A NEW PERSPECTIVE ON FEEDING DAIRY HEIFERS: PROMOTING GOOD HEALTH, EFFICIENCY, AND BEHAVIOR

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INTRODUCTION

Replacement heifer feeding programs must be designed to allow heifers to be bred efficiently, calve out by 24 months of age, and produce to their maximum potential. To achieve this, heifers must be fed to grow at a high rate, while not becoming over-conditioned, as well as to remain healthy. The costs of replacement dairy heifer rearing are second only to the feed costs of lactating cows, representing 15 to 20% of total farm operational expenses (Heinrichs, 1993). Of these costs, feed represents the greatest expense in heifer rearing costs (Gabler et al., 2000). The primary nutritional goals of a successful dairy replacement rearing program are, thus, to feed heifers for maximal production potential, at a low economic and environmental cost, without compromising animal health or welfare.

We have seen much advancement, particularly in the past decade, in replacement heifer nutritional research directed to these goals. Concurrently, we have also seen a significant rise in the amount of scientific research relating behavior to the management of dairy cattle, particularly with respect to the interaction with health. Much of this research has been focused on using information on the natural behavioral patterns of dairy cattle to make management decisions that are beneficial for the health, productivity, and welfare of these animals. This review describes those primary areas where researchers have considered the interaction of behavior and nutritional management in replacement dairy heifer rearing. In particular, I will focus on both immediate and potential long-term effects of such behavioral patterns on replacement heifer growth, efficiency, health, and welfare.

DEVELOPMENT OF FEEDING BEHAVIOR PATTERNS

Observations of feeding behavior patterns, including feed sorting and meal patterns, of individual cows have revealed considerable variation between cows in performance of feeding behaviors (Leonardi and Armentano, 2003; Melin et al., 2005). Interestingly, individual cows are relatively consistent in feeding patterns over time (Melin et al., 2005), suggesting that they have developed their own unique feeding behavior patterns. This would suggest that dairy cattle feed consumption patterns are not only affected by the animals' current situation, but also may have been learned earlier in life through previous experiences (Provenza and Balph, 1987). There is new data to suggest that some feeding behaviors may develop and be maintained through experiences that occur early in life.

Total mixed rations (TMR) are believed to be the optimal way to provide the balance of nutrients that ruminants need to maintain a stable and efficient microbial population. Following milk weaning, replacement heifers are typically fed a diet consisting of grain concentrate and forage (hay or silage) until approximately 6 months of age (Murphy, 2004). Under commercial management settings, the grain concentrate is provided in different ways, typically separate from the roughage, on top of the roughage ('top dressing'), or mixed in with the roughage. In recent research we have shown that feeding growing dairy heifers concentrate top-dressed on forage results in the rapid consumption of the concentrate portion of their ration in very few, large meals prior to consuming the forage (DeVries and von Keyserlingk, 2009; Greter et al., 2010a). This consumption was also associated with high levels of competitive behavior at the feed bunk (Greter et al., 2010a). Such competition is likely attributed to the desire to consume the concentrate, and thus contributes to the rapid consumption of this feed soon after feed delivery. Rapid consumption of the concentrate portion of the ration in few, very large meals, as observed in these studies, may cause large post-prandial drops in rumen pH (Quigley et al., 1992).

Alternatively we found that heifers fed a TMR from a young age were able to distribute their feeding activity more evenly throughout the day and compete less for feed than heifers fed a top-dressed ration. In that study these behavioral patterns persisted in both treatment groups even when there was a ration change to an unfamiliar TMR (Greter et al., 2010b) This suggests that the animals had not only learned these behavioral patterns, but that these patterns became habitual and may be difficult to extinguish over time. These findings are of concern as they provide some evidence that early life feed delivery methods may impact the development (and maintenance) of behavioral patterns in dairy cattle. Thus, providing growing dairy heifers a well-formulated TMR from a young age may not only have immediate benefits on rumen health, but the persistence of these behaviors into maturity may help prevent other feeding-related or associated problems from developing (i.e. excessive sorting and feed bunk competition, lameness, or metabolic disorders) when the animals enter the lactating herd.

There is empirical evidence to suggest that feeding patterns develop in ruminants already during the milk-feeding phase. We recently completed a study in which dairy calves were subjected to different feed types (either concentrate or hay) early in life and determined if feed familiarity affected sorting of dairy calves once fed a mixed ration after weaning off milk (Miller-Cushon and DeVries, 2011). Immediately after weaning, calves sorted the mixed ration in favor of the familiar feed type and against the novel feed type. However, after 4 weeks of consuming a common mixed ration, sorting was similar between treatments, with all calves sorting for concentrate and against hay. Even though the distinct sorting preference was not retained, all calves developed strong sorting patterns early in life. It is possible that the limited exposure to a variety of feeds at that stage may have pre-disposed these calves to the development of sorting behavior patterns.

