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Effects of dietary physically effective neutral detergent fiber content on the feeding behavior, digestibility, and growth of 8- to 10-month-old Holstein replacement heifers

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ABSTRACT

The objective of this study was to evaluate the effects of dietary physically effective neutral detergent fiber (peNDF) content on the feeding behavior, digestion, ruminal fermentation parameters, and growth of 8- to 10-mo-old dairy heifers and to predict the adequacy of dietary fiber in growing dairy heifers. Twenty-four Holstein dairy heifers (245 ± 10.8 d of age, 305.6 ± 8.5 kg initial live weight) were randomly divided into 4 treatments with 6 replicates as a completely randomized design. During the 60-d period with a 10-d adaptation, heifers were offered 1 of 4 diets, which were chemically identical but included different $peNDF_{8.0}$ (particle size is >8 mm and <19 mm) content (% DM): 10.8, 13.5, 18.0, or 19.8%, which was achieved by chopping forage into different lengths (fine = 1 cm, short = 3 cm, medium = 5 cm, and long = 7 cm). The concentrate and silage were mixed and fed restrictedly and exclusive of forage (Chinese ryegrass hay) were offered ad libitum. The body weight and frame size of the heifers were measured every 15 d during the experimental period. Samples of the rumen content (2 h after the morning feeding) were taken for pH, ammonia, and volatile fatty acid determination. The dry matter intake and average daily gain of the heifers were not significantly affected by $peNDF_{8.0}$ content. The body frame size (including withers height, body length, and heart girth) of the heifers was not increased significantly by enhanced $peNDF_{8.0}$ content. Ruminal pH and ammonia concentration were both increased with increasing dietary $peNDF_{8.0}$ content. The ruminal total volatile fatty acid concentration and percentage of acetate and butyrate profiles were not significantly affected by dietary $peNDF_{8.0}$ content. However, the enhanced $peNDF_{8.0}$ content led to a decrease in the propionate percentage. The ratio of acetate to propionate in the 13.5% treatment was highest among the treatments. Increasing the particle size and dietary $peNDF_{8.0}$ content resulted in increased eating and chewing time but had no effect on rumination time. Heifer total eating and chewing time and eating and chewing time per kilogram of dry matter intake were increased with increasing dietary $peNDF_{8.0}$ content. The apparent digestibility of acid detergent fiber and crude protein was improved with an increasing content of dietary $peNDF_{8.0}$. The results suggest that an optimal or advisable dietary particle size and $peNDF_{8.0}$ content improves chewing activity, rumen fluid pH, and ruminal fermentation. The data based on feeding behavioral and growth responses of heifers as well as rumen fermentation and digestion by improving total eating and chewing time indicate that 18.0% dietary $peNDF_{8.0}$ content is the most suitable for 8- to 10-mo-old Holstein heifers.

Key words: physically effective neutral detergent fiber, feeding behavior, body growth, Holstein replacement heifer

INTRODUCTION

Heifer herd feeding and management are expensive and require extensive labor, often accounting for approximately 15 to 20% of total farm expenses (Heinrichs, 1993; Hoffman, 1997). The ability to develop strategies for raising dairy heifers efficiently is important for dairy farmers to increase profitability. Efficient utilization of feeds by dairy heifers can help to minimize rearing costs. Traditionally, heifers are often fed high-forage diets, which are inefficiently digested due to high levels of lower digestibility forage in heifer rations (Zanton and Heinrichs, 2007). Determination of the adequate amounts of dietary fiber is essential to maintaining a highly efficient rumen metabolism, the ultimate goal in heifer rearing and is a key concern in dairy cattle nutrition. Reducing the age of onset of puberty, early breeding, and thereby reducing the age at first calving are alternative ways to minimize expenses when rearing heifers. To achieve this, high concentrate diets composed of high energy and high protein are being fed frequently to accelerate growth rates of calves and

