Feeding Management in the AMS: Limits to Precision Feeding Approaches

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Introduction

There are two main goals of the nutritional program for cows milked with automated milking systems (AMS). The first, is to stimulate cows to voluntarily enter the AMS by providing a nutritional reward in the AMS. It is clear that removal of the nutritional reward compromises voluntary attendance to the AMS or pre-selection area (Jago et al., 2007; Scott et al., 2014; Shortall et al., 2018) along with milk yield. Moreover, altering the composition of the feed provided in the AMS can further enhance motivation to enter (Madsen et al., 2010; Johnson et al., 2022). The second goal, as with all planned nutritional programs, is to provide a diet that meets nutrient requirements for maintenance and production. However, with AMS systems, dietary components are provided in a partial mixed ration at a common feed bunk and within the AMS. There is a perception that altering the quantity or type of concentrate provided in the AMS allow dietary specification at a cow level. However, there are very few studies testing the ability to use precision feeding approaches.

In one study (Maltz et al., 2013) testing the concept of precision feeding, energy balance was determined weekly by measuring cow BW, milk energy output and DMI. The diet was then reformulated on a weekly basis for each cow to enable delivery of energy exceeding requirements by 5 Mcal/d. When nutrient consumption and nutrient utilization are known, applying the precision feeding approach increased milk yield and milk energy output, avoided extremes in energy balance, and limited changes in BW. While only 1 study and clearly challenging from a practical point of view, it is an excellent example for the application of precision feeding and opportunities that can arise.

Can We Apply Precision Feeding Strategies in AMS Systems?

For precision feeding systems to be effective in AMS systems, concentrate intake in the AMS and consumption of the PMR must be known. Moreover, varying the amount of concentrate must lead to predictable changes in AMS concentrate and PMR intake. The data are clear that increasing the quantity of AMS pellet offered in the AMS increases the day-to-day variability in the delivery of of the AMS pellet (Bach et al., 2007; Bach and Cabrera, 2017) and this response occurs in both guided (Hare et al. 2018; Menajovsky et al. 2018; Paddick et al. 2019) and free-flow traffic systems (Henriksen et al. 2019; Schwanke et al. 2019). Based on the available data from our laboratory (Hare et al. 2018; Menajovsky et al. 2018; Paddick et al. 2019), the coefficient of variation (CV) in AMS pellet delivered averages 13.5%. Using this CV, we can calculate the standard deviation for AMS pellet delivery by multiplying the amount delivered by the CV (Figure 1). A more recent study has reported a CV value of 13.0% (Schwanke et al., 2022). Using this approach, it is clear that as the amount of AMS pellet delivered increases, the day-to-day variation in the amount delivered also increases. In fact, we would expect that the day-to-day variation in the amount of pellet delivered for 96% of the cows would increase from 0.54 kg/day to 2.7 kg/day as the AMS pellet delivered increases from 2 to 10 kg/day. Using a 10 kg/day value and a fixed DMI of 28 kg/day, we would expect that AMS pellet would range between 8.7 and 11.4 kg/day. If we assume that total DMI (AMS pellet + PMR) is relatively constant, the variability in AMS pellet delivery could imply that PMR intake could also vary from 19.4 to 16.7 kg/d. However, the amount of pellet offered in the AMS did not affect PMR intake or variability in PMR intake in previous studies in guided (Hare et al. 2018; Menajovsky et al. 2018; Paddick et al. 2019) or free-flow barns (Henriksen et al. 2019; Schwanke et al. 2019, 2022). Similar to increased day-to-day variation for AMS concentrate offered within a cow, one study has reported that with increasing AMS allocation there is greater variation among cows that should receive the same AMS allocation (Henriksen et al., 2019). The greater variability among cows may create additional challenges as nutritionists work to troubleshoot and improve farm performance indicators.

