Effects of Different Neutral Detergent Fiber Levels in Starter Feed on Slaughter Performance, Organ Indices, and Rumen Development in Calves (Postprint)

Authors: Chunyan Ren, graduation research, Du Hanchang, Yu Bo, Tu Yan, Guo Yanli, Diao Qiyu

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Abstract

This experiment aimed to investigate the effects of different neutral detergent fiber (NDF) levels in starter feed on slaughter performance, organ indices, and compound stomach development in calves. Sixty Chinese Holstein calves aged 1-3 days with similar birth weight [(42.0±2.5) kg] and fed adequate colostrum were selected, including 36 male calves and 24 female calves. They were randomly divided into 4 groups, with 9 male calves and 6 female calves per group, and weaned at 70 days of age. Starting at 15 days of age, groups A, B, C, and D were fed starter feed with NDF levels of 29.74%, 31.37%, 34.28%, and 36.53%, respectively. The experimental period was 112 days. The results showed that: the body weight gain of calves in group B was significantly higher than that in groups C and D ($P<0.05$); the dressing percentage and net meat percentage in group B were significantly higher than those in group D ($P<0.05$), and the carcass weight, meat-to-bone ratio, and carcass meat yield percentage were also higher than the other three groups, but the differences were not significant ($P>0.05$); regarding compound stomach development, the proportion of rumen weight to total compound stomach weight and the proportion of reticulum weight to total compound stomach weight in group B were significantly higher than those in group D ($P<0.05$), while the proportion of omasum weight to total compound stomach weight in group D was significantly higher than that in group A ($P<0.05$); the pH in the rumen of groups A and B was significantly higher than that in groups C and D ($P<0.05$). Under the conditions of this experiment, in the starter feed for calves aged 15–112 days

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Effects of Different Neutral Detergent Fiber Levels in Starter Feed on Slaughter Performance, Organ Indexes and Development of Stomachus Compositus of Dairy Calves

REN Chunyan[1,2,3], BI Yanliang[2,3], DU Hanchang , YU Bo , TU Yan[2,3], GUO Yanli[1]*, DIAO Qiyu[2,3]*

[1]College of Animal Science and Technology, Gansu Agricultural University, Lanzhou 730070, China
[2]Key Laboratory of Feed Biotechnology of Ministry of Agriculture, Feed Research Institute, Chinese Academy of Agricultural Sciences, Beijing 100081, China
[3]Beijing Key Laboratory for Dairy Cow Nutrition, Beijing 100081, China
Shandong Yinxiangweye Group Co., Ltd., Heze 274400, China

Abstract

This study aimed to investigate the effects of different neutral detergent fiber (NDF) levels in starter feed on slaughter performance, organ indexes, and development of stomachus compositus in dairy calves. Sixty newborn Holstein calves (36 males and 24 females) with similar birth weight [(42.0±2.5) kg] and adequate colostrum feeding were randomly assigned to four groups at 1–3 days of age. Each group comprised 9 male and 6 female calves, and all calves were weaned at 70 days of age. Starting at 15 days of age, groups A, B, C, and D were fed starter feeds containing 29.74%, 31.37%, 34.28%, and 36.53% NDF, respectively. The experimental period lasted 112 days. The results showed that body weight gain in group B was significantly higher than in groups C and D ($P<0.05$). Dressing percentage and net meat percentage in group B were significantly higher than in group D ($P<0.05$). Group B also exhibited higher carcass weight, meat-to-bone ratio, and meat percentage of carcass compared with the other three groups, though these differences were not significant ($P>0.05$). Regarding stomachus compositus development, the proportions of rumen weight and reticulum weight to total stomachus compositus weight were significantly higher in group B than in group D ($P<0.05$), while the proportion of omasum weight to total stomachus compositus weight was significantly higher in group D than in group A ($P<0.05$). Groups A and B had significantly higher ruminal pH compared with groups C and D ($P<0.05$). Under the conditions of this experiment, a starter NDF level of 31.37% for calves aged 15–112 days improved body weight gain and slaughter performance while promoting the development of visceral organs and the gastrointestinal tract.

