

What We Have Learned With Feeding in Automatic Milking Systems and Opportunities for Advancements in the Future

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Introduction

Automated milking systems (AMS) have been milking cows for over 30 years, with marked increases in adoption in North America over the last 20 years. Consistently, the top reasons producers have implemented AMS on their farms is to reduce routine milking labor, improve cow performance, and enhance the producer's quality of life (de Jong et al., 2003, Lage et al., 2024). To meet these expectations in both guided and free-flow AMS systems, producers must work closely with their nutritionist to formulate feeding programs that entice cows to voluntarily visit the robot multiple times a day with minimal human intervention.

Where We Have Been

Current formulation strategies

The principal method of enticing cows to the robot is through the feed, with an allocation of one or multiple concentrate feeds in the AMS station and the remaining forages and concentrates at a common feed bunk as a partial mixed ration (PMR). This can present a challenge for a nutritionist, as they may be most comfortable using a total mixed ration (TMR) to cost-effectively meet the nutritional requirements of multiple groups of cows. The use of a PMR/robot feed scheme is often a challenging task that requires considerably more

attention to detail, and in many cases, significant experience to successfully implement.

Generally, nutritionists tend to gravitate toward a few common formulation strategies when balancing rations for AMS herds, with some main differences associated with guided versus free-flow barn designs:

1. For free-flow AMS systems: Nutritionist will formulate the PMR to support 10 to 30 lb of milk below the herd average, typically on a metabolizable energy allowable milk basis. The remaining nutrients come from robot feed with a range of 8 to 14 lb of feed per 100 lb milk, depending on stage of lactation.
2. In guided-flow AMS systems: PMR is formulated 5 to 15 lb below herd average, with a correspondingly lower amount of feed offered in the robot (2 to 10 lb of feed per 100 lb of milk). In this case, the robot feed is often thought of more as a lure for cows coming into the robot from a commitment pen and less of a primary nutrient source.
3. Fixed feeding amount: All cows are fed a similar amount of feed in the robot, regardless of production level. Ramp-up and ramp-down periods are likely utilized in early and late lactation. Feed amount is also

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likely dependent on barn design (guided vs. free-flow traffic) and use of pelleted versus other forms of feed.

4. Only forage is fed at the feed bunk, with most if not all concentrate feeds fed in the AMS or separate feeder. Feed amount offered in the robot may vary widely based on production level of the farm, guided versus free flow traffic, and quality of forage. A variant of this approach is often seen in grazing systems utilizing AMS technology.

Robot feed considerations

A highly palatable robot feed is the primary method of luring the cows to the AMS station. In TMR fed herds, ingredients with poor palatability, such as minerals, some byproduct feeds, and many additives, are well diluted and masked by the ensiled forages and major concentrate feeds. In AMS systems where robot feed is offered separately from the PMR, the palatability of individual feeds provided in the robot should receive much more consideration from the nutritionist. Ruminants have been shown to have preferences and aversions for certain feeds (Miller-Cushon et al., 2014; Spörndly and Asberg, 2006) based on highly integrated signals of post-digestive feedback (Provenza, 1995). A summary of feed palatability adapted from multiple sources is provided in Table 1.

Pelleted feed is the most common form of feed utilized in AMS systems. Much work has been done over the last 25 years to provide guidance on pellet formulation and allocation, and this work has been well summarized by others (Rodenburg, 2017; Penner and DeVries, 2023). Pellet palatability, durability, and composition play a key role in voluntary visits and subsequent milk production. A primary

advantage of pellets is the increased eating rate compared to ground meals. Eating rates for pelleted feeds vary widely, with a typical range of 0.22 to 0.66 lb/min (Spörndly and Asberg, 2006); however, rates of over 1.25 lb/min have been reported (Kertz et al, 1981). The increased cost associated with custom pellet production and reduced ability to utilize on-farm feeds can be a concern for producers utilizing AMS technology. In the field, these concerns can be a significant factor in the choice between free-flow and guided-flow barn designs.

Some producers have also found success feeding ground meals, flaked or rolled feeds, and even high-moisture grains in the robot. In many cases, this can be an economically advantageous decision as the producer can use on-farm feedstuffs and eliminate the additional cost of a custom formulated pellet. A couple key considerations are needed when offering non-pelleted feeds. Ground feed will tend to bridge up in drop tubes and robot feeders. As a remedy, many producers have installed small vibratory devices to aid in feed flow (Figure 1). Additionally, ground feed will typically have a lower eating rate than pellets, with a range of 0.11 to 0.55 lb/min. This can be a major limitation to the amount of ground feed that can be allocated in the robot, especially to fast milking cows, or cows with fewer visits per day. Top producing cows, especially those with fast milk times and/or moderate visits per day will quickly run out of time to eat feed to which they are entitled. This can lead to reductions in peak milk, and if feed speed settings are open, buildup of un-eaten feed in the feed bowls.