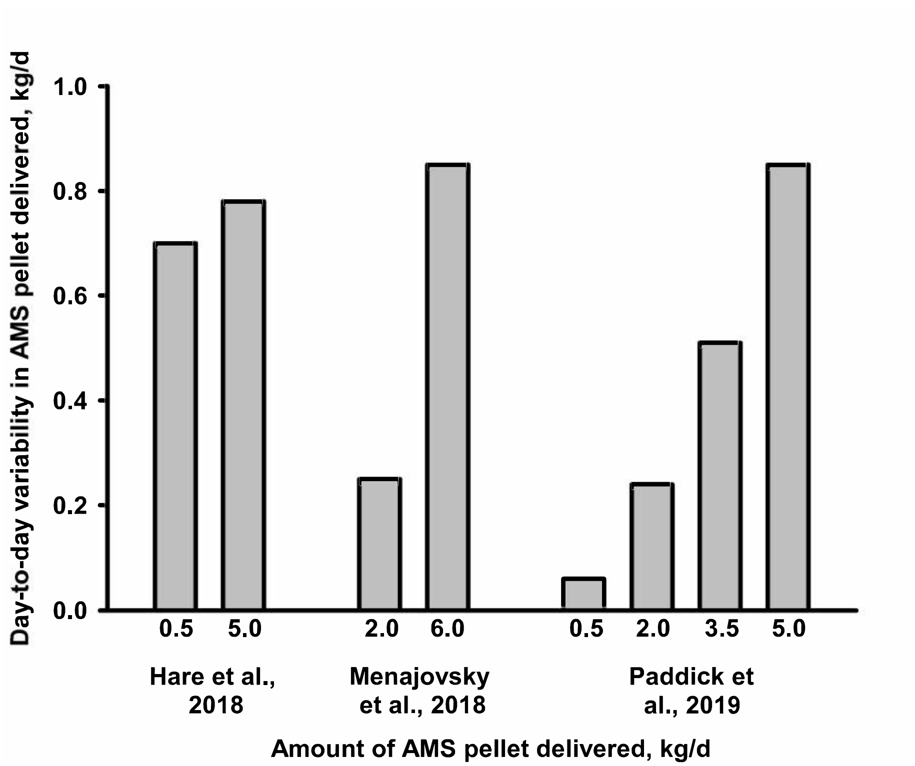

Figure 1. Variability in day-to-day pellet delivered in the AMS based on the amount of pellet offered in the AMS.

In addition to variation in the amount of concentrate delivered on a daily basis, cows offered more concentrate in the AMS also leave more concentrate behind as they exit the AMS (Bach and Cabrera, 2017). Unfortunately, very few AMS have the ability to remove or record the amount of concentrate left as refusals in the manger. In one such study, it was shown that increasing the amount of pellet offered in the AMS resulted in greater quantities of pellet refusals and that refusals were greater for Holstein than Jersey and greater for primiparous than multiparous cows (Henriksen et al. 2019).

Providing more concentrate in the AMS does not necessarily translate to greater DMI (Table 1). For example, Hare et al. (2018) reported that for every 1 kg increase in AMS pellet delivered, there was a corresponding decrease in PMR DMI of 1.58 kg. Bach et al. (2007) reported a 1.14 kg reduction in PMR DMI and Paddick et al. (2019) reported that PMR DMI decreased by 0.97 kg for every one kg DM increase in AMS pellet delivered while. More recently, a substitution of up to 5:1 has been reported for cows in early lactation (Henriksen et al., 2019). A study targeting substation rate has demonstrated that PMR characteristics influence the response (Menajovsky et al., 2018) providing some of the first known data evaluating reasons for substitution. The variable reduction in PMR DMI with increasing AMS concentrate intake may imply that nutrient intake may not be positively affected. In contrast, Schwanke et al. (2019) reported that for every 1 kg increase in AMS pellet intake there was only a 0.63 kg reduction in PMR DMI. In that case, providing more pellet in the AMS resulted in greater total DMI and likely explains the numerical improvement in milk yield observed in that study. The variable and currently unpredictable substitution rate may challenge the ability to formulate diets for individual cows in the same pen given that only the amount or types of concentrate in the AMS can differ. It should be noted that the inability to predict the substitution rate (and hence PMR intake) does not preclude imposing such precision feeding programs; we simply cannot evaluate the individual response or adequately predict the outcome. Clearly, this remains a challenge for nutritionists and producers alike.

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 pellet 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). Few studies have been conducted to test these responses for cows in AMS. In an unpublished study (Haisan et al. unpublished) we tested providing 3 vs. 8 kg of pellet in the AMS with cows provided 8 kg divided into a rapid adaptation (concentrate increased from 3 kg to 8 kg in 5 d) or moderate rate of adaptation group (3 kg to 8 kg in 14 d). Rate of adaptation did not affect responses, but cows offered the high pellet allocation never consumed their target AMS pellet, had lower PMR intake, tended to visit the AMS less frequently, and had lower milk fat yield. In addition, Henriksen et al. (2019) reported that early lactation cows did not produce more milk or energy corrected milk when offered a greater quantity of concentrate in the AMS. Clearly there is a need for future research under AMS conditions to help understand factors that influence ability to deliver a specific diet to individual cows.

Table 1. Effect of concentrate allocation in the AMS on substitution of the concentrate for the PMR. The substitution rate indicates the quantity of PMR intake reduction (DM basis) for every 1 kg increase in AMS concentrate consumed. Studies highlighted in grey are from free flow traffic systems and studies without shading are from guided flow systems.