Keywords: Holstein calf; neutral detergent fiber level; starter; feed intake; slaughter trait; organ index; stomachus compositus development

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Introduction

In traditional calf rearing, restricted milk or milk replacer feeding is commonly practiced to encourage early consumption of grain-based feed, thereby achieving early weaning, reducing diarrhea, and lowering feeding and management costs [1]. Previous studies have demonstrated that starter feed serves as a crucial nutritional source for calf growth and development [2], promoting rumen development and shortening weaning age. As an essential component of ruminant diets, dietary fiber stimulates saliva secretion, rumination, rumen buffering, and maintains rumen wall health [3]. Research has shown that incorporating appropriate proportions of forage into starter feed can increase feed intake [4], improve the rumen environment, promote digestive organ tissue development and digestive function, and enhance overall performance [5-7]. Furthermore, starter feeds containing adequate digestible crude fiber facilitate the establishment of rumen microbial flora and stimulate rapid rumen development [2]. However, excessive dietary fiber intake can reduce fiber digestibility, cause accumulation of undigested forage in the rumen, and decrease feed intake [8]. Other studies have confirmed that sufficient but not excessive physical stimulation from forage improves growth performance and rumen development [9]. Nevertheless, due to various factors such as fiber source, physical form, and feeding method [10], the optimal dietary fiber content in starter feed for calf growth and development remains unclear. Therefore, this experiment was designed to investigate the effects of different NDF levels, achieved by adjusting the forage (alfalfa and oat hay) to concentrate ratios in starter feed, on slaughter performance, organ indexes, and stomachus compositus development in calves. The findings aim to provide data support for establishing appropriate NDF levels in calf starter feeds and theoretical basis for rational starter formulation to improve economic efficiency in dairy farming.

1.1 Experimental Location and Duration

The experiment was conducted from April to September 2017 at the Second Farm of Shandong Yinxiangweye Group Co., Ltd.

1.2 Experimental Design

Sixty newborn Holstein calves (36 males and 24 females) with birth weight of (42.0±2.5) kg and adequate colostrum feeding were selected at 1-3 days of age (referred to as 1-day-old). Using a completely randomized block design, calves were randomly assigned to four groups (A, B, C, and D), with 9 male and 6 female calves per group. The experimental design is presented in Table 1 . Beginning at 3 days of age, calves were fed pasteurized milk twice daily (06:30 and 17:00) at 5 L/d from days 3-28, 8 L/d from days 29-65, reduced to 4 L/d after day 66, and weaned at day 70. Starting at 15 days of age, the four groups were fed starter feeds with NDF levels of 29.74%, 31.37%, 34.28%, and 36.53%, respectively, twice daily (07:00 and 16:30). Feed was provided ad libitum with daily refusals, and clean water was available at all times. The experimental period lasted 112 days.

1.3 Experimental Starter Feed

The composition and nutrient levels of the experimental starter feeds are shown in Table 2 . All starter feeds were pelleted (6 mm diameter) with consistent crude protein levels across groups.

1.4 Management Practices

Before the experiment, all calf hutches were thoroughly cleaned and disinfected, then dried before use. All experimental calves followed normal immunization protocols and were housed individually in calf hutches. Bedding was replaced daily after morning feeding to ensure hutches remained dry and clean. Clean water was available ad libitum throughout the experimental period.

1.5 Measurement Indicators

1.5.1 Feed Intake and Feed-to-Gain Ratio From days 15-112, daily feed offered and refusals were recorded for each calf to calculate dry matter intake (DMI). Body weight was measured before morning feeding on days 1 and 112 as initial and final weight, respectively, to calculate body weight gain.

