# Adapting Current Practices for Automatic Milking Systems: Pros and Cons

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## Take Home Messages

- Milking cows using automatic milking systems (AMS) goes against some basic behavioral drives of cattle: gregarious and crepuscular feeding activity.
- The most commonly recommended way of milking cows with an AMS is using free-traffic and investing in labor to fetch cows during times of the day when the waiting area is less cluttered.
- If possible, try to separate primiparous from multiparous cows in order to maximize the number of daily milkings of primiparous cows.
- Using large feed allowances in the AMS does not seem to be an effective strategy to improve milking frequency. Palatability of the feed may be more important than its actual nutrient composition.
- Delivering PMR twice daily or more and limiting concentrate allowance in the AMS to 3-4 kg/d seems to be the optimal strategy to maximize consistency of milkings.
- A combination of multiple concentrates (both in terms of total amount and proportion) to precisely meet nutrient requirements of each cow in the herd is an effective strategy to improve economic returns in herds with AMS

## Introduction

The first commercial automatic milking system (AMS) was installed in 1992, and today there are more than 12,000 units installed worldwide. However, the installation of AMS in a dairy herd not only implies a change in the milking parlor, it also entails drastic changes in management, feeding, and even the layout of the facilities. Cows in herds equipped with conventional milking parlors are kept under a structured, consistent, and social milking and feeding routine, whereas in herds equipped with AMS cows are milked at different times every day and at different milking intervals. Furthermore, in most cases of herds with conventional milking parlors, cows obtain all their nutrients from a TMR. Conversely, in herds equipped with AMS, a fraction of their nutrients is provided during milking, mainly as a means to attract cows to the milking system, whereas the remaining fraction is supplied in the feed bunk through a partial mixed ration (PMR). Because of these two aspects, the AMS presents both a challenge and an opportunity for feeding cows. The main challenge resides in that milking frequency in the AMS is dependent not only on the nutritional offer (in terms of both composition and amount) at the AMS (Bach et al., 2007) but also on many other aspects including the social structure of the herd (Bach et al., 2006a), the farm layout design (Thune et al., 2002), the type of traffic imposed to cows (Hermans et al., 2003), and the health condition of the cow, especially lameness (Bach et al., 2006b; Borderas et al., 2008). This article summarizes and discusses behavioral, feeding, and economic aspects when milking cows with AMS in an attempt to overcome challenges and seize opportunities, and contains several excerpts from a review article by Bach and Cabrera (2017).

## ■ Behavioral Considerations

In herds equipped with an AMS, cows need to attend the milking system individually, which is an unnatural behavior because dairy cows are gregarious and show marked synchronized behaviors (Benham, 1992). Furthermore, diurnal patterns of feeding and lying behaviors of cattle are quite marked with fewer cows feeding and more cows lying down during the night (DeVries et al., 2011; Jacobs, 2011). This behavior tends to be present in both conventional herds and herds equipped with AMS, which typically results in cluttering of the waiting area early and late in the day in herds with AMS. Forcing the cows to break these inherent social behaviors represents one of the most challenging aspects of AMS. Although, it is not difficult to find herds with an average number of milkings per cow and day of about 2.5 (Wagner-Storch et al., 2003; Bach et al. 2009; Deming et al., 2013), in some instances, individual variation in the number of milkings can be high. Most (67%) cows milked in AMS have milking intervals between 6 to 12 h, with 11% of intervals <6 h and 21.5% surpassing the 12 h (Gygax et al., 2007). However, these figures do not represent voluntary milking visits, as they include some cows that had to be fetched and brought to the AMS because their milking interval was excessively long. Uneven and extended milking frequency has been associated with increased risk of mastitis (Stefanowska et al., 2000) and decreased daily milk yield, especially in multiparous cows (Bach and Busto, 2005). Furthermore, after an omitted or a failed milking, cows stand longer in cubicles and lay less than cows that are successfully milked (Stefanowska et al., 2000), which may potentially increase the risk of lameness, the latter of which may affect the number of visits to the AMS (Bach et al., 2006b).

