# Optimal Feeding Programs with Automated Milking Systems (AMS)

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## Take Home Messages

- Increasing concentrate provision in the AMS will likely not improve milk yield or milk component yield.
- Providing a more energy dense partial mixed ration as a strategy to reduce the amount of concentrate in the AMS may increase dry matter intake without negatively affecting voluntary visits in a guided-traffic flow barn.
- Achieving the targeted amount of consumption of AMS concentrate requires an AMS concentrate allocation above the target quantity. The magnitude of difference between the amount allocated and the target quantity for consumption must increase with increasing AMS concentrate provision.
- High AMS concentrate intake relies on frequent AMS visits, but increases variability in AMS concentrate intake.
- Low AMS concentrate provision strategies may allow for more flexibility for the type of feed used in the AMS.

## Introduction

In addition to rising labour costs, finding skilled labour is a major challenge for dairy producers. One strategy to offset some of the labour costs is to adopt AMS (Rotz, 2003). However, the adoption of AMS requires an initial capital investment and a fundamental shift in management practices. There are over 530 herds with AMS in Canada with the proportion of herds milked with AMS in Manitoba (18.7%) and Alberta (10.8%) being greatest (7.9% overall; Tse et al., 2016). It appears that dairy production in Canada may be following trends observed in other countries and a continued expansion in herds using robotic milking systems could be expected (de Koning, 2010; Haan et al., 2012). It is not clear at what point adoption of AMS will stabilize.

Feeding management in AMS herds differs substantially from conventional free-stall or tie-stall barns. In AMS, the feed is provided as a PMR offered at a feed bunk, with concentrate provided in the AMS. The primary goal of the feeding program in an AMS system is to meet nutrient requirements while encouraging cows to voluntarily enter the AMS thereby promoting frequent milking and high milk flow/h harvested in the AMS, and minimizing labour associated with fetching cows. One of the barriers for the adoption of AMS systems, and for producers that have adopted these systems, is the lack of information regarding feeding strategies that optimize performance and maximize profitability. A lack of guidelines is problematic because most of the recommendations are based on empirical evidence or from single-farm case studies. Few studies have compared the amount of concentrate provided, type of concentrate provided, and energy density of the PMR. Understanding these issues is paramount for the success of dairy operations with AMS.

## ■ Current Feeding Recommendations and Cow Traffic

Feeding management in an AMS relies on a solid understanding of nutrition and behaviour. It is clear that motivation for cows to be milked is not as strong as the motivation to eat (Prescott et al., 1998). A greater motivation for eating relative to milking has been used to rationalize the concept that more concentrate provision equates to more voluntary visits and hence, greater milk yield (Rodenburg, 2011). Other than serving as an attractant, there is no scientific evidence demonstrating that increased AMS concentrate allocation will increase milk yield. Despite the lack of evidence, and in fact, evidence to the contrary, recommendations suggest the use of feeding programs that provide cows with greater milk production more concentrate. Based on a producer survey, feeding high levels of concentrate is common, with 22% of producers providing more than 5 kg/d of concentrate in the AMS (de Jong et al., 2003). Salfer and Endres (2014) reported that the upper limit for concentrate allocation in AMS in their survey was 11.3 kg/cow/d. With this amount, each cow would need to consume over 2.8 kg/milking (assuming 4 milkings/day) equating to 350 to 400 g/minute if milking duration was between 7 and 8 minutes. This high rate of concentrate feeding may outpace the ability of cows to consume concentrate while milking, and likely would result in a significant quantity of concentrate that is not consumed by the cow.

Unfortunately, previous surveys rarely provide an indication for how feeding management differs based on cow traffic flow, and rarely do they consider the PMR when discussing AMS programs. From a diet formulation perspective, the PMR and AMS concentrate must be considered together. However, it appears that the amount of concentrate needed, based on what producers are implementing, to encourage cows to enter the AMS is less for guided and forced traffic barns than free-flow barns (Salfer and Endres, 2014). That said, even in forced-traffic systems, providing small quantities (0 vs. 300 g/milking) results in a marked improvement in voluntary attendance at the AMS (Scott et al., 2014).