1.5.2 Slaughter Performance At the end of the experiment, after fasting, live weight was recorded. Six male calves with body weight closest to the group average were selected from each group. Calves were slaughtered by exsanguination via jugular vein, and carcass weight was recorded after removal of head, hooves, tail, skin, viscera (excluding kidneys and perirenal fat), and reproductive organs. After complete deboning, total meat and bone weights were recorded. Dressing percentage, net meat percentage, meat percentage of carcass, and meat-to-bone ratio were calculated according to Yang et al. [11] using the following formulas:

- Dressing percentage (%) = 100 × carcass weight (kg) / pre-slaughter live weight (kg)
- Net meat percentage (%) = 100 × net meat weight (kg) / pre-slaughter live weight (kg)
- Meat percentage of carcass (%) = 100 × net meat weight (kg) / carcass weight (kg)
- Meat-to-bone ratio (%) = 100 × net meat weight (kg) / bone weight (kg)
- Visceral organ proportion (%) = 100 × visceral organ weight (kg) / carcass weight (kg)

1.5.3 Visceral Organ and Gastrointestinal Tract Measurements After slaughter, the entire gastrointestinal tract was immediately removed by ligating the cardia. The stomach and intestines were separated by ligating the abomasum-duodenum junction, and intestinal contents were removed before weighing. The rumen, reticulum, omasum, and abomasum were opened, and all digesta were completely removed and washed before individual weighing. Fresh weights of visceral organs and gastrointestinal tract (after content removal) were recorded [12].

1.5.4 Gastrointestinal pH Measurement After slaughter, each gastrointestinal segment was isolated and ligated. Contents from each stomach compartment and intestinal segment were collected into 15 mL centrifuge tubes, and pH was immediately measured using a PHB-2 portable pH meter for rumen, abomasum, duodenum, jejunum, ileum, and cecum contents.

1.6 Statistical Analysis

Data were analyzed using one-way ANOVA in SAS 9.1 software. Significant differences were further analyzed using Duncan' s multiple comparison test. Differences were considered significant at P<0.05.

2.1 Effects of Different NDF Levels on Body Weight and Feed Intake

As shown in Table 3 , initial body weight did not differ significantly among groups (P>0.05), confirming successful randomization. Group B had the highest final body weight and body weight gain, which were 3.37 kg (P>0.05), 10.86 kg (P<0.05), and 10.94 kg (P<0.05) higher than groups A, C, and D, respectively. Body weight gain in group B was 4.53 kg (P>0.05), 11.54 kg (P<0.05), and 11.72 kg (P<0.05) higher than groups A, C, and D, respectively. DMI in group B was 0.25, 0.06, and 0.02 kg/d higher than groups A, C, and D, respectively, though these differences were not significant (P>0.05).

2.2 Effects of Different NDF Levels on Slaughter Performance

As shown in Table 4 , dressing percentage and net meat percentage were significantly higher in groups A and B compared with group D (P<0.05). Group B showed no significant differences from the other three groups in carcass weight, net meat percentage, meat-to-bone ratio, or meat percentage of carcass (P>0.05), though the apparent values were higher than groups A, C, and D.

2.3 Effects of Different NDF Levels on Organ Indexes

As shown in Table 5 , heart and lung indexes were significantly higher in groups A and B compared with groups C and D (P<0.05). Kidney index was significantly higher in group B than in groups C and D (P<0.05). Stomachus compositus index in group B was 9.32%, 8.50%, and 17.93% higher than groups A, C, and D, respectively, though the difference was not significant (P>0.05).

2.4 Effects of Different NDF Levels on Stomachus Compositus Development

As shown in Table 6 , the proportion of rumen weight to total stomachus compositus weight was significantly higher in groups A, B, and C compared with group D ($P<0.05$). Rumen weight followed the order B > A > C > D, though differences among groups were not significant ($P>0.05$). With increasing NDF levels, reticulum weight decreased sequentially, while omasum and abomasum weights increased sequentially, though differences were not significant ($P>0.05$). The proportion of omasum weight to total stomachus compositus weight was significantly higher in group D than in group A ($P<0.05$).

2.5 Effects of Different NDF Levels on Gastrointestinal pH

As shown in Table 7 , ruminal pH was significantly higher in groups A and B compared with groups C and D ($P<0.05$). Cecal pH followed the order C > A > B > D.