Another social aspect to consider with AMS is the social structure of herd or pen. Cows tend to form a hierarchy among individuals to prioritize access to limiting resources. As a result, dominant cows spend less time in the waiting area than subordinate cows (Melin et al., 2005), and thus milking frequency of subordinate cows is typically lower than that of dominant cows (Halachmi, 2009). Furthermore, experiencing negative social interactions at the waiting area of the AMS may reduce the motivation of cows to revisit the AMS a second time (Jacobs et al., 2012), and thus, subordinate cows are likely to progressively visit the AMS less frequently.

Ironically, all these negative aspects stemming from social behavior of cows milked in AMS could present a great opportunity of AMS because if overcome, it would allow dairy herds to assign different milking frequencies to different cows consistently day after day.

To minimize the variation in milking frequency in cows milked using AMS due to social dominance, gregarious behavior, and crepuscular behavior, it has been proposed to entice cows using feed in the AMS (as discussed later) or imposing cows to what is known as forced or guided traffic, which mainly consists of forcing the cows to visit the AMS before they can reach the feed bunk, or less commonly the resting area. However, both strategies attempt to address a social or behavioral challenge by providing a solution based directly (when feeding in the AMS) or indirectly (when using guided traffic) on nutrition.

Forced or guided traffic consists of controlling access of cows to precious resources (i.e., water, feed, resting) before reaching the AMS. Imposing a forced or guided traffic to cows milked in an AMS improves milking frequency and reduces variation in milking intervals, but it has been reported to also reduce the time that cows have access to the feed bunk (Melin et al., 2007) and it ultimately compromises feed intake (Bach et al., 2009). On the other hand, the negative repercussions of social hierarchy seem to be more relevant under guided- than under free-traffic conditions (Rodenburg, 2012), and guided traffic may compromise the resting times of cows (Thune et al., 2002). It is likely that both the reduction of time access to the feed bunk and lying time with guided traffic situations are the main reasons for the reported decrease in milk production compared with free traffic conditions in a multivariate analysis of field data conducted by Tremblay et al. (2016). Thus, today, the most effective way of milking cows in an AMS is using free-traffic and investing in labor to fetch cows during times of the day when the waiting area is less cluttered.

Lastly, the number of daily visits per cow to the AMS is also dependent on stage of lactation and parity. For instance, primiparous cows visit the AMS more often than multiparous cows (Bach et al., 2006a), and the number of visits to an AMS seems to reach a maximum plateau around 100 DIM (Clark et al., 2014). Addressing the different behavior of primiparous compared with multiparous cows is relatively easy if the herd has several AMS; in that situation the solution consists of grouping all primiparous cows in a single AMS (Figure 1). A more challenging pitfall is the stage of lactation, because cows that are advanced in the lactation curve not only produce less milk and show less visits to the AMS, but they will also be less attracted by the offer of feed in the AMS, which makes it difficult to maintain an adequate milking interval without human intervention.

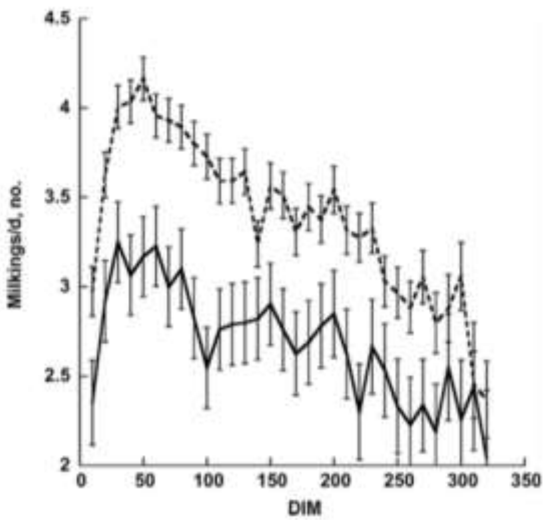


**Figure 1. Number of daily milkings of primiparous cows as affected by stage of lactation and grouping strategy. Solid line represents number of daily milkings of primiparous cows housed with multiparous cows; dashed lines represent the number of daily milkings of primiparous cows housed alone (Adapted from Bach et al., 2006a).**

