

Nutritional Strategies for Replacement Dairy Heifers: Using High Concentrate Rations to Improve feed Efficiency and Reduce Manure Production

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Raising dairy heifers from birth to calving has been found to comprise the second largest expense on the dairy farm towards the production of milk, while deriving no revenue until the onset of lactation (Heinrichs, 1993). Therefore, many experiments involving dairy heifers have focused on ways to minimize the costs associated with the growth period or decreasing the unproductive period of the animal's life.

Reducing the length of the growing period by decreasing age at first calving below recommendations (22 to 24 months) could overcome this lag between expenditure and revenue generation and reduce costs associated with the nonproductive period. This could be accomplished by increasing prepubertal average daily gain (ADG; (Hoffman, 1997)), which would subsequently result in a lower age at first breeding and presumably a lower age at first calving. Although this strategy would ultimately accelerate return-on-investment, it has been demonstrated that increased prepubertal ADG has a negative impact on mammary development (Radcliff et al., 1997; Sejrsen et al., 1982) and first lactation milk yield (Lammers et al., 1998; Radcliff et al., 2000; Van Amburgh et al., 1998). In summarizing recent literature on the association between prepubertal ADG and first lactation milk production, total first lactation milk and protein yields were maximized when prepubertal ADG was around 800 g/d for Holstein heifers (Zanton and Heinrichs, 2005a). Many researchers, however, are looking for ways to allow for greater ADG while maintaining optimal levels of mammary development and milk production. To date many of the approaches have shown little progress, conflicting results, or impracticable recommendations to enable a producer to overcome the problems associated with accelerated prepubertal growth.

Because improving prepubertal ADG necessitates nutritional alterations, most experiments investigating the effects of prepubertal growth have also altered the nutritional status of the heifers in one or several groups. For instance, some studies altering prepubertal ADG have fed rations of vastly different composition for *ad libitum* consumption (i.e. high forage or high concentrate rations); others have fed an identical diet to each experimental group, but controlled intake to obtain different ADG. What is minimally represented in the literature are the effects that different proportions of forage and concentrate have on milk production, when fed to maintain a constant rate of growth. Sejrsen and Foldager (1992) investigated this question using 8 animals per treatment through 130 days of their first lactation. They concluded that there were no differences in milk production between groups fed high or low forage rations that achieved equal ADG during rearing. 108

Feed costs make the greatest contribution to the expenses associated with raising heifers, comprising about 60% of all heifer expenditures (Gabler et al., 2000). Therefore, it would be logical to expect that a reduction in feed costs could significantly decrease overall cost for raising dairy heifers. Because there is an optimum ADG for heifer growth, feed costs should be expressed in a manner which considers both the cost of feed per unit of feed weight and the amount that must be fed to obtain the optimal ADG. In the United States, concentrates are usually more cost effective per unit of energy and protein than forages. If the energy requirement is fixed by the amount needed to obtain the optimal ADG, feed costs could be reduced by replacing more expensive forage energy with energy from concentrates. Also, if there are no differences in milk production when heifers are fed high forage (HF) or high concentrate (HC) rations during the rearing period, then the costs to raise dairy heifers could be reduced.

There is currently very little data in the literature concerning the effects of feeding HF or HC rations, when delivered for the same level of growth, on responses in dairy heifers. Reynolds et al. (1991a; 1991b) investigated the effects of differing the proportions of forage and concentrate in rations fed to growing beef heifers on energy metabolism at the level of the whole animal as well as for the portal-drained viscera tissues and the liver. Reynolds et al. (1991b) found that when fed a constant level of metabolizable energy, heat production was lower for animals fed the HC ration (25:75 vs. 75:25 forage:concentrate) resulting in significantly increased tissue energy accretion. The portal-drained viscera accounted for proportionately less oxygen consumption for the HC ration; however, the splanchnic tissue consumption of oxygen did not differ between diets. Glucose release to the periphery was also significantly increased when feeding a HC ration, possibly due to decreased glucose metabolism by the portal-drained viscera as glucose output by the liver was not significantly different between diets (Reynolds et al., 1991a). While nitrogen dynamics were discussed, the responses are difficult to resolve or to ascribe to a particular forage-to-concentrate ratio due to differences in nitrogen intake between treatments. However, while nitrogen intake was greater for the HF ration, tissue retention of nitrogen was greatest for the HC ration. Relative to intake, heifers fed the HF ration excreted more fecal dry matter, nitrogen, and energy and more urinary nitrogen. While it is unclear if the improved nitrogen efficiencies were due to differences in nitrogen intake, the flow of some nitrogen containing compounds (ammonia, α -amino nitrogen, and urea) across the portal-drained viscera were not significantly affected by the rations fed, indicating that post-absorptive nitrogen efficiency may be improved by low forage rations.