RATION COMPOSITION AND FEEDING LEVEL

To meet the objectives of rearing replacement dairy heifers, feeding strategies utilized are variable. Heifers have traditionally been provided diets that contain high-fibre, economically priced forages (MidWest Plan Service, 2003), which adequately meet their energy requirements (NRC, 2001). Feeding replacement heifers a high-forage, moderate-energy diet has the potential to control caloric intake and allow producers to target the growth rate of the heifers. From a behavioral perspective, such rations allow for continuous access throughout the day, and thus the expression of natural feeding behavior patterns. The primary behavioral nuance with such rations would be the excessive sorting of such rations, whereby the diet consumed is much different from that originally formulated. Such sorting can result in increase variability not only within animals within days, but also between animals within a day or across days.

There has been much recent interest in investigating how caloric intake can be controlled through the provision of a nutrient dense diet fed in a limited amount. Limit feeding allows for the effective control of average daily gain in replacement heifers, and also effectively decreases fecal excretion, increases feed efficiency, and reduces feed costs in some cases (Hoffman et al., 2007; Zanton and Heinrichs, 2007; Lascano et al., 2009; Kitts et al., 2011).

Unfortunately, limit feeding does pose behavioral concerns for dairy heifers. Limit feeding has been shown to reduce eating and lying time, resulting in animals spending more time standing while not eating, particularly at the feedbunk when no feed is available (Hoffman et al., 2007; Kitts et al., 2011; Greter et al., 2011). Limit feeding dairy cattle has also been associated with increased levels of oral stereotypies, including tongue rolling, constant head nodding, and bar biting/licking (Redbo et al., 1996; Redbo and Nordblad, 1997). The changes in behavior associated with limit feeding may be attributed to hunger and frustration as a result of lack of satiety. The lack of satiety observed in limit-fed heifers results from not only having feed available in a limited amount, but also for a very short duration. The 1 to 2 h of feeding duration observed in limit-fed heifers (Hoffman et al., 2007; Kitts et al., 2011; Greter et al., 2011) is a stark contrast from the 4 - 9 hours that dairy cattle, under natural grazing conditions, would engage in foraging behavior throughout the day (Hafez and Bouissou, 1975). Moreover, there is potential for some of these behavioral effects to result in negative health implications. For example, increased time spent standing, particularly on hard flooring surfaces, may increase the risk of hoof pathologies (Cook et al., 2004). Further, the consumption of a highly-fermentable ration, when eaten rapidly and ruminated less, may cause greater within-day bouts of sub-acute ruminal acidosis (Moody et al., 2007), which are known to be detrimental to health and feed efficiency.

An alternative to limiting the amount of feed provided would be to limit the nutrient density of a feed offered ad libitum (Hoffman et al., 1996). One possible method is to add a low-nutritive, low-value feedstuff to the diet that would satisfy the natural feeding behavior patterns of limit-fed animals, as feeding duration would be increased. In

addition to achieving satiety this feeding method may also reduce the risk of sub-acute ruminal acidosis. A low-nutritive feedstuff will decrease passage rate and increase rumination time, thus increase saliva production and rumen buffering. Greter et al. (2008) recently added straw (by 10 and 20% of DM) to a TMR fed ad libitum to replacement dairy heifers and found that daily DMI, feeding rate, meal size, and meal frequency decreased with increased straw in the diet while feeding time and meal duration increased. Interestingly, DMI also decreased with the addition of the straw to the ration. Based on these intakes, these researchers found that all requirements for maintenance and growth of 1.0 kg/d could be sufficiently met with 10% straw in the diet. Further, they found that sufficient nutrients were consumed with 20% straw in the diet to meet the requirements to achieve a 0.9 kg/d growth rate. Overall, these findings suggest that, if a ration is balanced properly, the addition of an inexpensive, low-nutritive feedstuff may help reduce DMI and enable producers to target caloric intake for desirable weight gain and development while allowing heifers to engage in more natural foraging behavior.

One of the drawbacks of that study was the finding that additional straw increased the amount of sorting of the ration (Greter et al., 2008). This result, coupled with ad libitum intake, could potentially increase within-group variability in nutrient intake. Thus, as follow-up to this, Kitts et al. (2011) conducted a study in which a low-nutritive feedstuff (straw) was provided with (either within or alongside) a limit-fed ration. These researchers found that the provision of straw with limit-fed ration allowed heifers to increase their feeding time (to a similar amount of time observed for heifers fed ad libitum), increase rumination, and decrease inactive standing time. These findings suggest that the provision of straw allowed heifers to express their natural foraging behavior patterns as well as achieve satiation and promote better rumen activity. Kitts et al. (2011) also found that the target ADG (0.9 kg/heifer/d) could be maintained with the provision of straw alongside the limit-fed ration. As follow-up to that research, Greter et al. (2011) similarly found that the consumption of straw alongside a limit-fed TMR contributed to greater satiety due to the consumption of sufficient bulk over a longer period throughout the day. Kitts et al. (2011) also assessed the economic implications of the provision of straw alongside a limit-fed TMR. Interestingly, they also found that the provision of straw did decrease feed efficiency and increase the cost of gain, but both not to the extent of that typically seen on a high-forage ad libitum-fed ration.