## ■ Feeding Considerations

Concentrate feeding at the AMS is commonly recommended as a means of attracting cows to milking and minimize fetching because cows, if given a choice, will choose feeding over milking (Prescott et al., 1998). A common feeding strategy on many dairy farms equipped with AMS is to start with a low level of concentrates at calving, followed by a linear increase during the first weeks of lactation (Kokkonen et al., 2004). Around lactation peak, from week 3 until weeks 10–14, concentrate supply increases as milk yield increases, and after that, concentrate allowance is lowered following the decline in milk yield (André et al., 2010). But, in addition to the progressive decline in milk yield and subsequent appetite, a challenge to overcome is the relatively large variation in the number and frequency of visits to the AMS. These deviations in feed intake between days may carry some negative consequences beyond those associated with inconsistent milking frequency. Variation in nutrient supply, per se, has been shown to negatively affect milk production. For example, Sova et al. (2014) described a negative relationship between the coefficient of variation of NEl content of a TMR and milk production across 22 surveyed dairy herds. On the other hand, it has been shown that cows subjected to 4 and 6 h feeding periods were able to learn each routine and adapt the timing of their movement to and from the feed bunk to match the duration of the feeding period (Livshin et al., 1995). Thus, if feed is provided during milking, in a conventional herd, cows could anticipate they would be fed in the parlor and thus they could adapt their eating pattern to accommodate that meal. In an AMS, however, the fluctuations in milking and eating patterns make it difficult for the cow to maintain a constant intake of PMR and concentrate and keep the proportion of forage to concentrate in the total diet constant.

Cows do not typically consume all their concentrate allowance in the AMS, especially when concentrate offer is high (i.e., > 4 kg/d) and the amount of unconsumed concentrate seems to increase as concentrate allowance increases (Bach and Cabrera, 2017). In addition, large concentrate allowances in the AMS are typically coupled with feeding a PMR with a low nutrient density, and thus if cows do not consume all concentrate allocated in the AMS their nutrient supply is compromised, which could hamper milk production and profits. In fact, Tremblay et al. (2016) found a negative association between concentrate allowance in the AMS and milk yield. Interestingly, Halachmi et al. (2005) compared milking frequency when limiting concentrate delivery at each milking to 1.2 kg vs. a maximum allowance of 7 kg/d, and reported no difference in the number of voluntary visits to the AMS. Similarly, Bach et al. (2007) compared a concentrate allowance of 3 to 8 kg/d and reported no differences in the number of daily visits to the AMS. Thus, using large amounts of feed to improve milking frequency does not seem to be an effective strategy, as evidenced by some authors successfully milking cows on pasture with as little as 300 g of concentrate per visit (Scott et al. 2014) or even without supplementing concentrate in an AMS (Jago et al., 2007).

Another reason for limiting concentrate supply in the AMS is the time constraint that cows face when attempting to consume their entire concentrate allowance. Cows typically consume TMR and PMR at a rate ranging between 50-150 g/min (Bach et al., 2007; Bach et al., 2009; DeVries et al., 2009) and pellet concentrates between 250 and 400 g/min (Kertz et al., 1981). Considering an average time spent in the AMS per milking of about 7 min (Castro et al., 2012), cows could consume at most an average of about 2.8 kg of concentrate per milking. Because in most occasions the average number of visits to an AMS is < 3/d (Wagner-Storch et al., 2003; Bach et al., 2009; Deming et al., 2013) a cow could consume a theoretical maximum average of 8.4 kg of concentrate per day. Therefore, using concentrate allowances > 8 kg/d are likely to fail, and to take advantage of precision feeding approaches (as discussed later) in AMS, the amount of concentrate allowance should be kept low (i.e., < 4 kg/d). However, an interesting approach to increase the motivation to visit the AMS may consist of offering the PMR more frequently. Deming et al. (2013) reported that cows fed a PMR twice daily visited the AMS about 2 h closer to each feed delivery time than cows fed once a day, which would indicate that delivering PMR is a strong motivating stimulus for cows to visit the AMS (under free traffic conditions).

