Revising Heifer Nutrition to Reduce Manure and Ammonia Output

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Raising dairy heifers to an adequate size and with an age at first calving between 22 and 24 months can optimize profitable milk production. This achievable goal requires proper nutrition and feeding management so heifers are large enough to breed at 13 to 15 months old. On many dairy farms, heifer management is not the most critical part of the day-to-day activities; however, chronic neglect of nutrition, feeding management, and preventative health care can lead to stunted growth. This results in heifers that calve much later than 24 months of age and that produce considerably less milk during their lifetime than those that are properly fed and well grown. Not only are undersized heifers smaller and less productive, but they also are prone to more problems at calving. On the other hand, accelerating the growth of heifers until they become fat also reduces their lifetime milk production and longevity.

In addition, 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—all while deriving no revenue until the onset of lactation (Heinrichs, 1993). Therefore, many of the 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 the age at first calving below recommendations (22-24 months) could overcome this lag between expenditure and revenue generation and reduce the 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 lead to a sooner 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 yield was found to be maximized when prepubertal ADG was around 800 g/d for Holstein heifers (Zanton and Heinrichs, 2005). 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.

Since accelerating prepubertal ADG necessitates nutritional alterations, most of the 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 restrictively to obtain the 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. Serjsen and Foldager (1992) investigated this question using eight animals per treatment through 130 days of the first lactation. They concluded that there were no differences in milk production between the group that was fed the high or the low forage rations and achieved equal ADG during rearing.

Since feed costs make the greatest contribution to the expenses associated with raising heifers; comprising about 60% of the all heifer expenditures (Gabler et al., 2000), it would follow that a reduction in feed costs could significantly contribute to decreasing the overall cost for raising dairy heifers. Since 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 the more expensive forage energy with energy from concentrates. Also, if there are no differences in milk production when heifers are fed high forage or high concentrate 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 high forage (**HF**) or high concentrate (**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 the animals fed the HC ration (25:75 vs. 75:25 forage:concentrate) resulting in a significantly increased tissue energy accretion. The portal-drained viscera (PDV) accounted for proportionately less oxygen consumption for the HC ration, however the total splanchnic tissue (TST) 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 the decreased glucose metabolism by the PDV 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 the 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 are due to differences in nitrogen intake, the flow of some nitrogen containing compounds (ammonia, α-amino nitrogen, and urea) across the PDV were not significantly affected by the treatment 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 N was removed by the liver in the heifers fed the HC ration. Similarly, Huntington et al. (1996) fed iso-nitrogenous and iso-energetic diets to six 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 was released by the TST to the periphery when fed 37% forage, while acetate release was significantly reduced. Amino acid release by the TST was greater for the low forage diet, however statistical significance was not attained.

It is critical that data can be produced where 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 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 recently conducted an experiment, the objective of which was 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, 2005). Organic matter digestibility was linearly increased ($P<0.05$) by decreasing levels of DMI, while NDF 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 have recently been 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 feeding different a HC or a HF ration at restricted intakes on feed efficiency and growth characteristics, and the effects on first lactation milk yield. Less DM was consumed by the heifers fed HC than for HF (5.41 HC vs. 5.95 HF kg/d ± 0.11; *P*<0.01) at similar ADG leading to significantly improved feed efficiency for the 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 when the level of intake is restricted to achieve a controlled ADG. Reproduction and first lactation data are currently being monitored.

Given the nutritional efficiency that we observed to arise by 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 a greater efficiency than when an equivalent amount of energy and nitrogen is given in a high forage 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 ± 4d; 263 ± 6kg) and Old (**O**; 666 ± 8d; 583 ± 6kg) heifer blocks given HC and HF twice daily to four cannulated heifers per block for four, 28d 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 dry matter as forages.

Organic matter 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 ($P>0.20$). NDF digestibility was not significantly 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 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 hr.; $P<0.01$).

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 ± 1.00g/d; $P<0.01$). We conclude 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 conclude 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.

Researchers from Wisconsin (Hoffman et al., 2007) have also recently shown that limit feeding 40% concentrate diets will have similar effects as our studies in reducing manure output and improving feed efficiency with no effects on lactation performance. They fed pregnant heifers to 80 or 90% of ad libitum and showed no long term heifers.

In total, theses studies have shown that feeding higher concentrate, 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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