## How Much Concentrate Should be Fed in the AMS?

Producers need to decide how much concentrate to feed in the AMS and what the energy density of the PMR should be. The decision on how much concentrate to provide in the AMS will affect AMS concentrate formulation and the delivery of minerals, vitamins, and feed additives. This decision will also affect feed cost and utilization of the starch and protein sources, given that pelleted feeds are commonly used in the AMS (Bently et al., 2013). Pelleting feeds is known to alter the rate and extent of ruminal degradation (Fox et al., 1992). The altered ruminal availability may present a challenge of optimizing dietary formulation when a substantial proportion of the diet is fed as a pellet.

Recommended ranges for concentrate allocation in the AMS vary between 1.8 and 7.7 kg/day depending on the manufacturer. Determining how much to feed in the AMS is generally accomplished by adjusting the amount of concentrate provided in the PMR such that the total daily intake of concentrate is managed. Measuring PMR intake does little to assist with the verification of total dry matter intake (DMI) because these measurements can only be conducted at a pen level, whereas the AMS concentrate is delivered on an individual basis. Bach et al. (2007) reported that increasing the amount of concentrate offered in the AMS decreases DMI of the PMR. Quantitatively, for every 1 kg increase in concentrate consumed in the AMS, cows decrease PMR intake by 1.14 kg without a corresponding change in milk or milk component yield (Bach et al., 2007). Given that the PMR contained 58% concentrate, the reduction in PMR intake and increase in AMS concentrate intake resulted in diets that contained 62.8 and 71.6% concentrate for the low and high concentrate allocation in the AMS, respectively. Such dramatic changes in the forage-to-concentrate ratio pose a challenge for efficient fibre utilization and likely do not optimize feed costs and milk revenue.

We recently conducted two studies to evaluate how the amount of concentrate fed in the AMS rather than the PMR affects voluntary visits to the AMS and milk and milk component yield. In the first study (Hare et al., unpublished; Table 1), 8 cows were used in a cross-over design with 30-day periods. The dietary treatments were iso-caloric but differed in the location of the concentrate provision. In the low AMS treatment, cows were provided 540 g pellet/day to achieve 500 g/day of pellet intake on a DM basis. Cows in the high AMS treatment were provided with 5.2 kg pellet/day to target a 5.0 kg/day intake (DM basis). The PMR for the low AMS treatment contained a greater proportion of concentrate relative to the high AMS treatment such that total dietary concentrate was equal. In that study, we achieved AMS concentrate intakes of 0.5 and 5.0 ± 0.1 kg/day, demonstrating that under low and high AMS allocation, providing an AMS concentrate allocation above that which is targeted can be used to ensure consumption of concentrate equals that formulated. As cows were housed in a guided-traffic flow barn (feed first), we observed that feeding a PMR with a greater energy density coupled with the low provision of concentrate in the AMS resulted in 0.5 more milkings/day, and 3 kg/day greater milk (Figure 1). Interestingly, providing the concentrate in the AMS rather than in the PMR resulted in a disproportionate decrease in PMR intake. For example, for every 1 kg increase in concentrate provided in the AMS, cows consumed 1.33 kg less PMR. Thus, it appears that for cows in guided traffic flow systems, large quantities of concentrate in the AMS are likely not needed.