Taking into account the nutritional composition of the concentrate offered in the AMS is also important. For example, feeding concentrates with a high content of starch may not only affect the appetite and feeding behavior of the cows, but also the rate and extent of NDF digestibility and rumen pH, which may in turn alter milk composition and production, as well as increase the risk of lameness (Oba and Wertz-Lutz, 2010) – all of which may decrease the frequency of visits to the AMS (Bach et al., 2006b; Borderas et al., 2008). Regarding milk production and composition, Miron et al. (2004) reported that feeding concentrates high in starch content increased milk protein content and feeding concentrates rich in digestible fibre (e.g., soybean hulls) increased milk fat content. On the other hand, Halachmi et al. (2006) compared 2 concentrates (25 vs 49% starch) and reported similar numbers of voluntary milkings (3.31 vs. 3.39 visits/cow.d), milk yield, and milk components. The difference in these 2 studies was mainly that Miron et al. (2004) used 8 kg/d of concentrate allowance, whereas Halachmi et al. (2006) limited concentrate allowance to 3 kg/d. Thus, it can be inferred that if concentrate allowance is kept low (i.e., 3 kg/d) nutrient composition of the concentrate at the AMS has minor repercussions on yield, milk composition, and number of visits to the AMS. Therefore, more than the provision of nutrients, it seems that offering palatable feed is what drives cows to visit the AMS. Madsen et al. (2010) concluded that cows prefer concentrates based on a mixture of barley and oat, and that cows prefer wheat over corn or barley. Regarding the physical form of the concentrate offered at the AMS, a pellet form is preferred over mash or meal form (Spörndly and Åsberg, 2006). Also, the hardness of the pellet should be high as crumbles and fines diminish the intake of dairy cows (Rodenburg et al., 2004).

Lastly, the supply of minerals and vitamins with AMS should also be considered. Typically, these components are thought to have poor acceptability by cows and are commonly excluded from the concentrate used in AMS and are only supplied through the PMR. However, as milk yield increases and concentrate allowance at the AMS is also increased, the amount of minerals that the cow will consume might be limited because the increase in DMI is mainly driven by an increase in concentrate intake rather than PMR intake. For instance, Bach et al. (2007) evaluated milk and intake responses in cows milked using an AMS and offered either 3 or 8 kg of concentrate/d, and calculated that for every unit of increase in concentrate intake at the AMS, there was a concomitant reduction in PMR consumption equivalent to 1.15 units.

## ■ Social and Economic Considerations

Many producers install AMS because they either have difficulties hiring labour or want to minimize external labour on the farm. However, AMS systems reduce the need for milkers but do not necessarily reduce the labour needed, for instance, fetching cows. The number of cows needed to be fetched into the AMS bears important economic costs both from a labour and a loss of production stand point, and it typically voids the expected profits (i.e., reduced labor and increased milk yield) behind the decision of installing an AMS. A Canadian survey reported that 4 to 25% of the cows had to be fetched to the AMS for milking (Rodenburg and House, 2007). Further, a study conducted in the Netherlands (Steeneveld et al., 2012) concluded that herds with AMS have greater capital costs per unit of milk produced over conventional herds, but both types of herds have similar labour costs (thus, the apparent labour savings associated with AMS were not realized in practice).

Nevertheless, maximum return on the investment of an AMS is attained, in theory, when cows adapt their own daily routine and traffic around the system, resulting in full utilization of the AMS with little or no human intervention. This can be achieved, as discussed above, by addressing behavioral and nutritional aspects. But, AMS systems offer an interesting opportunity to feed cows using a precision feeding approach. Precision feeding has the potential to improve productivity, and most importantly, efficiency of production by meeting each individual cow's nutrient requirements accurately. The AMS technology bears the appealing opportunity to overcome the inefficiencies linked to TMR or PMR feeding, where cows are fed to an average production and some cows receive either less or more nutrients than what they need. Furthermore, cows need to consume the right amount of a balanced-nutrient meal. In other words, because intake is variable between and within cows, depending on stage of lactation, BW, etc..., a "balanced" mouthful of TMR for one cow may be an "imbalanced" mouthful for another cow in the same pen. As a result, both energy and protein balance progressively differ at different proportions as milk production deviates from the one the ration was originally balanced for (Figure 2).

