Feeding Strategies and Economic Returns in Robotic Milking Systems

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With exception of the economic case study, this paper is an excerpt from Bach and Cabrera (2017).

**Introduction**

**Rationale**

Cows in conventional milking parlors:
- Kept structured, consistent, and social milking and feeding routine
- Obtain all their nutrients from a TMR

Cows in automatic milking systems (AMS):
- Obtain a fraction of their nutrients during milking and through a partial mixed ration (PMR)
- Their milking frequency and time of milking vary across time

**AMS**

**Challenges**: milking frequency not only dependent on concentrates at the AMS, but
- the social structure of the herd,
- the farm layout design,
- the type of traffic imposed to cows,
- the type of flooring,
- the health condition of the cow

**Opportunities**
- manipulate the number of cows per AMS
- milking more frequently
- feeding more precisely

**Behavioral Considerations**

**Crucial**
- maximizing milking frequency and minimizing fetching

**Challenge**
- consistent milking frequency throughout time

**Overcome challenges and capture opportunities**

- Behavioral Considerations
- Nutritional Considerations
- Economic Considerations

Bach & Cabrera, 2017

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Behavioral Considerations

Common ➜ ~2.5 average milkings
Wagner-Storch et al., 2003; Bach et al. 2009; Derring et al., 2013

Variation ➜ can be high

Change frequency of milkings ➜ change in the AMS DMI

Behavioral Considerations

↑AMS visits & ↓variability

Palatable feed

Forced (guided) traffic

Forced traffic reduces PMR intake Bach et al., 2009

Forced traffic decreases milk yield Tremblay et al., 2016

Feed Bunk

Feeding behavior does not visits Bach et al., 2007

300 g/visit attracts grazing cows Scott et al., 2014
Behavioral Considerations

Cows are gregarious ➞ Sync behaviors
Benham, 1992

**AMS force individualism ➞ unnatural**

Dominant cows ➞ less time in waiting area
Halachmi, 2009

<table>
<thead>
<tr>
<th>Time spent in the waiting area, min</th>
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<tbody>
<tr>
<td>0</td>
</tr>
<tr>
<td>Dominant</td>
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<tr>
<td>Subordinate</td>
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Nutritional Considerations

AMS concentrate feeding ➞ main attraction to milking
Prescott et al., 1998

**Cows do not consume all concentrate ➞ > 4 kg/d**

AMS concentrate presentation ➞ better pellet than mash
Halachmi et al., 2006

Nutritional Considerations

AMS time/milking ➞ 7 min
Castro et al., 2012

A cow can consume ➞ < 2.8 kg/milking

Theoretically, a cow can consume ➞ < 8.4 kg/3 milkings per d

To avoid variation ➞ better an allowance of 4 kg/d

Flavoring agents ➞ in general no positive effects
Harper et al., 2016

Minerals and vitamins ➞ normally not provided in AMS ➞ becomes an issue when cows rely more in concentrate

Nutritional Considerations

Inconsistent nutrient supply ➞ affects negatively milk yield
MacBeth et al., 2013

> AMS concentrate allowance ➞ < density PMR

Milk yield decreased ➞ NEL variability in 22 herds
Sova et al., 2014

Milk yield decreased ➞ > AMS concentrate allowance
Tremblay et al., 2016

Precision feeding opportunity

TMR or PMR inefficiencies ➞ improved by AMS supplementation
Leonardi and Armentano, 2007

Cows sort

Composition changes
Kronkoff and Heinrichs, 2003

Intake is variable ➞ between cows and within cows

Balanced diet for a cow ➞ unbalanced diet for another cow
**Economic considerations**

Maximizing milk production per AMS proposed as goal for economic efficiency

Sonck & Donkers, 1995

More cows per AMS -> milkings reduced and time AMS used by cows increased

Tremblay et al., 2016

Maximizing milking frequency -> should be the main goal of AMS

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**Precision feeding opportunity**

Decrease imbalance ➞ AMS concentrate

Most AMS only have single bin to deliver concentrates

Imbalance ➞ will remain and progressively increase

How to overcome it ➞ provide a custom-made cow-specific concentrate

On the basis of milk, BW, state, components, etc.