In a subsequent study, we evaluated whether the energy density of the PMR and amount of concentrate offered in the AMS interact to affect DMI, milk yield and composition, and ruminal fermentation (Menajovsky et al., unpublished; Table 2 and 3). Diets were formulated to contain a PMR with either low energy density (forage:concentrate ratio of 64:36) or high energy density (forage:concentrate ratio of 44:56). Within each PMR, cows were either provided with a low AMS concentrate provision (2 kg/day; DM basis) or high AMS concentrate provision (6 kg/day). The low PMR/high AMS and high AMS/low PMR contained the same dietary energy density but the majority of the concentrate was either provided in the AMS or PMR, respectively. Within a PMR treatment, we were interested in knowing whether providing additional concentrate would improve performance, and whether the energy density of the PMR would influence the magnitude of reduction in PMR intake for each additional kg of AMS concentrate provided. For example, would feeding a low energy PMR reduce the substitution rate when the AMS concentrate was increased?

**Table 1. Effect of providing a low-energy PMR (LE-PMR) coupled with high AMS concentrate allowance (5 kg/day) or a high-energy PMR (HE-PMR) coupled with a low AMS concentrate allowance (0.5 kg/day) on milk yield, milking frequency, and milk composition. Data from K. Hare, K. Schwartzkopf-Genswein, T. DeVries, and G. Penner, unpublished.**

| | Treatment | | | |
|---|---|---|---|---|
| Parameter | LE-PMR | HE-PMR | SEM | *P*-value |
| DMI, kg/d | 23.5 | 25.7 | 1.23 | 0.13 |
| AMS concentrate DMI, kg/d | 5 | 0.5 | 0.1 | <0.001 |
| Partial mixed ration DMI, kg/d | 18.5 | 25.1 | 1.18 | 0.002 |
| Milk yield, kg/d | 33.6 | 36.3 | 2.95 | 0.09 |
| Milking frequency, no./d | 2.82 | 3.27 | 0.19 | 0.09 |
| Milk composition | | | | |
| Fat, % | 3.99 | 4.18 | 0.135 | 0.23 |
| Protein, % | 3.35 | 3.42 | 0.075 | 0.27 |
| Lactose, % | 4.64 | 4.59 | 0.042 | 0.15 |
| Total solids, % | 12.94 | 13.2 | 0.17 | 0.18 |
| MUN, mg/dL | 12.14 | 13.07 | 0.43 | 0.13 |
| Yield, kg/day | | | | |
| Fat | 1.33 | 1.52 | 0.105 | 0.22 |
| Protein | 1.12 | 1.25 | 0.081 | 0.28 |

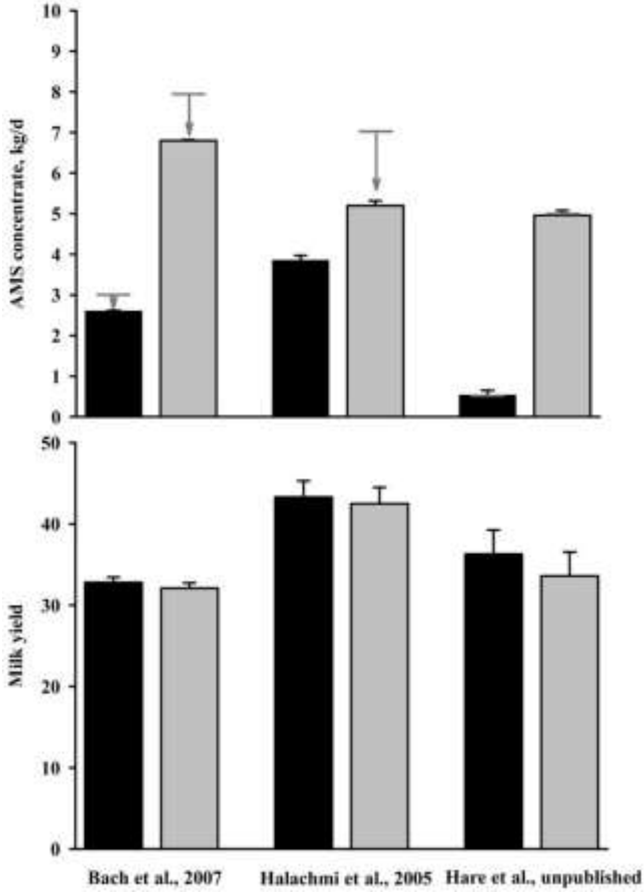


**Figure 1. Targeted and actual concentrate delivery (kg/day) for cows in AMS feeding systems and their subsequent milk yield (kg/day). The black bars indicate low AMS concentrate provision in each study and the grey bars indicate the high AMS concentrate provision. The grey bar with an arrow indicates the target quantity for the AMS concentrate.**

