not different (P>0.05) on NFC0.8, NFC1.0, NFC1.2 and NFC1.4 treatments (3.91, 5.35, 6.17, and 5.91 g/goat/day, respectively). Besides, the daily weight gain increased with the NFC/NDF ratio. In summary, increasing NFC/NDF levels from 0.8 to 1.4 in diets containing *O. turpethum* vines improved in forage utilization, nutrient consumption, nutrient digestibility, nitrogen retention, and weight gain in goats.

**Keywords** | Small ruminant, Local feed, Digestibility, Energy feed, Weight gain, Goat

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## INTRODUCTION

Small ruminants are beneficial for low-income farmers in developing countries. They require relatively low investment for breeding and feeding. The local feed and agri by products are opportunities for conversion to cash by the rumen.

According to Sun *et al*. (2022), the majority of ruminant feed consists of carbohydrates, and carbohydrate digestion provides energy while contributing to enteric methane emissions. However, forages can offer a complete diet for ruminant animals. A key role in the nutrition characteristics of forages is neutral detergent fiber (NDF) and other nonstructural or non-fiber carbohydrates (NFC), as

concluded by Villalba *et al.* (2021). Another study, Chen *et al.* (2022) suggested that the proportion of NFC to NDF affects feed utilization and production performance of ruminants. Moreover, the *in vitro* study revealed that NFC is more important than NDF in producing methane from different forages (Truong and Thu, 2021). Another study *in vitro* gas, Bich *et al.* (2023) susggested that it was that an increase NFC/NDF levels from 0.5 to 2.0 improved OM digestibility, decreased methane production and further studies on the NFC/NDF levels should be performed in Boer crossbred goats. To our knowledge, the Boer crossbred goat is more prevalent than other crossbreds in the Mekong Delta of Vietnam. Nevertheless, the effects of dietary NFC/NDF levels in Boer crossbred goats raised in the Mekong Delta of Vietnam were not investigated.

Therefore, this study hypothesizes that the NFC-to-NDF ratio affects feed consumption, nutrient digestibility, and nitrogen retention in Boer crossbred goats.

## MATERIALS AND METHOD

### Location and time

This study was practiced at the experimental farm in An Giang University, An Giang Province, Vietnam from June 2023 to September 2023.

College of Agriculture, Can Tho University: Laboratory E205 of the Faculty of Animal Sciences, was analyzed as a sample in this study.

### Experimental design

Four Boer-crossbred goats, approximately nine months old with an average initial body weight of 23.4 ± 1.91 kg, were used in this experiment. The present study design was arranged in a Latin square (4x4), including four treatments and four periods with 21 days/period. Four treatments were the proportion of NFC/NDF in the diet: 0.8, 1.0, 1.2, and 1.4, corresponding to NFC0, NFC1.0, NFC1.2, and NFC1.4 treatments, suggested by Bich *et al.* (2023). The chemicals in the feed and ingredients in diets are shown in Tables 1 and 2.

**Table 1:** Chemical composition of feeds.

| Feeds | DM | In DM% | | | | | |
|---|---|---|---|---|---|---|---|
| | | OM | CP | NDF | ADF | EE | NFC |
| Maize | 86.8 | 98.1 | 8.10 | 18.9 | 4.51 | 4.67 | 66.5 |
| *Operculina turpethum* vines | 12.1 | 87.5 | 11.3 | 44.8 | 36.5 | 3.80 | 27.6 |
| Pennisetum purpureum | 14.5 | 90.1 | 7.52 | 64.8 | 38.7 | 2.52 | 15.2 |
| Urea | 99.6 | - | 286 | - | - | - | - |

Dry matter (DM), organic matter (OM), crude protein (CP), neutral detergent fiber (NDF), acid detergent fiber (ADF), Ethe extract (EE), non-fiber carbohydrate (NFC).