Recently, more farms are adopting multiple feed types that allow greater formulation flexibility and decreased cost. A successful combination commonly used is to include a high-energy, home grown (or locally sourced) ground or flaked feed, combined with a custom

protein pellet or bulk commodity pellet, such as corn gluten feed. The increased eating rates associated with pellets allow cows to consistently clean feed bowls, while the highly palatable feed, even if provided in a smaller amount, acts as an effective attractant for the cows to the robot. Ultimately, regardless of feed form used, there are some key aspects that can aid in successful robot feed formulation:

- Provide highly palatable, high-energy feed to entice cows into the robot.
- Keep robot feed bowls clean from buildup and manure.
- Avoid low palatability feeds, minerals, additives, and fats in robot feed.
- If using pellets, make sure they are durable and palatable.
- Multiple robot feed types provide flexibility and likely cost savings.

PMR formulation considerations

Formulation of the PMR should follow many of the recommendations related to TMR formulation. Physical form, palatability, and sort-ability are of perhaps heightened importance in AMS herds. The goal should be to provide a very rumen-friendly diet, promoting high rumination levels. When balancing rations for AMS herds, we are often removing some highly fermentable, non-forage feeds from the mixed ration and providing them in fewer, larger meals at the robot. Interestingly, increased intake of concentrates at the robot alone does not consistently result in lower rumen pH. Instead, reductions in PMR forage: concentrate ratio, through formulation or sorting at the feed bunk, may be a larger risk factor for ruminal acidosis in AMS herds. Menajovsky et al., (2018) found that lower forage: concentrate ratio in the PMR tended to lead to more pronounced dips in rumen pH, while amount of robot feed intake itself did not have an effect on pH measurements. Cows

must be able to consume diets with adequate physically effective fiber to promote good rumination activity.

Where We Are Going

Precision feed management

With the adoption of AMS, farms can collect a large amount of data from their cows that can be useful for ration formulation. In many systems, key nutritionally relevant data, such as milk weights, components, rumination, body weight, and amount of dispensed feed, are collected on a daily basis. However, even with this vast array of individualized data, many nutritionists still condense this information into distinct cattle groups and formulate around herd or pen averages. Users may model a cow that represents the entire milking herd average, individual pen averages, or subsets of cows in a group, such as peak and high cows. In many cases, we are holding back top producers and over-feeding low producers using this approach. Are we missing an opportunity to adopt a more precise and cost-effective feeding strategy? Are we ready to start formulating diets to meet the nutrient requirements of individual animals? Penner and DeVries (2023) addressed this concept and summarized a great deal of the AMS feeding research in the last 20 years. The authors pointed out that precision feed management on an individual basis remains challenging due to the lack of consistent, predictable cow performance in response to changes in PMR and robot feed formulation and allocation.

Estimating intake remains a major challenge to individualized ration balancing

Commercial ration formulation models rely on accurate dry matter intake to calculate nutrient requirements and supply. In AMS herds, intake of the PMR and robot feed(s)

must be considered separately. Intake of PMR can be measured and monitored on a pen-basis on-farm, but there is still a limited ability to estimate individual cow PMR intake. Prediction equations have been adapted for PMR + concentrate feeding systems (Gruber et al., 2004) but have rarely been evaluated for use in North American style diets. There also remains considerable challenges with determining actual intake of feed in the robot box (Paddick et al., 2019). Robot feed is typically reported as the amount dispensed to the cow per day. This has been reported to have a high coefficient of variation at around 13% (Penner and DeVries, 2023) and that number does not account for uneaten feed left in the feed bowl. These challenges remain a major limit in the application of advanced formulation techniques. Intake is a highly integrated behavior and will continue to have a large error associated with its estimation.

A look to the future

With the major advances in computer power, technology, and data analysis, nutritionists should expect to see more novel approaches and the introduction of adaptive predictive algorithms to guide robot feed allocation and ration formulation. These advancements can be independent of the aforementioned intake prediction challenge. For example, the Lely AMS software has the option to automatically adjust and optimize robot feed allocation using an adaptive, feedback-oriented approach. Advances in sensor technology, such as DeLaval's automated body condition scoring system, can help more accurately describe energy budgets through lactation. Major ration balancing programs, such as AMTS and NDS, offer formulation tools to aid in robot feed formulation and allocation, and advances are being made to automatically import data from herd management systems to enhance nutrient requirement calculations. An example in the

AMTS software suite is provided in Figure 2. This formulation tool accounts for change in milk production, components, body condition score, growth, and PMR intake over the entire lactation cycle. Users can more accurately and efficiently target nutrient requirements of multiple types of cows simultaneously through formulation and allocation of a robot feed. A lactation balancing approach such as this may be one step closer to precision feeding in AMS production systems.