3.1 Effects of Different NDF Levels on Feed Intake and Body Weight Gain

Adequate solid feed intake promotes rumen development and post-weaning calf health, thereby improving post-weaning body weight gain [8]. Numerous studies have shown that providing forage to pre-weaned calves can increase solid feed intake [13-14] and body weight [7,15]. The positive effect of forage on solid feed intake is associated with improved rumen environment and enhanced rumen development [16]. Coverdale et al. [5] also found that providing calves with forage containing certain NDF levels improved the rumen environment and increased DMI. Dietary NDF level is considered one of the most important factors affecting calf growth performance [17-18], and forage supplementation is believed to increase DMI in post-weaned calves [18]. Consistent with these studies, increasing NDF level increased DMI in the current experiment, with the 31.37% NDF group showing higher intake than the other three groups, though the difference was not significant. This may be attributed to individual variation and weather conditions during the experiment, which introduced statistical error and prevented significant differences in feed intake. Final body weight and body weight gain at 112 days were significantly higher in the 31.37% NDF group compared with the 29.74%, 34.28%, and 36.53% NDF groups, with improvements of 3.37, 10.86, and 10.94 kg in final body weight, and 4.53, 11.54, and 11.72 kg in body weight gain, respectively. This may be because providing appropriate NDF levels improved the rumen environment, which in turn stimulated feed intake and enhanced calf performance [13]. Therefore, for calves aged 15–112 days, a starter NDF level of 31.37% is optimal for improving feed intake and weight gain.

3.2 Effects of Different NDF Levels on Slaughter Performance

Dressing percentage and net meat percentage are important indicators of animal growth and slaughter performance. Dressing percentage and net meat percentage were significantly higher in the 29.74% and 31.37% NDF groups compared with the 36.53% NDF group, with values of 51.53% and 38.27% for the 29.74% NDF group, and 52.81% and 39.66% for the 31.37% NDF group, respectively. These results are consistent with those reported by Deng [19] and Zhang [20] for 3-4 month-old calves, indicating that excessively high NDF levels in calf starter feed negatively affect slaughter performance. Yang et al. [21] fed 3-6 month-old Holstein bull calves with four complete pelleted feeds differing in concentrate-to-forage ratios (75:25, 70:30, 65:35, and 60:40) and found no significant effects on slaughter performance, which contradicts our findings. This discrepancy may be due to differences in calf age, as our study used 1-4 month-old calves with different NDF requirements. In the current experiment, the 31.37% NDF group showed higher apparent values for carcass weight, net meat weight, meat-to-bone ratio, and meat percentage of carcass compared with the other groups.

3.3 Effects of Different NDF Levels on Organ Indexes

Organ indexes are biological indicators that reflect functional capacity to some extent [22]. Webster [23] suggested that visceral indexes are closely related to dietary energy and protein utilization. Johnson et al. [24] proposed that changes in organ and intestinal weights are directly related to digestible and absorbable nutrients in the diet. Guilin et al. [25] found that dietary concentrate-to-forage ratio affected organ weights in Holstein bulls, with high-concentrate diets promoting heart, liver, spleen, lung, and kidney development, particularly in terms of absolute weight and weight proportion to body weight. Our study found that lung and heart indexes were significantly higher in the 29.74% and 31.37% NDF groups compared with the 34.28% and 36.53% NDF groups, and kidney index was significantly higher in the 31.37% NDF group compared with the 34.28% and 36.53% NDF groups, consistent with the aforementioned studies. The spleen is a peripheral immune organ, and spleen index can reflect its functional capacity to some degree. In this experiment, different NDF levels in starter feed had no significant effect on spleen index, suggesting that dietary NDF level does not adversely affect immune function.

Proper small intestine development is crucial for nutrient digestion and utilization. In this study, different NDF levels had no significant effects on duodenum, jejunum, or ileum indexes, though the 31.37% NDF group showed higher jejunum and ileum indexes than the other groups. These results align with Wang [26], who reported that adding appropriate levels of forage to increase NDF level benefits intestinal development in calves.

Additionally, organ indexes in the 34.28% and 36.53% NDF groups were lower than those in the 29.74% and 31.37% NDF groups, possibly because higher

NDF levels reduced passage rate through the gastrointestinal tract, decreasing digestibility of organic matter, non-fibrous carbohydrates, crude protein, and fat [27], thereby affecting organ development.