**Table 2:** Ingredient composition of the diet.

| Ingredients (%DM) | NFC 0.8 | NFC 1.0 | NFC 1.2 | NFC 1.4 |
|---|---|---|---|---|
| Maize | 30.0 | 30.0 | 30.0 | 30.0 |
| *Operculina turpethum* vines | 3.90 | 26.3 | 43.8 | 57.9 |
| Pennisetum purpureum | 64.5 | 42.1 | 24.6 | 10.5 |
| Urea | 1.00 | 1.00 | 1.00 | 1.00 |
| Premix | 0.60 | 0.60 | 0.60 | 0.60 |
| Total | 100 | 100 | 100 | 100 |

The NFC0.8, NFC1.0, NFC1.2, and NFC1.4 treatments contained the non-fiber carbohydrates per neutral detergent fiber ratio at 0.8, 1.0, 1.2, and 1.4 (%DM).

### Measurements taken

### Feeding procedure

Before feeding, all the feed was weighed and supplied to the experimental goats separately. Before feeding, maize and urea were mixed with premix supplements. Depending on treatments, *Operculina turpethum* vines was fed at dry matter consumption. *Pennisetum purpureum* was fed *ad libitum*, and drinking water was *ad libitum*. Every morning, the refused feed was weighed before the next feeding.

### Feeds, nutrient and energy intakes

Feed offered, refusals and feces were analyzed for dry matter, organic matter, crude protein, total mineral, and ether extract (DM, OM, CP, Ash and EE, respectively) according to the procedures of AOAC (1990). The nitrogen (N) content of urine was analyzed using the Kjeldahl methods (AOAC, 1990). Both ADF (acid detergent fiber) and NDF (neutral detergent fiber) were analyzed by Van Soest *et al.* (1991) method. However, NFC (non-fiber carbohydrate) = OM-CP-EE-NDF.

### Apparent nutrient digestibility

Four crossbred Boer goats were housed individually. Each period lasted 21 days with 14 days of adaptation time, followed by 7 days for data collection such as feed intake, feces, and urine. The DM, OM, CP, NDF, and ADF digestibility were done following the method of McDonald *et al.* (2010).

### Metabolizable energy (ME)

The metabolizable energy (ME) was determined by the method of Bruinenberg *et al.* (2002):

- DOM/DCP<7.0: ME (MJ/animal/day) = 14.2 x DOM + 5.9 x DCP
- DOM/DCP>7.0: ME (MJ/animal/day) = 15.1 x DOM
- Digestible organic matter is DOM and digestible crude protein is DCP.

### Nitrogen balance (N)

Daily collected N intake minus N excreted in feces and urine, and the remainder is N retention: N retention = N intake - (N feces + N urine).

### Daily weight gains (DWG)

The beginning and end of each experimental period: the goats were weighed on two consecutive days.

### Statistical analysis

The data were analyzed using the ANOVA General Linear Model (GLM) in Minitab (Release 20; Minitab, 2021). Tukey's pairwise comparisons ($P < 0.05$) were applied to determine differences among treatments. Data were analyzed using the model $Y_{ijk} = \mu + T_i + A_j + P_k + e_{ijk}$; where $Y_{ijk}$: = the dependent variable, $\mu$: the overall mean, $T_i$ = the effect of NFC/NDF (i = 1 to 4), $A_j$: the effect of goats (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 experimental goat

The nutrient intake and ME were increased and the DM/BW ratio was improved as the offer level of NFC/NDF was increased (Table 3 and Figure 1).

