Feed Efficiency in Dairy Heifers

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INTRODUCTION

Dairy heifers represent a large expense of resources including feed, buildings, and labor; yet return no money to the dairy farm until they calve. Our overall management of these heifers must be handled in a manner that yields the best quality heifer, with a high potential to be productive, and at minimal cost to the farm and the environment.

Feed represents the largest component to the cost of heifer production (Gabler et al., 2000) and is such a large proportion that it easily represents the major way to control heifer costs. We are often reminded of the importance of feed efficiency (lb milk/lb feed) for lactating dairy cows; however, the concept is seldom mentioned for the growing heifer. Of course in heifers, we measure feed efficiency not in milk production, but in lb of gain/lb of feed. There are several factors that can greatly impact feed efficiency in the dairy heifer, such as genetics, forage quality (digestibility), growth rate or stage of growth, body condition or gain in body composition, gestation, heat or cold stress (environmental stresses), and exercise level.

From a genetic standpoint, as we increase body size relative to milk production, we increase maintenance costs for energy, protein, and most other major nutrients (Brody, 1945; Amert and Emmans, 2000; Gabler et al., 2000). Similar principles are true in terms of growth rates for the heifer. The smaller the BW of the heifer at a given age, the lower the maintenance requirements of that animal (Anrique et al., 1990; Amert and Emmans, 2000; National Research Council, 2001). This being said, the heifer must be large enough to cycle for breeding purposes and, more importantly, large enough to calve successfully. She must also have a large digestive capacity to achieve high dry matter intakes (**DMI**) in the first lactation to be considered successful. In addition, this growth must be accomplished in a timely manner since age at first calving can have a dramatic impact on heifer raising costs (Tozer and Heinrichs, 2001). The case can be made for achieving a steady state of growth from birth; therefore stabilizing these various elements of the maturation of the dairy heifer. Alternating rates of growth, leaving animals at or near maintenance followed by periods of energy and nutrient efficient compensatory growth, have been proven successful in research situations (Park et al., 1987; Park et al., 1998; Ford and Park, 2001). Although practice of this feeding system is limited, its principles of strategic animal energy conservation are sound.

Changing body composition over various stages of maturity is another factor that affects the feed efficiency of the heifer (Wright and Russel, 1991; Stelwagen and Grieve, 1992; Amert and Emmans, 2000). This includes the added requirements for heifers in late gestation (National Research Council, 2001). Environmental stresses and exercise are additional factors that affect maintenance requirements and thus will have direct effects on heifer feed efficiency (Garrett et al., 1959; Yan et al., 1997).

A final, yet extremely important aspect to feed efficiency is diet type and amount. This has been the subject of several research trials over the past 6 yr and continues to be studied at several universities.

USING HIGHLY DIGESTIBLE DIETS IN A LIMIT FEEDING ENVIRONMENT

Since there is an optimum average daily gain (**ADG**) for heifer growth (Zanton and Heinrichs, 2005a), feed costs should be expressed in a manner that 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 (Ishler, 2008). 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, b) investigated the effects of varying 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 (**PDV**) 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 PDV accounted for proportionately less oxygen consumption for the HC ration; however, the total 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 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 (**DM**), nitrogen, and energy and more urinary nitrogen.

It is critical that data 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 her nutrients 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.

Our earliest experiments tested the effects of restricting feed intake by dairy heifers, irrespective of the level of dietary forage and concentrate (Zanton and Heinrichs, 2004; Zanton and Heinrichs, 2005b). 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 DM. 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, we have evaluated heifer growth characteristics and nutrient utilization for rations of high or low energy density fed 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 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. In addition we found no difference in reproduction, age or body weight at calving, and a trend for increased milk ($P = 0.08$) and fat ($P < 0.01$) production (Zanton and Heinrichs, 2007b). 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 effects with similar levels of milk production.

Given the nutritional efficiency that we observed to arise by feeding HC rations at restricted intakes, we then 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 was 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, c) 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 four 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 2 treatment rations containing 75 or 25 % of the ration DM as forage.

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 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 ± 1.36 kg; $P < 0.01$). 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 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 improved in heifers receiving HC. 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 (Moody et al., 2007; Lascano and Heinrichs, 2007a, b).

Further studies from our lab have found that apparent N digestibility is greater with HC diets (Zanton and Heinrichs, 2007a). Recent work from our lab has shown that the digestion of N by dairy heifers in general is high, and that the majority of N appearing in the feces of dairy heifers is not of dietary origin and may be differentially affected by forage level (Zanton and Heinrichs, 2008). This leads us to the conclusion that the improved diet efficiency that we have seen is not only for energy but also applies to dietary protein.

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).

CONCLUSIONS

In total, theses studies have shown that feeding higher concentrate rations in a restricted manner to growing dairy heifers from 4 to 22 mo of age leads to similar growth performance with respect to weight gains and structural growth. Furthermore, no detrimental effects, either short or long term, were noted from this feeding management system in any of our studies. These results 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 successfully and can reduce feed costs and nutrient waste.

Feed efficiency in the dairy heifer can therefore be optimized by selecting animals that have the genetic propensity for high DMI in first lactation and have the ability to grow at uniform rates to meet the body size requirements for calving at 22 to 24 mo of age. Maintaining optimal body size during the growing phase is important to minimize heifer maintenance requirements. Finally, feeding limited amounts of highly digestible, high concentrate rations will minimize energy and protein requirements of the heifer.

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