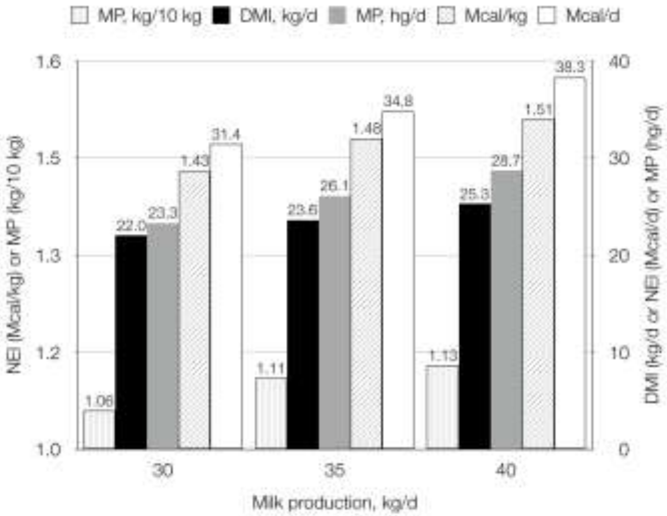


**Figure 2. Dry matter intake, metabolizable protein (MP) and net energy (NEl) for different milk yields according to NRC (2001). The proportion of MP and NEl in the total diet is not constant and increases at different rates for MP and NEl as milk yield increases (Adapted from Bach and Cabrera, 2017).**

Implementing precision feeding strategies with AMS (and in other situations such as parlor feeding) bears the challenge of estimating (and monitoring) the expected milk response obtained for any given concentrate supplementation. The efficiency at which the concentrate will be used to produce milk is a driver for profit, and thus, if milk yield response is below expectations, supplementing concentrates may not be a profitable decision, especially if milk prices are low and feed costs are high. Most AMS systems are equipped with one single bin for delivering concentrate to cows. Under this situation, as it would occur with TMRs, the AMS offers a feed with a fixed chemical and nutritional composition with the only variable in the system being the amount of concentrate that each cow is entitled to consume on a daily basis. Thus, depending on the nutrient density of the PMR, the stage of lactation and milk production, cows receive different amounts of feed. But, as described above, the composition of the pellet or mash offered is the same regardless of the amount of milk produced, and thus nutrient supply progressively becomes imbalanced as milk yield deviates from the one used to formulate the feed supplement. An interesting opportunity to maximize returns from an AMS is through using a combination of feeds (e.g., an energy source and a protein source) fed to cows at different proportions and quantities according to milk yield, BW, stage of lactation, and even, with some milking systems, milk components.

Lastly, milk harvested per cow and milking is related to the time elapsed since the previous milking – a relationship which is more or less linear until 16 h and constant thereafter (Delamaire and Guinard-Flament, 2006). Tremblay et al. (2016) showed that as the number of cows per AMS increases, the number of milkings is reduced (i.e., milking interval increases), and the time that cows occupy the AMS is increased. Despite the fact that both milking frequency and time spent in the AMS per milking increase milk production, these 2 aspects rarely increase simultaneously (Tremblay et al., 2016). It is commonly recommended that the number of animals per AMS should be around 60-70 cows. But, results from the literature suggest that to attain maximum milk harvesting capacity of an AMS, the goal should be maximizing milk yield per cow instead of increasing the number of cows. Typically, decreasing the number of cows per AMS decreases the time cows spend waiting in the pre-milking area, particularly for low socially ranked or less experienced cows (Halachmi, 2009). Moreover, small reductions in cow numbers are commonly compensated for by increases in milk production from the remaining cows because the number of milkings increases and time spent milking decreases (Tremblay et al., 2016).

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