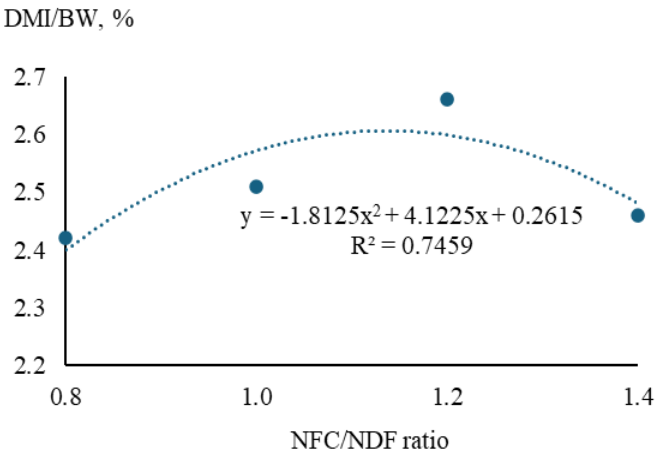


**Figure 1:** Effect of NFC/NDF levels on DM intake per body weight.

Both nutrient intake and ME consumption showed an increasing trend ($P > 0.05$) in this study (Table 3). The NFC1.2 treatment displayed the highest DM, OM and NFC intake values (554, 500 and 566 g/goat/day, respectively). The DMI/BW was not various ($P>0.05$) among treatments. It was 2.42, 2.51, 2.66 and 2.46% (NFC0.8, NFC1.0, NFC1.2 and NFC1.4 treatments, respectively). Figure 1 should indicate what the curve represents more clearly. The NFC1.4 treatment had lower DMI/BW than the NFC1.2 treatment. Because of the rising NFC/NDF ratio. Normal intestinal peristalsis can be stimulated and animals may feel full due to the presence of plant cell contents and readily fermentable components in NFC (Li *et al*., 2023). Moreover, Bai *et al*. (2023) reported that the relative abundance of total cellulose-degrading bacteria was highest when the diet (Sheep) NFC/NDF ratio was 1.37, and it decreased when the NFC/NDF ratio was more 1.37. The increase in NFC/NDF tended to decrease NDF and ADF consumption among treatments ($P>0.05$). It was hypothesized that goat diets with more NFC/NDF may increase goats' NFC intake due to an improvement in ME consumption in the present study. According to Chen *et al*. (2022), production performance, feed utilization efficiency, and rumen health of ruminants can all be influenced by the NFC to NDF ratio, which can reflect the levels of different types of carbohydrates.

**Table 3:** Feed and nutritive intakes of goat.

| Criteria | NFC 0.8 | NFC 1.0 | NFC 1.2 | NFC 1.4 | SEM | P |
|---|---|---|---|---|---|---|
| **Feed intake, g DM/animal/day** | | | | | | |
| Maize | 152 | 170 | 171 | 184 | 18.400 | 0.687 |
| *Operculina turpethum* vines | 14.6$^{b}$ | 168$^{a}$ | 260$^{a}$ | 285$^{a}$ | 26.30 | 0.001 |
| Pennisetum purpureum | 340$^{c}$ | 182b$^{c}$ | 114$^{b}$ | 46.0$^{a}$ | 17.80 | 0.001 |
| Urea | 5.06 | 5.68 | 5.72 | 6.13 | 0.616 | 0.686 |
| Premix | 3.02 | 3.40 | 3.42 | 3.67 | 0.368 | 0.685 |
| **Nutritive intakes, g DM/animal/day** | | | | | | |
| DM | 515 | 529 | 554 | 524 | 39.60 | 0.906 |
| DM/BW, % | 2.42 | 2.51 | 2.66 | 2.46 | 0.183 | 0.807 |
| OM | 467 | 478 | 500 | 473 | 36.00 | 0.923 |
| CP | 57.6 | 66.0 | 71.9 | 72.8 | 5.570 | 0.290 |
| NDF | 232 | 206 | 203 | 167 | 14.70 | 0.101 |
| ADF | 132 | 124 | 126 | 104 | 9.630 | 0.304 |
| NFC | 175 | 203 | 221 | 231 | 18.50 | 0.259 |
| ME, MJ/animal/day | 4.72 | 5.31 | 5.66 | 5.50 | 0.493 | 0.588 |
| **Output, animal/day** | | | | | | |
| Feces, gDM | 172$^{a}$ | 147$^{ab}$ | 144$^{b}$ | 127$^{b}$ | 5,280 | 0,005 |
| Urine, g | 1,105 | 1,184 | 1,238 | 1,234 | 102.0 | 0.777 |

The NFC0.8, NFC1.0, NFC1.2, and NFC1.4 treatments contained the non-fiber carbohydrates per neutral detergent fiber ratio at 0.8, 1.0, 1.2, and 1.4 (%DM). $^{abc}$ Means in the same row with different superscripts differ ($p<0.05$).