Study	DIM (Average ± SD)	Cows, parity, and study design	Dietary Strategy	Substitution Ratio (kg DM)
Bach et al., 2007	191 ± 2.13	69 Primiparous and 46 Multiparous, Completely randomized	Isocaloric	1.14
Hare et al., 2018	227 ± 25 123 ± 71	5 Multiparous and 3 Primiparous, Cross-over	Isocaloric	1.58
Henriksen et al., 2018	32-320 14-330	22 primiparous Holstein 19 multiparous Holstein 11 wk study	Static PMR with 2 concentrate	0.58 – 0.92
Henriksen et al., 2018	29-218 17-267	14 primiparous Jersey 28 multiparous Jersey 11 wk study	Static PMR with 2 concentrate	0.69-0.50
Menajovsky et al., 2018	141 ± 13.6	8 Multiparous, Replicated 4 ´ 4 Latin square	LF-PMR HF-PMR	0.89 0.78
Henriksen et al., 2019	Early (5 to 14) Mid (15 to 240) Late (240 to 305)	Continuous lactation study 128 cows (68 Holstein + 60 Jersey)	Static PMR	5 1.1 2.9
Paddick et al., 2019	90.6 ± 9.8	8 Primiparous, Replicated 4 ´ 4 Latin square	Isocaloric	0.97
Schwanke et al., 2019	47.1 ± 15.0	15 Primiparous, Cross-over	Isocaloric	0.62

Does Increasing the AMS Concentrate Allocation Increase Voluntary Attendance and Milk Yield?

One of the most common claims with AMS feeding strategies is that increasing the amount of pellet delivered in the AMS will stimulate voluntary attendance and milk yield. While there are studies partially or fully supporting this claim (Scott et al., 2014; Schwanke et al., 2019), there are also numerous that contradict that claim (Table 2). Variation responses have been attributed to wide range of possible explanations including traffic flow, stage of lactation for the cows in the study, forage quality in the PMR, diet formulation strategy, and composition of the pellet. In addition, it is likely that magnitude of substitution of the AMS concentrate and PMR influence whether voluntary visits and milk yield are affected.

Table 2. Summary of studies evaluating AMS feeding strategies and their response for voluntary visits and milk yield. Studies highlighted in grey are from free flow traffic systems and studies without shading are from guided flow systems.

Study	DIM (Average ± SD)	Cows, parity, and study design	Dietary Strategy	Visit or milk yield response
Halachmi et al., 2005	Not described	453 cows Parity not described	Common PMR 2 amounts of concentrate	Increased yield, no change in visits
Bach et al., 2007	191 ± 2.13	69 Primiparous and 46 Multiparous, Completely randomized	Isocaloric PMR with 3 vs. 8 kg of pellet	No
Tremblay et al., 2016	Not described	Herd-based analysis	Herd-based comparison	Decreased
Henriksen et al., 2018	32-320 14-330	22/14 primiparous Holstein/Jersey 19/28 multiparous Holstein/Jersy 11 wk study	Common PMR with 2 amounts of concentrate	Increased yield, no change in visits
Henriksen et al., 2019	Early (5 to 14) Mid (15 to 240) Late (240 to 305)	Continuous lactation study 128 cows (68 Holstein + 60 Jersey)	Common PMR with 2 amounts of concentrate	No
Schwanke et al., 2019	47.1 ± 15.0	15 Primiparous, Cross-over	Isocaloric PMR with 2 vs. 6 kg pellet	Increased visits, numeric yield
Schwanke et al., 2022	123.9 ± 53.2 DIM	15 multiparous, Cross-over	Common PMR with 2 vs. 6 kg pellet	No
Hare et al., 2018	227 ± 25 123 ± 71	5 Multiparous and 3 Primiparous, Cross-over	Isocaloric with 2 amounts of concentrate	No
Menajovsky et al., 2018	141 ± 13.6	8 Multiparous, Replicated 4 ´ 4 Latin square	2 PMR energy densities and 2 amounts of concentrate	Tendency for visits and yield
Paddick et al., 2019	90.6 ± 9.8	8 Primiparous, Replicated 4 ´ 4 Latin square	Isocaloric with 4 amounts of concentrate	No
Haisen et al., unpublished	0 to 56	20 Holstein cows/treatment Low (3 kg/d), rapidly adapted to 8 kg/d, or gradually adapted to 8 kg/d	Common PMR with 3 vs. 8 kg/d	Less visits, reduced milk fat yield

Is the AMS pellet likely to induce ruminal acidosis?