3.4 Effects of Different NDF Levels on Stomachus Compositus Development

The degree of stomachus compositus development in young ruminants directly affects future feed intake and digestive capacity, with rumen development being particularly critical. Well-developed rumen is fundamental for ruminants to achieve optimal production performance and feed conversion efficiency [28]. Pelleted feed intake plays an important role in rumen development, and the proportion of visceral organ weight to body weight is closely related to energy and amino acid consumption [29]. Suárez et al. [30] reported that feeding calves starter feed with low NDF level promoted balance of rumen microbial flora and increased rumen polysaccharidase activity, thereby enhancing rumen development. In this study, the proportion of rumen weight to total stomachus compositus weight was significantly higher in the 29.74%, 31.37%, and 34.28% NDF groups compared with the 36.53% NDF group. Moreover, increased feed intake corresponded with increased stomachus compositus and rumen weights. Stomachus compositus weight in the 31.37% NDF group was 0.20, 0.20, and 0.67 kg higher than groups A, C, and D, respectively; rumen weight was 0.21, 0.25, and 0.92 kg higher, respectively. This may be because the appropriate NDF and crude protein levels in the 31.37% NDF group provided necessary nutrients for rumen development, established a suitable rumen environment, increased DMI, and promoted rumen development. In this experiment, omasum and abomasum weights increased sequentially with increasing dietary NDF level, with the proportion of omasum weight to total stomachus compositus weight being significantly higher in the 36.53% NDF group than in the 29.74% NDF group. This may be due to enhanced physical stimulation in the gastrointestinal tract with increasing NDF levels, promoting digestive organ volume and muscle development and increasing gastrointestinal weight [31]. These results are consistent with Guilin et al. [25] in 3–6 month-old calves. Therefore, adding appropriate levels of forage to increase NDF level in calf starter feed promotes digestive system development, which in turn facilitates nutrient digestion and absorption and promotes healthy calf growth.

3.5 Effects of Different NDF Levels on Gastrointestinal pH

Appropriate gastrointestinal acidity is essential for normal digestive function and regulates acid-base and electrolyte balance [22]. Rumen pH affects rumen development by influencing volatile fatty acid proportions and is critical for normal growth, rumen development, and health [32]. Rumen pH is affected by dietary structure, saliva secretion, volatile fatty acid fermentation and absorption rates, passage rate, and buffering capacity of digesta [33]. The normal range is 5.5–7.5, and maintaining pH within this range is prerequisite for normal rumen fermentation, with variation patterns depending primarily on diet composition and time after feeding [34]. In this study, ruminal pH values for groups A, B, C, and D were 6.22, 6.25, 5.58, and 5.55, respectively, all within the normal range. The lower ruminal pH in the 34.28% and 36.53% NDF groups may be due to high NDF levels producing large amounts of acid during fermentation, which exceeded the absorption capacity of the underdeveloped rumen wall, resulting in decreased pH [33]. Additionally, cellulolytic bacterial activity is inhibited when pH falls below 6.2, impairing fiber digestion and passage [28,35] and affecting calf growth.

Beauchemin [36] found that total mixed ration particle size and forage particle length significantly affected chewing time and ruminal pH in ruminants. In this experiment, all groups were fed starter feeds with similar particle size, eliminating particle size effects on ruminal pH and demonstrating that increasing NDF level in calf starter feed significantly affects ruminal pH. Generally, the gastrointestinal tract maintains a relatively stable internal environment with certain buffering capacity [37]. In this study, no significant differences were observed in pH of duodenum, jejunum, ileum, cecum, or abomasum among groups, indicating that NDF level does not adversely affect pH in gastrointestinal segments other than the rumen.

4 Conclusions

1. During the rapid growth phase of 15–112 days of age, dietary NDF level in starter feed is a critical factor that significantly affects body weight gain, slaughter performance, and development of heart, lungs, kidneys, rumen, and omasum in dairy calves.
2. Under the conditions of this experiment, the optimal NDF level in starter feed for 15–112 day-old calves is 31.37%.

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Note: Figure translations are in progress. See original paper for figures.