To achieve the desired AMS concentrate intake, the actual amount of concentrate provided exceeded the target intake. For example, to achieve 6 kg of AMS concentrate intake, on average, 6.5 kg of AMS pellet was necessary (DM basis). To achieve 2 kg of AMS pellet intake, offering 2.05 kg of pellet on a DM basis was adequate. Variability in AMS pellet consumption among days, within a treatment, was not different, with actual AMS pellet intake averaging 2.0 and 6.2 for the low and high AMS allocations, respectively. While increasing the amount of pellet offered was an effective strategy to ensure average AMS intake meets the target (a requirement for ration formulation), it should be noted that variability in intake is present (Table 2). For example, cows receiving the high AMS concentrate allocation had a mean minimum intake of 5.08 and a maximum of 7.05 kg/day while the low AMS groups had a minimum and maximum of 1.72 and 2.26 kg/day. The previously mentioned data demonstrate a challenge with the concept of allowing for ‘carry-over’ from one day to another within the AMS concentrate allocation settings. As a final result, cows offered greater quantities of AMS concentrate had greater variability in AMS concentrate intake than cows with the low AMS concentrate allocation (0.22 vs. 0.83 kg/d; $P < 0.01$). Thus, while the average AMS intake for each group was similar to the target, it should be noted that substantial variability occurred among days. Interestingly, changes in AMS intake did not affect variability in PMR intake.

Although total DMI (PMR + AMS) was not affected in the current study (averaging 27 kg/day), cows fed the high AMS allocation consumed 3.5 kg/day less PMR ($P < 0.01$) and 4.2 kg/day more AMS concentrate ($P < 0.01$). Thus, for every 1 kg increase in AMS concentrate cows ate 0.85 kg less PMR, regardless of the PMR energy density. Energy density of the PMR had no effect on PMR intake. In contrast to previous studies, cows fed more concentrate in the AMS in this study had a greater number of voluntary milking events per day (3.7 vs. 3.5; $P = 0.02$ as shown in Table 3), but this only translated into a tendency for greater milk yield (39.2 vs. 38.0 kg/d; $P = 0.10$). The frequent milking events observed in the present study are based on generous milking permissions to ensure dietary treatments can induce a response without milk permission criteria limiting performance. For example, milking permission was granted if 4 h had elapsed since the previous milking or if expected milk yield was greater than 9 kg. The marked impact of the amount of concentrate offered in the AMS on production outcomes, and the minimal impact of PMR energy density suggests that AMS feeding strategies may have a greater influence on DMI than does the PMR.

**Table 2. Effect of feeding a low PMR (forage-to-concentrate ratio of 64:36) or high PMR (forage-to-concentrate ratio of 54:46) in combination with a low (2 kg/d) or high (6 kg/d) AMS concentrate allocation on DMI and ruminal fermentation. Data from S. Menajovsky, C. Walpole, T. DeVries, M. Walpole, K. Schwartzkopft-Genswein, M. Steele, and G. Penner, unpublished.**