There is often concern about risk for ruminal acidosis with AMS because a component feeding system is imposed and large quantities of pelleted feed may be programmed to be offered through the AMS. We have recently reported that the PMR formulation, rather than the quantity of pellet in the AMS, has a greater impact on ruminal pH (Menajovsky et al., 2018). It is logical that the PMR had greater impact than the AMS pellet considering it accounted for over 80% of the DMI in that study. Additionally, AMS pellet meal size in that study was constrained to a maximum of 2.5 kg and the amount delivered in the AMS was managed to not exceed 6 kg/cow/day on a DM basis. Based on recent information, cows in commercial operations may be provided up to 11.2 kg (as fed basis) of pellet in the AMS (Salfer and Endres, 2018). With this strategy, large swings in dietary composition can occur based on the expected reduction in PMR intake and increased pellet intake in the AMS. Under such scenarios, we could expect that the dietary physically effective NDF content would be dramatically reduced (and potentially deficient) and that ruminally degradable carbohydrate content would increase thereby creating a diet (PMR + AMS pellet) that could be perceived to be high risk for ruminal acidosis. Currently, there are no data to support or dispute the previous claim.

How important is the type of supplement provided in the AMS?

In addition to general feeding management, palatability of the pellet provided in the AMS is also important. Madsen et al. (2010) evaluated pellets containing barley, wheat, a 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. To reduce fermentability, pellets could be prepared with low-starch alternatives (Miron et al., 2004; Halamachi et al., 2006 and 2009). Substituting starch sources with soyhulls did not negatively affect voluntary attendance at the AMS or milk yield (Halamachi et al., 2006, 2009), and may slightly improve milk fat and reduce milk protein concentrations (Miron et al., 2004).

Producers may also choose to use home-grown feeds in the AMS. In a recent study, we tested whether feeding a pellet was required or if we could deliver steam-flaked barley as an alternative (Johnson et al., 2022) in a feed-first guided-traffic flow barn. In that study, the pellet comprised only barley grain and the same source of barley grain was used for the steam-flaked treatment. In all cases, cows were programmed to have 2.0 kg of the concentrate in the AMS delivered. While PMR (27.0 kg/d DM basis) and AMS concentrate intake (1.99 kg/d DM basis) did not differ among treatments, cows fed the steam-flaked barley tended to have fewer visits (2.99 vs. 2.83) to the AMS, tended to have a longer interval between milking events (488 vs. 542 min), and spent 28 minutes more in the holding area prior to entering the AMS than those fed pelleted barley. While this did not translate into differences in milk yield (average of 44.9 L/d), it may be expected that with a longer-term study, production impacts would be observed. In contrast, Henriksen et al.

(2018) reported greater voluntary visits when a texturized feed (combination of pellet and steam-rolled barley) was provided in comparison to a pellet alone. Regardless, utilization of a pellet as the sole ingredient or part of the mix may limit the ability of producers to use home-grown feeds in the AMS.

Partial Mixed Ration: The Major, but Forgotten Component of the Diet

As mentioned previously, all surveys that have been published to date focus on AMS feeding with little or no information collected to describe PMR composition or intake. The lack of focus on the PMR is likely because only group intakes can be determined and many of the studies have been conducted using retrospective analysis. However, drawing conclusions or making recommendations for feeding management without considering the PMR could lead to erroneous decisions. We recently completed a study where we varied the formulation of the PMR such that we increased the energy density of the PMR by a similar magnitude to that commonly used when increasing the amount of pellet in the AMS (Menajovsky et al., 2018). 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. In several studies we have also noted that formulation of the PMR impacts sorting characteristics of the PMR (Menajovsky et al., 2018;Paddick et al. 2019). In both cases, reducing the energy density of the PMR (greater forage content as a percentage of DM) increased the sorting potential of the PMR. This may lead to cows selecting for dietary components in an undesirable manner (Miller-Cushon and DeVries, 2017).

More recently, survey-based studies have confirmed that factors such as greater bunk space and more frequent PMR push-ups improve milk yield responses for cows in AMS(Matson et al., 2021). These findings supported previous research by Siewert et al. (2018) highlighting that management factors associated with the PMR are important factors that can affect the success of AMS. Future research is needed to understand how PMR feeding management and PMR composition affect the ability to stimulate voluntary visits and to meet nutrient requirements for cows milked with AMS.

Conclusions

While a commonly stated goal of AMS is to enable precision feeding strategies, current data have highlighted a few key challenges that must be addressed. Specifically, ensuring cows are delivered and eat the AMS allocation is one hurdle along with the ability to predict or measure PMR intake and the change in intake that occurs with increasing AMS concentrate allocation. As such, precision feeding cannot solely focus on AMS concentrate feeding, but rather must consider whole farm management and specifically management of the PMR.

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