Conclusions

Ration balancing on AMS farms can be a challenging and rewarding process. General methods of formulation vary across production systems, barn designs, and producer goals. Much attention has been paid to the form and amount of pellet offered to the cows in the AMS milking station and should continue to be a key focus of nutritionists. However, we must also focus on successful PMR formulation and be open to feeding schemes that may not include a custom formulated pellet. Advances in sensor technology and advanced formulation tools have and will continue to allow nutritionists to take one step closer to precision feed management on an individual cow basis.

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Table 1. Relative palatability of common feeds used in feed formulation for AMS herds.

High Palatability	Low Palatability
Corn gluten feed	Raw soybeans
Brewers grains	Canola meal
Hominy feed	Palm kernel
Molasses	Rumen buffers
Beet pulp	Rumen-protected amino acids
Flaked corn	Corn gluten meal
Moderate Palatability	Very Low Palatability
Soybean meal	Fish byproducts
Roasted soybeans	Tallow
Ground corn	Fats
Barley	Mineral mixes
Wheat middlings	Niacin
Distillers grains	Many feed additives

Data adapted from Spörndly and Asberg, 2006; Miller-Cushon et.al., 2014; and Carroll et al., 2024.



Figure 1. A vibratory apparatus to aid in feed flow of non-pelletized feed in an automated milking system feeder.

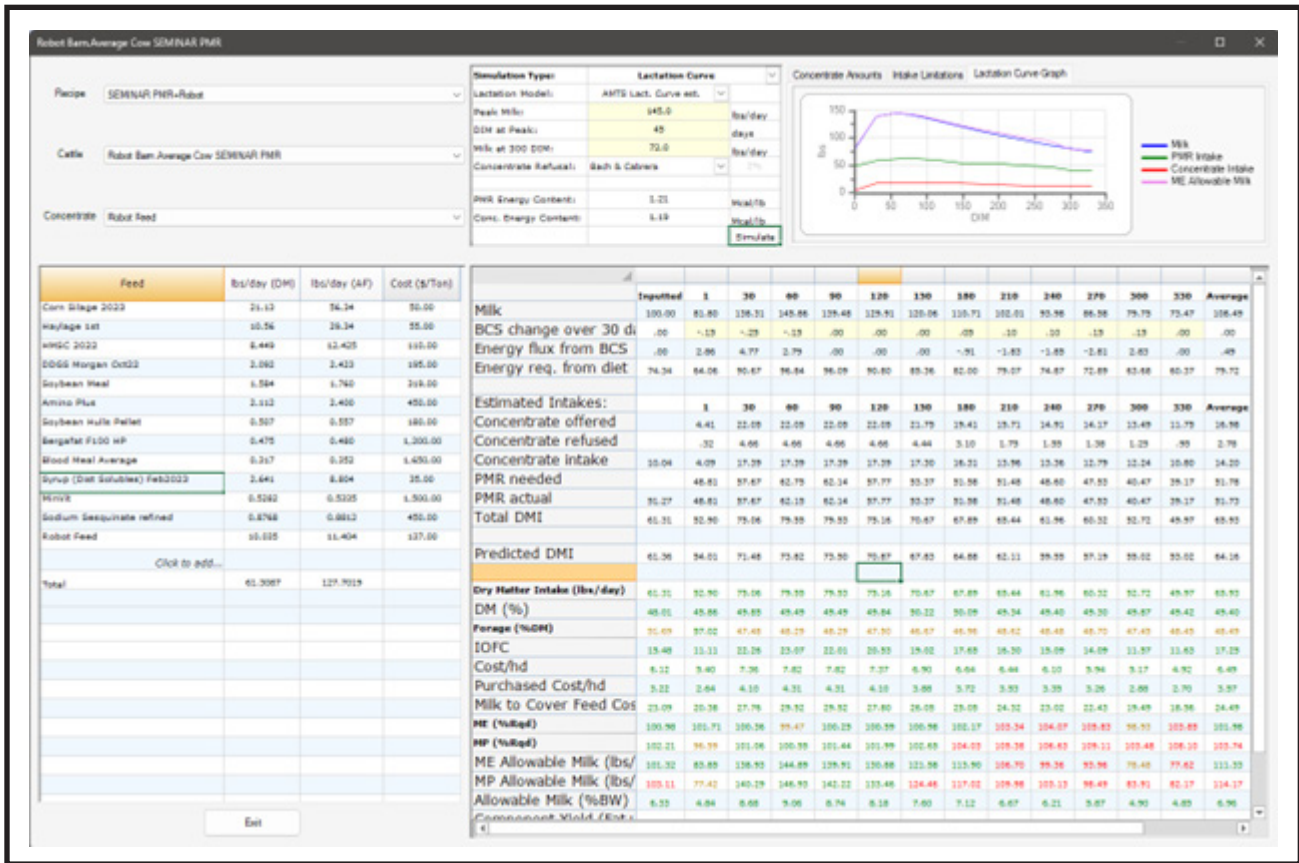


Figure 2. Screenshot of an advanced formulation tool in AMTS.Cattle.Pro for balancing diet in herds utilizing partial mixed ration (PMR) and robot feeding.