| | Low PMR energy density | | High PMR energy density | | | *P* value | | |
|---|---|---|---|---|---|---|---|---|
| Variable | Low AMS | High AMS | Low AMS | High AMS | SEM | PMR | AMS | PMR x AMS |
| DMI, kg/d | 26.7 | 27.5 | 27.2 | 27.7 | 0.95 | 0.18 | 0.46 | 0.68 |
| PMR, kg/d | 24.6 | 21.26 | 25.2 | 21.6 | 0.84 | 0.39 | < 0.01 | 0.85 |
| Min PMR intake, kg/d | 22.7 | 18.0 | 22.5 | 18.2 | 1.54 | 0.94 | < 0.01 | 0.78 |
| Max PMR intake, kg/d | 26.1 | 22.2 | 25.1 | 21.9 | 1.19 | 0.38 | < 0.01 | 0.65 |
| Standard deviation | 1.49 | 1.87 | 1.11 | 1.49 | 0.356 | 0.17 | 0.15 | 0.98 |
| AMS, kg/d | 2.0 | 6.3 | 2.0 | 6.1 | 0.22 | 0.65 | < 0.01 | 0.34 |
| Min AMS intake, kg/d | 1.72 | 5.02 | 1.80 | 5.08 | 0.324 | 0.84 | < 0.01 | 0.98 |
| Max AMS intake, kg/d | 2.26 | 7.05 | 2.23 | 6.83 | 0.216 | 0.56 | < 0.01 | 0.65 |
| Standard deviation | 0.24 | 0.89 | 0.19 | 0.76 | 0.093 | 0.33 | < 0.01 | 0.64 |
| Ruminal pH | | | | | | | | |
| Minimum pH | 5.39 | 5.43 | 5.37 | 5.21 | 0.099 | 0.09 | 0.36 | 0.15 |
| Mean pH | 6.14 | 6.12 | 6.15 | 5.94 | 0.093 | 0.23 | 0.14 | 0.20 |
| Maximum pH | 6.81 | 6.86 | 6.93 | 6.70 | 0.099 | 0.85 | 0.35 | 0.15 |
| Duration, min/d | 209 | 219 | 233 | 516 | 135.1 | 0.13 | 0.18 | 0.21 |
| Area, pH x min/d | 46.0 | 51.0 | 68.3 | 170.2 | 49.40 | 0.07 | 0.17 | 0.22 |

**Table 3. Effect of feeding a low PMR (forage-to-concentrate ratio of 64:36) or high PMR (forage-to-concentrate ratio of 54:46) in combination with a low (2 kg/d) or high (6 kg/d) AMS concentrate allocation on milk and milk component yield. Data from S. Menajovsky, C. Walpole, T. DeVries, M. Walpole, K. Schwartzkopft-Genswein, M. Steele, and G. Penner, unpublished.**

| | Low PMR energy density | | High PMR energy density | | | *P* value | | |
|---|---|---|---|---|---|---|---|---|
| Variable | Low AMS | High AMS | Low AMS | High AMS | SEM | PMR | AMS | PMR x AMS |
| Milking frequency, no./d | 3.56 | 3.74 | 3.52 | 3.67 | 0.144 | 0.46 | 0.02 | 0.75 |
| Yield, kg | | | | | | | | |
| Milk | 37.4 | 38.4 | 38.5 | 40.0 | 2.13 | 0.10 | 0.10 | 0.73 |
| Crude protein | 1.19 | 1.24 | 1.23 | 1.3 | 0.065 | 0.10 | 0.07 | 0.74 |
| Fat | 1.38 | 1.35 | 1.36 | 1.36 | 0.070 | 0.93 | 0.76 | 0.54 |
| Milk composition, % | | | | | | | | |
| Fat | 3.70 | 3.55 | 3.57 | 3.46 | 0.169 | 0.11 | 0.09 | 0.78 |
| Crude protein | 3.19 | 3.24 | 3.21 | 3.25 | 0.055 | 0.47 | 0.04 | 0.97 |
| Lactose | 4.54 | 4.57 | 4.59 | 4.61 | 0.060 | < 0.01 | 0.04 | 0.44 |
| MUN, mg/d | 14.4 | 13.7 | 13.3 | 12.3 | 0.535 | < 0.01 | 0.02 | 0.74 |