COMPETITION FOR FEED ACCESS

In addition to the type and formulation of ration provided, there are other non-direct nutritional factors (related to housing and management) which may influence the nutritional potential of the rations provided. An example of this would be the feed bunk stocking density that replacement dairy heifers are faced with. The intensification of the dairy industry, along with rapid growth in herd sizes, have resulted in housing dairy cattle, including young stock, at higher densities (i.e. over stocking). This management practice is often justified as it can be argued that heifers only spend a small fraction of their day consuming feed (3 to 3.5 h/d; Greter et al., 2008) and, thus, it could be assumed that the provision of a feeding place for each individual heifer within a pen is

not be necessary. However, cattle tend to synchronize their behavior; that is, many animals in the group will feed, ruminate, and rest at the same times. When cattle are fed in groups, the initiation to feed by one animal will often stimulate the other animals regardless of whether they show signs of hunger. Further, synchronized peaks in feeding activity occur at certain times of the day, such as when fresh feed is delivered (DeVries et al., 2003). As a result, provision of fewer feeding places than animals may result in high levels of competition for feed, particularly during these peak periods of feeding activity. Alternatively, the synchrony between animals has the potential to break down in such situations of high competition, and may lead to animals feeding at different times to avoid excessive aggression (Miller and Wood-Gush, 1991).

Competition for feed appears to have similar effects, across feeding strategies, on the feeding behavior of replacement dairy heifers. DeVries and von Keyserlingk (2009b) recently found that ad libitum fed heifers exposed to high feed bunk competition (2 heifers per feed bin) tended to have 10% shorter daily feeding times (192 vs. 213 min/d) than heifers with no feed bunk competition (1 heifer per feed bin). Similarly, decreases in feeding time have also been reported in studies on limit-fed heifers. Keys et al. (1978) found that increasing pen stocking density and, thus, decreasing feed bunk space (from 0.81 to 0.20 m/heifer) for yearling heifers linearly decreased their time spent eating by 26%. In a series of experiments on feed bunk space, Longenbach et al. (1999) reported that heifers (ranging from 4 to 21 months of age) subjected to increasing competition (by reducing feed bunk space from up to 47 down to 15 cm/heifer), resulted in heifers spending 25 to 50% less time eating. Interestingly, despite the reduction in feeding time, researchers have not reported any effect of competition for feed on the DMI of replacement dairy heifers fed ad libitum (DeVries and von Keyserlingk, 2009b) or, less surprisingly, those that are limit fed (Keys et al., 1978; Longenbach et al., 1999).

To maintain similar DMI in situations of high competition, heifers compensate by eating faster throughout the day, particularly during periods of peak feeding activity, and by shifting their intake patterns such that a greater proportion of their DMI occurs in the later hours after feed delivery (DeVries and von Keyserlingk, 2009b). Competition for feed access also appears to change the meal patterning of heifers, resulting in consumption of fewer meals per day, which are larger and longer in duration (DeVries and von Keyserlingk, 2009b). Given that within-day rumen pH declines increase with meal size (Allen, 1997), large and long meals may have significant impact on rumen fermentation. Results from González et al. (2008) support this hypothesis; these researchers found that greater feed bunk competition for concentrate in heifers, fed roughage ad libitum separately, resulted in lower rumen pH, greater lactate concentration, increased serum haptoglobin levels, and increased proportion of abscessed livers. For heifers fed a higher forage ration ad libitum, these rumen effects are likely far less extreme with the exception of situations where excessive sorting of the ration is observed. Sorting against long fiber particles by heifers (Greter et al., 2008; DeVries and von Keyserlingk, 2009a,b), could exacerbate any reductions in rumen pH caused by changes in meal pattern.

Another concern when feed bunk competition is high for replacement dairy heifers is the variable effect it has on individual animals kept in groups. Recent work has demonstrated that competition for feed in dairy heifers increases the day-to-day variation in meal duration, feeding time and meal size (DeVries and von Keyserlingk, 2009b), resulting in inconsistent feeding behavior patterns. González et al. (2008) also found that the variability in feeding time and body weight tended to increase in groups of heifers fed competitively, suggesting disparity between group members in their ability to access feed and maintain DMI. Longenbach et al. (1999) reported that competition increased the variability in live weight gain within pens of replacement dairy heifers. It has been demonstrated in heifers that competition for feed is most intense during the first hour after feed delivery, with these effects greatest in situations where competition for feed bunk access is increased as the number of animals able to feed simultaneously decreases (Keys et al., 1978). The variability in feeding behavior and weight gain observed in these studies may be explained, in part, by certain animals dominating the feed bunk after feed delivery and consuming excess DM. At the same time, this likely increases the risk that subordinate animals show reduced DMI.

CONCLUSIONS

There is a growing body of literature on dairy cattle behavior and how this field of science can aid in making science-based recommendations for best management practices. For replacement dairy heifers, much of this research has been focused on the interactions between nutritional management and behavior, and how these interactions may have both immediate and long-term implications. This research has provided us with a basic understanding of nutritional management practices that promote feeding behavior patterns related to more consistent nutrient intake, improved rumen health, and less variation in growth rates.

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