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**Data from a North Catalanian farm**

**AMS 1**
- 64 cows
  - Primiparous (PMC)
  - AMS concentrate
    - 3.84 kg/d
    - [0.98 - 7.42]
  - Milk yield
    - 32.6 kg/d
    - [15.6 - 46.0]

**AMS 2**
- 70 cows
  - Multiparous (MPC)
  - AMS concentrate
    - 4.70 kg/d
    - [1.60 - 9.04]
  - Milk yield
    - 41.3 kg/d
    - [17.3 - 59.6]

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**Dataset**

**AMS concentrate**
- 2.07 Mcal of NEI/kg
- 22.4% CP
- €274/MT

**PMR feed**
- 1.62 Mcal of NEI/kg
- 15.6% CP
- €92.5/MT

**Cow consumption**
- DMI: NRC (2001)
  - NEI & CP: milk yield

**Income over feed cost** (IOFC)
- Milk price at €0.32/kg

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**Economic analyses**

Maximizing milk production per AMS proposed as goal for economic efficiency

Sonck & Donkers, 1995

More cows per AMS -> milkings reduced and time AMS used by cows increased

Tremblay et al., 2016

Maximizing milking frequency -> should be the main goal of AMS
1 - Change number of cows per AMS

70 to 65 MPC

Total milk harvested per AMS remained constant
Tremblay et al., 2016

2,892 kg milk AMS/d
- 70 MPC = 41.3 kg/cow.d
- 65 MPC = 44.5 kg/cow.d

Extra 3.2 kg/cow.d
- Required ~2.5 Mcal NEI/cow.d

Additional PMR
- Maintaining AMS concentrate allowance equal

65 MPC increased IOFC
- Less feed for maintenance

1 - Change number of cows per AMS

70 to 65 MPC

↑€2,453/AMS.yr
↑€6.72/cow.d

IOFC
- 70 MPC = €720.8/AMS.d
- 65 MPC = €727.5/AMS.d

2 - Limit amount of AMS concentrate

PMC
- 3.74 to 2 kg/cow.d
- €7.9 to €8.1/cow.d
- ↑€6,710/AMS.yr

MPC
- 4.70 to 3 kg/cow.d
- €10.0 to €10.3/cow.d
- ↑€6,748/AMS.yr

2 - Limit amount of AMS concentrate

3 - Precision feeding

AMS concentrate
- normally same density of nutrients for all animals
- ideally, it could be formulated individually

AMS concentrate
- 2 kg/cow.d PMC
- 3 kg/cow.d MPC

Less allowance of AMS concentrate
- minimize variability in concentrate consumption
- reducing feed costs
- lower cost per unit of nutrient with PMR

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Tremblay et al., 2016

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Conclusions economic considerations

Reducing number of animals per AMS could improve IOFC if production does not decline

Restricting concentrate allowance to kg/cow.d improves IOFC and minimizes variation nutrient intake

Precision feeding to meet cow-specific nutrient requirements may greatly improve IOFC

Keeping concentrate allowance low help to reduce digestion problems, feed costs, concentrate refusals, and milking regularity

Economic considerations

From an economic efficiency perspective, the main target is maximizing milk production per AMS (Sonck and Donkers, 1995). Milk harvested per cow and milking is related to the time elapsed since previous milking, with this relationship being more or less linear until 16 h and becomes 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 increases. 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 to 70 cows. This number stems from the time required to clean the AMS, unit attachment failures, periods of nonattendance, and technical maintenance, which leaves around 20 to 22 h/d of available time for milking (Halachmi, 2004; Lyons et al., 2014), and because a single AMS has a limited capacity of around 8 milkings/h (Ketelaar- de Lauwere et al., 2000), leading to a theoretical total number of cows that can be milked 2.5 times every day between 60 and 70 cows. 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); likewise, small reductions in cow numbers are commonly compensated by increases in milk production from the remaining cows because the number of milkings increase and time spent milking decreases, especially when cows are selected for high milking speed (Tremblay et al., 2016).