Reynolds et al. (1991a) also found that the maximal contribution of amino acid to gluconeogenesis tended ($P < 0.10$) to be reduced, and significantly less ($P < 0.05$) α -amino acid nitrogen was removed by the liver in heifers fed the HC ration. Similarly, Huntington et al. (1996) fed iso-nitrogenous and iso-energetic diets to 6 multi-catheterized beef steers to investigate the dynamics of nitrogen when fed varying proportions of forage and concentrate. In a comparison of diets containing 63 or 37% forage, significantly more urea nitrogen and glucose were released by the splanchnic

tissues to the periphery when fed 37% forage, whereas acetate release was significantly reduced. Amino acid release by the splanchnic tissues was greater for the low forage diet; however statistical significance was not attained.

It is critical that data can be produced in which these factors are closely controlled so that nitrogen excretion for these diets can be more thoroughly understood in the context of the different levels of forage fed to growing dairy heifers. Furthermore, the combination of lower acetate with the possibility of increased amino acid release to the periphery could have effects on the composition of gain in heifers due to the preferential use of acetate for lipogenesis in ruminants (Bergman, 1990), as well as the increased availability of amino acids for protein synthesis (Owens et al., 1993).

A typical dairy heifer is fed a ration in which the majority of its nutrition is derived from forages as opposed to concentrated feedstuffs. However, there is a large inefficiency associated with this method of feeding due to lower digestibility of most forages, greater metabolic protein and energy requirements associated with digesting forage, and higher feed costs per unit of energy as compared to concentrates. The potential therefore exists to replace a significant proportion of the forage dry matter (DM) in a ration with concentrate DM, reducing the inefficiency associated with raising dairy heifers while maintaining similar ADG. To address this concept for raising dairy heifers, a series of experiments have recently been conducted to evaluate heifer growth characteristics and nutrient utilization when given HF or HC rations at restricted intakes to achieve a similar ADG.

To test the effects of restricting the intake of feed to dairy heifers, irrespective of the level of dietary forage and concentrate, we conducted an experiment to determine the effects of differing intakes of dry matter on the nutritional and nitrogen efficiency in growing dairy heifers (Zanton and Heinrichs, 2004; Zanton and Heinrichs, 2005b). Organic matter digestibility was linearly increased ($P < 0.05$) by decreasing levels of dry matter intake, while neutral detergent fiber digestibility was unaltered by treatment. Nitrogen excretion in the feces and urine increased linearly ($P < 0.05$) with increasing intake of nitrogen and dry matter. Nitrogen retained as either a proportion of nitrogen consumed or nitrogen apparently absorbed was quadratically affected by treatment ($P < 0.05$) with nitrogen efficiency peaking at intermediate levels of intake.

To further address the concept of restricting intake for dairy heifers on productive efficiency, experiments were conducted to evaluate heifer growth characteristics and nutrient utilization when given rations of high or low energy density for similar levels of ADG. The objective of the first experiment (Zanton and Heinrichs, 2006a) was to elucidate the effects of feeding HC or HF rations at restricted intakes on feed efficiency and growth characteristics, and the effects on first lactation milk yield. Less DM was consumed by heifers fed HC than for HF (5.41 HC vs. 5.95 HF kg/d \pm 0.11; $P < 0.01$) at similar ADG, leading to significantly improved feed efficiency for heifers receiving HC ($P < 0.01$). Daily gains of skeletal measurements were not different between treatments. From these results we conclude that feeding a HC ration leads to similar growth performance as a HF ration when the level of intake is restricted to achieve a controlled

ADG. First and second lactation data on reproduction showed no differences between high forage and high concentrate diets.