Feeding the PMR with a greater energy density tended to increase milk yield (39.2 vs. 37.9 kg/d; $P$ = 0.10) likely because of greater energy supply. Feeding larger quantities of concentrate in the AMS also tended to increase milk yield, as noted above. That said, milk fat concentration tended ($P$ = 0.09) to be reduced with greater AMS concentrate (3.51 vs. 3.64%) such that milk fat yield did not differ among treatments. The reason for the reduction in milk fat concentration is likely related to the potential negative effect of feeding a pelleted concentrate on ruminal fermentation. Despite this, the minimum and maximum ruminal pH tended ($P$ = 0.15) to be lower for cows fed a high energy PMR with the high AMS allocation, but was not different among cows fed the low energy PMR regardless of AMS concentrate allocation. Mean pH tended ($P$ = 0.14) to decrease with increased AMS concentrate provision (6.03 vs. 6.15). Although not statistically different, the duration of time below pH 5.8 was 516 minutes/day for the high PMR with high AMS concentrate allocation and approximately 220 min/day for the other treatments. These data suggest that feeding more concentrate (and consequently increased total energy supply) in the AMS may marginally improve voluntary visits to the AMS and milk yield, although milk fat yield was not improved and ruminal pH may be reduced. When considering iso-caloric diets (Low PMR and high AMS vs. high PMR and low AMS), there appears to be no benefit of adding additional concentrate in the AMS. These findings support the previous conclusion that in guided-traffic flow barns, modest quantities of concentrate can be provided.

## Will Feeding Greater Quantities of Concentrate in the AMS Improve Performance?

While AMS systems are often promoted to allow for precision feeding of dairy cows, there is little data to support this concept. A recent study evaluated herd-level practices for producers with AMS (Lely only) in the United States. Interestingly, the study found a negative relationship between the amount of concentrate provided in the AMS and milk yield (Tremblay et al., 2016). Obviously, this contradicts the concept of precision feeding approaches. The authors of that study discounted the effect of increased concentrate provision on milk yield suggesting that it might be related to poor quality forage and the need for greater concentrate supplementation rather than precision feeding approaches. Nevertheless, these association results suggest that past recommendations promoting greater concentrate feeding strategies in the AMS may not optimize milk yield. Other studies have also shown no beneficial effect of supplemental concentrate on production (Figure 1). For example, studies published to date have found no relationship between voluntary visits and milk production based on differential levels of concentrate offered (Halachmi et al., 2005; Migliorati et al., 2005; Bach et al., 2007). In contrast, we did observe tendencies for increased visits and milk yield when cows were offered a greater quantity of concentrate (Table 3), but to our knowledge, this is the only study demonstrating such a response. While our studies seem contradictory to each other (Table 1 and Table 3) and to previous research, there are possible explanations for the differences. In the study of Menajovsky et al. (unpublished), differences among diets with the same total dietary energy supply did not result in differing performance (High PMR + Low AMS vs. Low PMR + High AMS). Clearly, this suggests that reducing the amount of concentrate provided in the AMS, without changing dietary energy density, does not negatively affect performance and is congruent with the available literature. That said, we also found tendencies for increased milk yield when dietary energy increased (High AMS vs. Low AMS). Differences between our study and previous studies are not clear. In our study we increased the AMS concentrate allocation to ensure cows consumed the targeted amount. This required providing an allocation that exceeded the target consumption quantity. Cows in past studies have not achieved the targeted concentrate consumption (Halachmi et al., 2005; Migliorati et al., 2005; Bach et al., 2007). In addition, cows in our study did not substitute concentrate intake for PMR intake. For example, past studies have reported that for every 1 kg increase in AMS concentrate intake, PMR intake decreased by more than 1 kg (Bach et al., 2007; Hare et al., unpublished). The overcompensation to reduce PMR intake with increased AMS concentrate intake could negate potential improvement for energy intake with increased AMS concentrate provision. The reason for why greater AMS concentrate did not decrease PMR intake in our study (Menajovsky et al., unpublished) to the same extent as other studies is not clear.