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heifers. Consequently, various reports have shown that rapid rearing by feeding high-concentrate diets not only reduces the age of sexual maturity but also decreases the time period it takes to reach the age of first calving (Gardner et al., 1977; Hoffman et al., 1996, 2007). However, high energy diets may cause undesirable fat deposition, thereby affecting mammary development and future milk yield potential (Sejrsen et al., 1982; Peri et al., 1993; Brown et al., 2005). Therefore, limit feeding has drawn attention in recent years because it offers great potential to reduce the costs associated with raising replacement dairy heifers. In addition, feeding a nutrient-dense ration in a limited amount has also the potential to reduce feed costs and nutrient or fecal excretion and to improve feed efficiency (Hoffman et al., 2007; Lascano et al., 2009; Greter et al., 2013). In fact, optimal utilization of rations by heifers is influenced by the chemical composition and physical characteristics of their rations. Carbohydrates often constitute 70% or more of the DM in dairy rations and are the major precursors of energy for ruminants. Both the amount and effectiveness of dietary fiber can affect feeding behavior, ruminal fermentation, and animal metabolism. To assess the adequacy of dietary fiber in dairy cattle, the concept of physically effective neutral detergent fiber (**peNDF**; Mertens, 1997) has received increasing attention because it amalgamates information on both chemical fiber content and physical characteristics (primarily particle size) of the feedstuffs. The peNDF of a diet is the product of its NDF concentration and its physical effectiveness factor (**pef**). In dairy cattle production, it is necessary to quantify the peNDF value in heifer diets to maintain the rumen function and growth and to achieve the optimal target BW. Hence, the peNDF in dairy cows has been intensively investigated recently, although the NRC (2001) does not recommend peNDF for any category of dairy heifers. Zebeli et al. (2008) developed practical models to assess and predict the adequacy of dietary fiber, and the method was used to evaluate the responses of ruminal pH and production performance to different variables including physical, chemical, and starch-degrading characteristics in the diet of high-yielding dairy cows. Furthermore, comprehensive meta-analyses about both $peNDF_{8.0}$ and $peNDF_{1.18}$ recommendations for dairy cows have been performed during the last decade (Zebeli et al., 2008, 2010, 2012). However, limited information is available documenting the influence of peNDF on heifers, and the optimal concentration of peNDF in dairy heifer diets is still uncertain. Therefore, finding an optimal balance of peNDF content in the diets of dairy heifers is critical to achieve the rearing targets for body size, optimal digestion, nutrient utilization, and improved productivity. We hypothesized that optimal peNDF content in diets would benefit to improve feed digestion and efficiency, ruminal fermentation, and body growth of heifers. Thus, the objective of this study was to determine the optimal dietary peNDF for growing replacement heifers.

MATERIALS AND METHODS

Animals and Feeding

Twenty-four Holstein heifer calves with similar genetic merit, initial age (245 ± 10.8 d), and BW (305.6 ± 8.5 kg) were randomly assigned to 4 treatments with 6 replicates. A completely randomized design was applied to this trial. Heifers were individually housed and fed in a tie-stall barn during the 4 treatments, and each animal was provided with an own feed bunk. Water was available ad libitum to the heifers through a water bowl in each stall. The experiment was conducted between May and August of 2013 at the Experimental Dairy Farm of Yangzhou University (Yangzhou, China), and the use of heifers in this study was approved by the Animal Care and Ethical Committee of Yangzhou University (no. 201206118).

The heifers were given a 10-d adaptation period before exposure to the experimental treatment; the experiment was conducted for 60 d. Feeding behavior was monitored continuously using 4 time-lapse video cameras (Panasonic WV-BP330, Osaka, Japan) installed on the outside of the pen following the method described by Kitts et al. (2011). Animal behaviors, including eating, chewing, and ruminating activity, were recorded as images. The vivid image signal was transmitted to a control computer. The number of jaw movements were summed each minute and stored for subsequent analysis. All other jaw movements were considered to be associated with licking, drinking, and grooming and were not included in the eating or ruminating categories. The amount of time spent feeding during the experimental period was recorded for 120 h for individual heifers using an instantaneous scan at each barn. Feeding, chewing activity, and rumination time were measured at 1-min intervals and recorded. For each scan, feeding was defined as when a heifer had her head completely past the feeding rail and over the feed. Total time spent eating, ruminating, and chewing (eating + ruminating) was based on the duration of each chewing activity. Chewing efficiencies were calculated by dividing voluntary DMI by the respective eating, rumination, or chewing time.

Diets and Treatments

Heifers were fed twice daily (at 0800 and 1600 h) with a ration that was formulated to meet the nutrient