Given the nutritional efficiency that we observed when feeding HC rations at restricted intakes, we conducted a study to evaluate the effects feeding different forage and concentrate levels on feed and nitrogen efficiency and on nitrogen utilization and ammonia volatilization from the resulting manure. We hypothesized that energy and nitrogen provided in a HC ration would be utilized with greater efficiency than when an equivalent amount of energy and nitrogen was given in a HF ration. Greater utilization of nitrogen by the animal, we further hypothesized, would lead to reduced nitrogen excretion and therefore reduced ammonia emissions into the environment. The experiment (Zanton and Heinrichs, 2006b; 2006c) was designed as a split plot design with young (Y; 313 ± 4 d; 263 ± 6 kg) and old (O; 666 ± 8 d; 583 ± 6 kg) heifer blocks given HC and HF twice daily to 4 cannulated heifers per block for four 28-d periods. Both the HC and the HF rations contained the same feed ingredients, but in differing proportions, yielding two treatment rations containing 75 or 25 percent of the ration DM as forages.

Organic matter (OM) intake was lower for heifers fed HC ($P < 0.01$), however due to improved OM digestibility (75.97 HC vs. 71.53 HF ± 0.70%; $P < 0.01$), intake of digestible OM was not different between treatments ($P > 0.20$). Neutral detergent fiber digestibility was not affected by dietary treatment (52.92 HC vs. 51.18 HF ± 1.46%; $P > 0.20$). The heifers fed HF had increased total rumen content wet weight (37.84 HC vs. 42.18 HF ± 1.36kg; $P < 0.01$). Total volatile fatty acid (VFA) concentrations were not altered by dietary treatment (110.80 HC vs. 112.87 HF ± 5.00 mM; $P > 0.14$). Similar concentrations of total VFA occurred due to higher acetate concentrations, lower butyrate concentrations (both $P < 0.01$), and a tendency for reduced propionate concentrations ($P > 0.07$) in HF. Mean rumen pH was lower for HC (6.24 HC vs. 6.51 HF ± 0.10; $P < 0.01$) and the amount of time that the pH was lower than 6.00 was greater in HC (7.12 HC vs. 3.15 HF ± 1.84 h; $P < 0.01$).

Fecal N excretion tended to be greater for HF ($P < 0.06$) and urinary N excretion was not affected by treatment ration ($P > 0.20$), leading to greater overall N retention for heifers fed HC ($P < 0.01$). The efficiency of N retention [0.2740 HC vs. 0.2126 HF (± 0.0128) g N retained/g N consumed; $P < 0.01$) and the environmental N load (2.92 HC vs. 4.72 HF ± 0.43 g N excreted/g N retained; $P < 0.01$) were also significantly improved in heifers receiving HC. The ammonia volatilization rate, when adjusted to reflect the greater production of urine and feces by HF, was greater for heifers fed HF (28.74 HC vs. 33.15 HF ± 1.00 g/d; $P < 0.01$). We concluded that feeding HC can produce changes in rumen fermentation in Y and O heifers, but the magnitude of these changes can be reduced by restricting intake. We further concluded that Y and O heifers fed HC will have improved efficiency of OM and N utilization when intake is controlled. Other experiments using corn silage as the sole source of forage have shown similar results (Daubert et al., 2006; Moody et al., 2006). Overall, utilizing HC compared to HF rations, fed to maintain optimum levels of daily gain, have shown that whole body growth and skeletal measurements were unaffected, feed costs dropped between 3 and 16%, and manure output fell between 12 and 40%

(depending on feedstuffs used). No detrimental effects, either short or long term, were noted from this feeding management system (Zanton and Heinrichs, 2009).

Our studies have shown that feeding high concentrate, low forage rations in a restricted manner to growing dairy heifers from 4 to 22 months of age leads to similar growth performance with respect to weight gains and structural growth. These results also lead to the overall conclusion that provided the level of intake is restricted to allow for an optimal level of ADG, HC rations can be fed to dairy heifers resulting in reduced feed costs and reduced levels of nutrient waste.

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