### Apparent digestibility

Increasing the NFC/NDF levels in the diet affected the digestibility of dry matter, organic matter and crude protein. As a result, this increased the digestible nutrients (Table 4 and Figure 2).

**Table 4:** Total-tract digestibility of nutrients.

| Criteria | NFC 0.8 | NFC 1.0 | NFC 1.2 | NFC 1.4 | SEM | P |
|---|---|---|---|---|---|---|
| **Digestibility, %** | | | | | | |
| DM | 65.9$^{b}$ | 72.1$^{ab}$ | 74.4$^{a}$ | 75.6$^{a}$ | 1.440 | 0.012 |
| OM | 66.9$^{b}$ | 73.6$^{ab}$ | 75.4$^{a}$ | 76.7$^{a}$ | 1.510 | 0.015 |
| CP | 70.2$^{b}$ | 77.5$^{a}$ | 78.2$^{a}$ | 78.8$^{a}$ | 1.390 | 0.014 |
| NDF | 55.1 | 61.6 | 62.7 | 63.9 | 2.110 | 0.094 |
| ADF | 49.5 | 57.0 | 58.1 | 59.0 | 4.010 | 0.389 |
| **Digestibility, g DM/animal/day** | | | | | | |
| DM | 342 | 382 | 410 | 398 | 35.50 | 0.591 |
| OM | 316 | 353 | 375 | 364 | 33.00 | 0.630 |
| CP | 40.5 | 51.3 | 56.1 | 57.4 | 4.480 | 0.120 |
| NDF | 131 | 127 | 126 | 106 | 13.30 | 0.584 |
| ADF | 67.2 | 70.5 | 73.1 | 61.7 | 10.00 | 0.864 |

The NFC0.8, NFC1.0, NFC1.2, and NFC1.4 treatments contained the non-fiber carbohydrates per neutral detergent fiber ratio at 0.8, 1.0, 1.2, and 1.4 (%DM). $^{abc}$ Means in the same row with different superscripts differ ($p<0.05$).