As alluded to above, a common challenge with providing a substantial quantity of concentrate in the AMS is that the amount of concentrate provided does not correspond with the amount consumed (Figure 1). For example, Bach et al. (2007) allocated either 3 or 8 kg/day in the AMS but only 2.6 and 6.8 kg/day were consumed, respectively. Halachmi et al. (2005) offered either 7 kg/day or 1.2 kg/visit to cows and reported that cows offered 7 kg/day only consumed 5.2 kg while those offered 1.2 kg/visit consumed 3.85 kg/day. Concentrate intake below that of the formulated diet is a major concern. Unfortunately, no studies to date have reported variability in AMS concentrate consumption across days. Based on our completed, but yet unpublished research, we have observed that the standard deviation in AMS concentrate intake among days is greater when the quantity of concentrate provided in the AMS increases (Table 1). Changing concentrate consumption, even without changes in the PMR consumption, results in unintended dietary changes and may reduce predictability in performance. Moreover, if cows do not consume the amount of concentrate or PMR targeted in the dietary formulation, the point of diet formulation becomes more of an exercise than a tool to enhance efficiency.

There are at least 2 approaches that can be used to solve the above mentioned problem. Firstly, producers and nutritionists can adjust the amount of concentrate eligible for each cow such that the average amount of concentrate provided in the AMS equates to that specified in the dietary formulation (as described above). While this is easy, evaluating concentrate intake is required for each cow or each group of cows within a phase of production, and as mentioned above, predicting PMR intake is necessary. Secondly, limiting the amount of concentrate provided in the AMS could reduce some of the variability because the AMS concentrate would contribute less to the total diet. However, minimizing the use of concentrate provided in the AMS is in contradiction with approaches currently used based on surveys and that recommended by manufacturers.

Automated milking systems also enable producers to impose adaptation programs for cows in early lactation. While increasing the energy density of the diet by increasing concentrate allocation may seem like a plausible option, recent results suggest that such an approach may actually decrease DMI and milk yield (Deiho et al., 2016). It should be cautioned that there are currently no studies known by the authors that have evaluated precision feeding strategies to determine whether such approaches improve milk and milk component yield and profitability. Studies that have evaluated fermentability of the diets following parturition have shown that increasing the rate of grain inclusion (Deiho et al., 2016), or increasing fermentability by including more rapidly fermentable grain sources may not be optimal (Albornoz and Allen, 2016). Deiho et al. (2016) reported that cows adapted to a diet that consisted of a concentrate supplement (45% DM basis) with the remainder of the diet consisting of grass silage, corn silage, and soybean meal. Their results showed that increasing cows gradually (0.25 kg/day increase for the supplement) resulted in greater milk production than when cows were adapted more rapidly (1 kg/day increase for the supplement). Despite the improvement in milk yield, fermentable organic matter intake was less for gradually adapted cows than rapidly adapted cows, suggesting that feeding strategies designed to more closely meet nutrient demand may overwhelm the ability of cows to consume such diets and may not improve performance. It should be noted that increased concentrate feeding is expected to increase feed costs without the corresponding increase in revenue. Although the study of Albornoz and Allen (2016) used a completely different model, they found that replacement of dry rolled corn with high moisture corn reduced DMI and milk yield. Collectively, these studies challenge the current recommendations for AMS feeding management and highlight the need for future research.

