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Robotic milking: Feeding strategies and economic returns[1]

Alex Bach*†[2] and Victor Cabrera‡
*Institució Catalana de Recerca i Estudis Avançats (ICREA), Barcelona 08010, Spain
†Department of Ruminant Production, IRTA (Institut de Recerca i Tecnologia Agroalimentàries), Torre Marimon, Caldes de Montbui, 08140, Barcelona, Spain
‡Department of Dairy Science, University of Wisconsin, Madison 53706

ABSTRACT

Cows in herds equipped with conventional milking parlors follow a structured, consistent, and social milking and feeding routine. Furthermore, in most cases cows in conventional herds receive all their nutrients from a total mixed ration, whereas in herds equipped with robotic or automatic milking systems (AMS) a fraction of their nutrients is provided during milking, mainly as a means to attract cows to the milking system. In this regards, AMS present both a challenge and an opportunity for feeding cows. The main challenge resides in maintaining a minimum and relatively constant milking frequency in AMS. However, milking frequency is dependent on many factors, including the social structure of the herd, the farm layout design, the type of traffic imposed to cows, the type of flooring, the health status of the cow (especially lameness, but also mastitis, metritis, among others), the stage of lactation, the parity, and the type of ration fed at the feed bunk and the concentrate offered in the AMS. Uneven milk frequency has been associated with milk losses and increased risk of mastitis, but most importantly it is a lost opportunity for milking the cow and generating profit. On the other hand, the opportunity from AMS resides in the possibility of milking more frequently and feeding cows more precisely or more closely to their nutrient needs on an individual basis, potentially resulting in a more profitable production system. But, feeding cows in the parlor or AMS has many challenges. On one side, feeding starchy, highly palatable ingredients in large amounts may upset rumen fermentation or alter feeding behavior after milking, whereas feeding high-fiber concentrates may compromise total energy intake and limit milking performance. Nevertheless, AMS (and some milking parlors, especially rotary ones) offer the possibility of feeding the cows to their estimated individual nutrient needs by combining different feeds on real time with the aim of maximizing profits rather than milk yield. This approach requires that not only the amount of feed offered to each cow but also the composition of the feed vary according to the different nutrient needs of the cows. This review discusses the opportunities and pitfalls of milking and feeding cows in an AMS and summarizes different feeding strategies to maximize profits by managing the nutrition of the cows individually.

Key words: automated milking system, feeding strategies, optimization, precision, robotic milking

INTRODUCTION

Since the first commercial systems appeared in 1992, automatic milking systems (**AMS**) have been installed at an increasing rate. From that time until 2011, AMS were installed on >10,000 farms worldwide (de Koning, 2011). Cows in herds equipped with conventional milking parlors are kept under a structured, consistent, and social milking and feeding routine. Furthermore, in most cases, cows obtain all their nutrients from a TMR; however, in herds equipped with robotic or 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 this, the AMS presents both a challenge and an opportunity for feeding cows. The main challenge resides in the fact milking frequency in the AMS is dependent not only on the nutritional offer (in terms of both composition and amount) at the AMS (Halachmi et al., 2005; Bach et al., 2007a) but also on many other aspects, including the social structure of the herd (Bach et al., 2006; Melin et al., 2006), the farm layout design (Thune et al., 2002; Halachmi, 2004), the type of traffic imposed to cows (Hermans et al., 2003), and the health condition of the cow, especially lameness (Bach et al., 2007b; Borderas et al., 2008). Uneven milking frequency has been associated with increased risk of mastitis

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[2]Corresponding author: alex.bach@icrea.cat

(Stefanowska et al., 2000) and decreased daily milk yield, especially in multiparous cows (Bach and Busto, 2005). Furthermore, after an omitted or 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, in turn, may affect the number of visits to the AMS (Spörndly and Wredle 2002; Bach et al., 2007b). On the other hand, opportunity from AMS resides in the possibility of milking more frequently, assigning different milking frequencies to different cows, and feeding cows more precisely or closely to their nutrient needs, potentially resulting in improved feed efficiency and economic returns rendering a more profitable production system than when using a single TMR. This article summarizes and discusses the literature regarding feeding cows in an AMS in an attempt to overcome the challenges and capture the opportunities of an AMS by considering behavioral, nutritional, and economic aspects.

SOCIAL, BEHAVIORAL, AND TRAFFIC CONSIDERATIONS

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. Under typical situations, most (67%) cows milked in AMS have milking intervals between 6 to 12 h, with 11% of intervals <6 h and 21.5% surpassing 12 h (Gygax et al., 2007). A Canadian survey reported that 4 to 25% of the cows had to be fetched to the AMS for milking (Rodenburg and House, 2007). The number of cows that need to bed fetched into the AMS bears important economic costs both from a labor and a loss of production stand points, and it typically voids the expected profits (i.e., reduced labor and increased milk yield) behind the decision of installing an AMS. A relatively recent 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 labor costs (thus, the apparent labor savings associated with AMS did not take place in practice). Nevertheless, maximizing milking frequency and minimizing the need to fetch cows to an AMS are pivotal aspects to make AMS profitable. However, one of the largest challenges with AMS is to obtain a consistent milking frequency of cows throughout time. 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); although, in some instances, individual variation in the number of milkings can be high. This aspect makes the design of a feeding program difficult, because if, for instance, milking frequency decreases, the amount of concentrate that the cow will be able to consume in the AMS will also decrease. To minimize variation in milking frequency, it has been proposed to attract cows to the AMS using palatable feeds or impose cows to what is known as forced or guided traffic, which consists on forcing the cows to visit the AMS before they can reach the feed bunk. However, Halachmi et al. (2005) compared milking frequency when limiting concentrate delivery at each milking to 1.2 kg versus a maximum allowance of 7 kg/d and reported no differences in the number of voluntary visits to the AMS. Similarly, Bach et al. (2007a) compared a concentrate allowance of 3 or 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 an effective strategy, and some authors have been able to effectively milk 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).

With AMS, cows can either have free access to milking (free traffic) or being forced or guided to access another resource (i.e., water, feed, resting) before reaching the AMS. Regardless of the type of traffic system, diurnal patterns of feeding and lying behaviors persist in AMS, with fewer cows feeding and more cows lying down during the night (DeVries et al., 2011; Jacobs, 2011; Munksgaard et al., 2011). 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 reduce the time that cows have access to the feed bunk (Hermans et al., 2003; Woolford et al., 2004; Melin et al., 2007) and compromise feed intake (Bach et al., 2009). In fact, a recent multivariate analysis of field data (Tremblay et al., 2016) reported that forced traffic was associated with decreased milk production compared with free traffic conditions. Therefore, the ideal situation would be free traffic and nutritional approaches that would reduce variation in the number of visits to the AMS. However, because the number of daily visits per cow to the AMS is also dependent on many other factors, other considerations, such as stage of lactation or group composition, should be considered. For instance, primiparous cows visit the AMS more often than multiparous cows (Bach et al., 2006), and the number of visits to an AMS seems to reach a maximum plateau around 100 DIM (Clark et al., 2014). In an AMS, cows need to attend the feeder and the milking system individually, which is an unnatural behavior because dairy cows are gregarious and show marked synchronized behaviors (Benham, 1982).