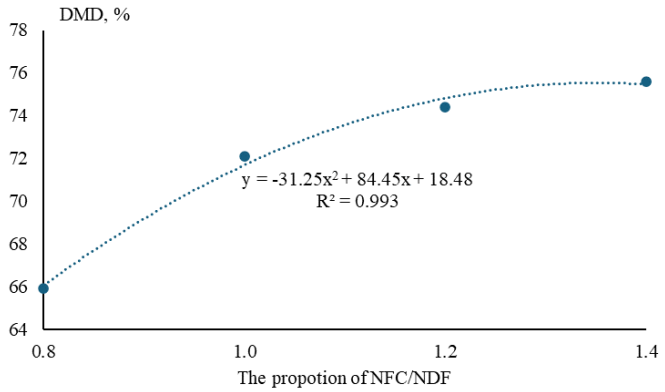


**Figure 2:** The increase in NFC/NDF feeding level caused a curvilinear trend in DM digestibility.

Table 4 shows that DM digestibility differed ($P<0.05$) in NFC0.8, NFC1.0, NFC1.2 and NFC1.4 treatments (65.9, 72.1, 74.4 and 75.6%, respectively). Increasing NFC/NDF increased OM digestibility from 66.9 to 73.6, 75.4 and 76.7% corresponding to NFC0.8, NFC1.0, NFC1.2 and NFC1.4 treatments. In a recent *in vitro* gas study, Bich *et al.* (2023) concluded that the OM digestibility gradually increased by increasing the NFC/NDF level from 1.00 to 2.00. Moreover, the CP digestibility increased ($P<0.05$) from NFC level 0.8 to 1.0, 1.2 and 1.4 corresponding to 70.2, 77.5, 78.2 and 78.8%. However, there was not different ($P>0.05$) at NFC1.0, NFC1.2 and NFC1.4 treatments for DM, OM and CP digestibility. The digestibility of both NDF and ADF was increased, but there was no difference ($P>0.05$) in this study. It was explored that the feces (g DM/goat/day) were lowest ($P<0.05$) in NFC1.4 (127 g) and highest in NFC0.8 treatment (172 g) but NFC1.0 (147 g), NFC1.2 (144 g) and NFC1.4 were not several ($P>0.05$) in this study (Table 3). Moreover, the increase in NFC/NDF level was regulated by the green forage source of *Operculina turpethum* vines which had a higher CP and NFC ratio than elephant grass. According to Wanapat *et al.* (2012), who reported that the quantity of non-structural carbohydrates in the diet was associated with an increase in rumen microbial populations. This is consistent with the nutrient digestibility trend of this study.

## Nitrogen balances and weight gain

The positive effects on daily weight gain value can be expected as change with NFC/NDF increased nitrogen retention in this study (Table 5).

**Table 5:** Nitrogen retention and change in weight of goats among treatments.

| Criteria | NFC 0.8 | NFC 1.0 | NFC 1.2 | NFC 1.4 | SEM | P |
|---|---|---|---|---|---|---|
| **N balances, g/animal/day** | | | | | | |
| N intake | 9.21 | 10.6 | 11.5 | 11.6 | 0.891 | 0.290 |
| N feces | 2.23 | 1.94 | 2.53 | 2.46 | 0.488 | 0.827 |
| N urine | 3.08 | 3.27 | 2.81 | 3.27 | 0.143 | 0.173 |
| N retention | 3.91 | 5.35 | 6.17 | 5.91 | 0.529 | 0.082 |
| N retention/BW $^{0.75}$ | 0.39 | 0.54 | 0.63 | 0.59 | 0.052 | 0.066 |
| **Body weight, kg** | | | | | | |
| Initial | 21.0 | 20.5 | 20.0 | 20.6 | 0.382 | 0.427 |
| Final | 22.0 | 21.7 | 21.3 | 21.9 | 0.443 | 0.697 |
| ADG, g/animal/day | 46.8 | 59.9 | 60.5 | 63.5 | 15.10 | 0.864 |

The NFC0.8, NFC1.0, NFC1.2, and NFC1.4 treatments contained the non-fiber carbohydrates per neutral detergent fiber ratio at 0.8, 1.0, 1.2, and 1.4 (%DM). ADG: Average daily gain. $^{abc}$ Means in the same row with different superscripts differ ($p<0.05$).

Nitrogen intake did not differ significantly ($P > 0.05$) among the four NFC levels, ranging from 9.21 to 11.6 g/head/day (Table 5). The N retention increased from 3.91 to 5.35, 6.17, and then decreased to 5.91 g/head/day for NFC0.8, NFC1.0, NFC1.2, and NFC1.4 treatments, respectively. The protein status of ruminants was commonly indicated by the N retention. A favorable environment for bacterial growth and increased energy availability for rumen microorganisms to multiply was created by providing a greater amount of rapidly fermentable carbohydrates in the form of NFC. Therefore, Pinho *et al.* (2019) concluded that the concentration of microbial protein in goats is more affected by NFC levels than by forage-neutral detergent fiber levels, and the increase in NFC levels promoted the increase in ammonia concentration. The weight change of experimental goats was not different ($P>0.05$) between NFC levels but showed an increase in daily weight gain (46.8, 59.9, 60.5 and 63.5 g/goat/day, respectively) when increasing NFC/NDF levels (0.8, 1.0, 1.2 and 1.4,

respectively) in this study. The daily weight gain in this study was similar to the result of Rahman *et al*. (2020) on growing crossbred goats, which was 73.2-93.7 g/animal/day.