## Opportunities with Low AMS Concentrate Feeding

In addition to general feeding management, it is clear that palatability of the concentrate provided in the AMS is important. Madsen et al. (2010) evaluated pellets containing barley, wheat, barley-oat mix, maize, artificially dried grass, or pellets with added lipid with all cows fed a common PMR. They observed that AMS pellet intake and voluntary visits were greatest when the pellets contained the wheat or the barley-oat mix. However, pelleted barley and wheat are expected to have a rapid rate of fermentation in the rumen, and feeding substantial quantities would be expected to increase the risk for low ruminal pH. As an alternative, pellets could be prepared with low-starch alternatives (Miron et al., 2004; Halamachi et al., 2006, 2009). Substituting starch sources with soyhulls did not negatively affect voluntary attendance atthe AMS or milk yield (Halamachi et al., 2006, 2009), and may slightly improve milk fat and reduce milk protein concentrations (Miron et al., 2004).

The opportunities to use simple feeds may increase with low AMS concentrate inclusion strategies. In a recent study, we set out to answer whether or not steam-rolled barley could be used as a substitute for pellets (Menajovsky et al., unpublished; Table 4). In this experiment, 8 cows in late lactation were used. Cows were provided the same basal PMR but were either provided steam-rolled barley or pelleted barley in the AMS to achieve intake of 2.5 kg/day. We observed no effect of AMS concentrate form on productive outcomes, although numerical trends were in support of using pelleted over rolled barley (Table 4). For example, AMS concentrate intake only tended to differ, with consumption of the pellet at 2.50 kg/day compared with 2.45 kg/day for the rolled barley ($P$ = 0.14). Voluntary milking frequency was not affected, with cows milking on average 3.4 times/day ($P$ = 0.27). Milk yield was not affected ($P$ = 0.17) although again, numerically, cows fed pellets had 2.6 kg/day greater milk yield. Milk composition and milk component yield were not affected. Collectively, these data suggest that with low-to-moderate concentrate provision in the AMS, there is more flexibility in feeding strategies for the AMS concentrate. Such strategies may be able to further reduce costs although further research is needed to confirm whether production may be affected.

**Table 4. Effect of feeding pelleted barley or steam-rolled barley in the AMS on AMS concentrate intake, milk yield and milk composition. Data from S. Menajovsky, K. Paddick, and G. Penner, unpublished.**

| | Treatment | | | |
|---|---|---|---|---|
| | Pellet | Steam-rolled | SEM | *P*-value |
| AMS concentrate intake, kg/d | 2.50 | 2.45 | 0.03 | 0.14 |
| Milking frequency, no./d | 3.55 | 3.29 | 0.23 | 0.27 |
| Yield, kg/d | | | | |
| Milk | 37.1 | 34.4 | 3.2 | 0.17 |
| Crude protein | 1.28 | 1.19 | 0.10 | 0.21 |
| Fat | 1.42 | 1.36 | 0.12 | 0.53 |
| Milk composition, % | | | | |
| Crude protein | 3.46 | 3.48 | 0.05 | 0.17 |
| Fat | 3.90 | 3.96 | 0.10 | 0.23 |
| Lactose | 4.61 | 4.55 | 0.06 | 0.25 |
| MUN, mg/dL | 14.1 | 15.0 | 0.67 | 0.21 |

## ■ Conclusions

The use of AMS systems is increasing in Canada and sound feeding management practices are needed to support efficient and cost effective milk production. The data that are available do not support the recommendation that feeding greater quantities of concentrate in the AMS will result in greater milk production, likely because of the overall shift in the diet as cows substitute PMR for concentrate. Moreover, feeding to meet milk production by increasing AMS concentrate provision may not result in the expected benefits, again potentially due to a reduction in PMR intake and the potential shifts in dietary forage-to-concentrate ratio when both the PMR and AMS concentrate are considered. Our data suggest that low-to-moderate AMS concentrate provision will help to minimize variability in AMS concentrate intake and therefore allow cows to consume diets more similar to that formulated. Low-to-moderate AMS concentrate provision may also allow for greater flexibility for the concentrate provided in the AMS. Regardless of the strategy employed, it is essential that producers not only consider the AMS feeding strategy but also the interaction between how AMS feeding approaches may alter PMR consumption.

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# NOTES