The findings of this study demonstrate that increasing the proportion of non-fiber carbohydrates to neutral detergent fiber (NFC/NDF) from 0.8 to 1.4 in the diet of Boer-crossbred goats significantly improves feed utilization and nutrient metabolism. While dry matter intake per body weight remained statistically similar across treatments, higher NFC/NDF ratios led to marked improvements in dry matter digestibility (increasing from 65.9% to 75.6%), organic matter digestibility (66.9% to 76.7%), and crude protein digestibility (70.2% to 78.8%). Notably, nitrogen retention showed a positive trend, peaking at 6.17 g/day with an NFC/NDF ratio of 1.2 before slightly decreasing at the 1.4 ratio, suggesting an optimal range for protein utilization. These digestive improvements translated into enhanced growth performance, with average daily gains reaching 63.5 g/day at the highest NFC/NDF level. The results indicate that an NFC/NDF ratio of 1.2 represents the most balanced formulation, optimizing both nutrient absorption and economic feasibility when incorporating local feed resources like *Operculina turpethum* vines. These findings provide valuable insights for smallholder farmers in the Mekong Delta region, offering a science-based approach to improve goat nutrition using locally available feedstuffs. Future research should focus on long-term growth trials, rumen microbiome dynamics, and practical adoption studies to further validate and extend these findings under diverse farming conditions. This study contributes to the development of sustainable feeding strategies that can enhance productivity in small ruminant systems while maintaining cost-effectiveness for resource-limited farmers.

## CONCLUSION

This study demonstrates that increasing the NFC/NDF ratio from 0.8 to 1.4 in the diet of Boer-crossbred goats enhances feed utilization, nutrient digestibility, and nitrogen retention. The optimal NFC/NDF ratio of 1.2 significantly improved dry matter digestibility (74.4%), organic matter digestibility (75.4%), and crude protein digestibility (78.2%), while also promoting higher nitrogen retention (6.17 g/day) and daily weight gain (60.5 g/day). These findings suggest that smallholder farmers in the Mekong Delta can improve goat productivity by incorporating locally available feedstuffs, such as *Operculina turpethum* vines, at an NFC/NDF ratio of 1.2. Future research should explore long-term growth performance and rumen microbiome dynamics to further validate these results.

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## NOVELTY STATEMENT

This study is the first to investigate the effects of varying NFC/NDF ratios (0.8 to 1.4) on feed intake, nutrient digestibility, and nitrogen retention in Boer-crossbred goats raised in the Mekong Delta of Vietnam. By utilizing locally available feedstuffs like *Operculina turpethum* vines, our findings provide practical, cost-effective dietary strategies for smallholder farmers to enhance goat productivity. The identification of an optimal NFC/NDF ratio (1.2) offers a novel approach to improving nutrient utilization in small ruminant systems.

## AUTHOR CONTRIBUTION

N.B. Truong, N.P. Bang and N.N. Bich conceived and designed the field trial; N.B. Truong analyzed the data; N.B.Truong, N.P. Bang, N.T.K. Dong, P. Nhan and N.N. Bich wrote the paper.

### Conflict of interest

The authors have declared no conflict of interest.

## REFERENCES

AOAC, Association of Official Analytical Chemists (1990). Official methods of analysis (15th edition). Washington, DC, 1: 69-90.

Bai T, Pu X, Guo X, Liu J, Zhao L, Zhang X, Zhang S, Cheng L (2023). Effects of dietary nonfibrous carbohydrate/neutral detergent fiber ratio on methanogenic archaea and cellulose-degrading bacteria in the rumen of karakul Sheep: A 16S rRNA Gene Sequencing Study. Appl. Environ. Microbiol., 89(1): e01291-22. https://doi.org/10.1128/aem.01291-22

Bich NN, Bang NP, Truong NB (2023). Effect of non-fibrous carbohydrates and neutral detergents levels on organic matter digestibility and methane production in *in vitro*. J. Anim. Husband. Sci. Tech., 290(7): 37-43 (Vietnamese version).

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

Chen Y, Gong X, Huang Y, Jiang M, Zhan K, Lin M, Zhao G (2022). Growth performance, rumen fermentation and inflammatory response on holstein growing cattle treated with low and high non-fibrous carbohydrate to neutral detergent fiber ratiopelleted total mixed ration. Animals, 12: 1036. https://doi.org/10.3390/ani12081036

Li S, Liu T, Wang K, Li C, Wu F, Yang X, Zhao M, Chen

B, Chen X (2023). The ratios of dietary non-fibrous carbohydrate (NFC) to neutral detergent fiber (NDF) influence intestinal immunity of rabbits by regulating gut microbiota composition and metabolites. Front. Microbiol., 14: 1146787. https://doi.org/10.3389/fmicb.2023.1146787

McDonald P, Edwards RA, Greenhagh JFD, Morgan CA (2010). Animal nutrition (7th edition), Longman Scientific and Technical, N. Y. USA.

Minitab (2021). Minitab reference manual. Release 20.3 for Windows, Minitab Inc, USA.

Pinho R, Santos EM, de Oliveira JS, de Carvalho GG, Alves JP, Macêdo AJDS, Pereira GA, Pereira DM, Perazzo AF, Zanine ADM (2019). Relationship between forage neutral detergent fiber and non-fibrous carbohydrates on ruminal fermentation products and neutral detergent fiber digestibility in goats. Rev. Colomb. Ciencias Pecuarias, 32(2): 126-138. https://doi.org/10.17533/udea.rccp.v32n2a06

Rahman MM, Abdullah RB, Mat KB, Ishigaki G, Nor MM, Akashi R (2020). Replacement of soybean meal with levels of inclusion of soya waste in the diet of growing goats. Trop. Anim. Health Prod., 52: 3085-3090. https://doi.org/10.1007/s11250-020-02330-6

Sun X, Cheng L, Jonker A, Munidasa S, Pacheco D (2022). A review: Plant carbohydrate types. The potential impact on ruminant methane emissions. Front. Vet. Sci., 9: 880115. Link: https://www.frontiersin.org/journals/veterinary-science/articles/10.3389/fvets.2022.880115/full, https://doi.org/10.3389/fvets.2022.880115

Truong NB, Thu NV (2021). Effect of neutral detergent fiber sources on methane gas production and carbodioxide by using an in vitro gas production. J. Anim. Husband. Sci. Tech., 262(1): 27-37 (Vietnamese version). https://hoichannuoi.vn/uploads/files/TAPCHICHANNUOI%20so%20thang%201_2_2021%20(1).pdf

Van Soest PJ, Robertson JB, Lewis BA (1991). Methods for dietary fiber, neutral detergent fiber and non-starch polysaccharides in relation to animal nutrition. J. Dairy Sci., 74: 3583-3598. https://doi.org/10.3168/jds.S0022-0302(91)78551-2

Villalba JJ, Ates S, MacAdam JW (2021). Non-fiber carbohydrates in forages and their influence on beef production systems. Front. Sustain. Food Syst., 5: 566338. https://doi.org/10.3389/fsufs.2021.566338

Wanapat M, Foiklang S, Rowlinson P, Pilajun R (2012). Effect of carbohydrate sources and cotton seed meal in the concentrate: II. Feed intake, nutrient digestibility, rumen fermentation and microbial protein synthesis in beef cattle. Trop. Anim. Health Prod., 44: 35-42. https://doi.org/10.1007/s11250-011-0014-z