Case study

Data from a farm in North Catalonia (Spain) with 2 groups of cows milked in 2 AMS were used as a case study to evaluate the economic value of changing the number of cows per AMS under some general assumptions. One AMS was milking 64 primiparous cows that consumed 3.84 kg/d (min=0.98, max=7.42) of concentrate in the AMS and produced 32.6 kg of milk/d (min=15.6 max=46.0), whereas the other AMS milked 70 multiparous cows that consumed 4.70 kg/d (min=1.60, max=9.04) of concentrate in the AMS and produced 41.3 kg of milk/d (min=17.3, max=59.6).

1. Change number of cows per AMS. It could be safely assumed that the overall milk harvested per AMS would remain constant when the number of cows decreases and therefore milk production per cow would increase together with the cow’s energy requirements (Tremblay et al., 2016). Furthermore, decreasing the number of cows per AMS could decrease the time cows spend waiting in the pre-milking area, particularly for low socially ranked or less experienced cows (Halachmi, 2009). Then, for an impartial analysis, cows were randomly selected out of the AMS system and the remaining cows’ production was proportionally adjusted to reach the original AMS milk yield. For example, the 70 multiparous cows produced originally 2,892 kg of milk/d or 41.3 kg/cow.d. Then, after randomly removing 5 cows, milk production of the remaining cows was adjusted to increase to 44.5 kg/cow.d to make up the 2,892 kg of milk/d in the AMS. This difference of 3.2 kg of milk/cow.d required between additional 1.95 and 2.50 Mcal of NEI/cow.d,
which was compensated by additional consumption of PMR. Decreasing the number of animals from 70 to 65 and maintaining AMS production resulted in an income over feed cost (IOFC) of €727.5/AMS.d, compared with the original IOFC of €720.8/AMS.d; a difference of €6.72/AMS.d or €2,453/AMS.yr in favor of the 65 multiparous cows. A similar exercise with 60 multiparous cows resulted in a difference of €20.2/AMS.d or 7,366/AMS.yr in favor of milking 60 multiparous cows compared with the original 70 multiparous cows. With respect to the primiparous cows, a reduction from the original 64 cows that produced a total of 2,088 kg milk/AMS.d or 32.6 kg/cow.d to 60 cows, which then were assumed to produce 34.8 kg/cow.d, (additional 2.17 kg/cow.d) requiring between additional 1.41 and 1.61 Mcal of NEI/cow.d. Once again, 60 primiparous cows, instead of 64, resulted in an improved IOFC of €3.74/AMS.d (€524.6 vs. the original €520.8) or €1,365/AMS.yr. Therefore, the goal with an AMS would be to attain maximum milk harvesting capacity by maximizing milk yield per cow instead of increasing the number of cows.

1. Scale the intake of AMS concentrate at the AMS. Limit the amount of AMS concentrate. To support the maximum possible milk yield, however, the economic return from the feed needs to be accounted for. Feed represents 50 to 70% of all costs in dairy production (Bozic et al., 2012); therefore, increasing feed efficiency has a major effect on profitability. Furthermore, improving feed efficiency has positive consequences for the environment (Reed et al., 2015). Data from the Catalan farm described above with 2 groups of cows milked in 2 AMS were used to illustrate potential improvements in IOFC by implementing precision feeding approaches. The concentrate offered in the 2 AMS was the same and contained 2.07 Mcal of NEI/kg and 22.4% CP and had a cost of 274 €/MT (DM basis); whereas the PMR (which was also the same for both AMS) contained 1.62 Mcal of NEI/kg and 15.6% CP and had a cost of 92.5 €/MT. Then, the NRC (2001) model was used to estimate cow-specific DMI of PMR (given that concentrate intake was known) and consumption of NEI (Mcal) and CP (kg) based on individual milk yield and DMI was estimated. Lastly, individual and group IOFC were calculated using local current milk prices (€0.32/kg). The hypothesis was that a herd with an AMS could improve IOFC by providing a minimum amount of concentrate in the AMS and promoting maximum consumption of PMR. With this strategy, IOFC would be maximized by 1) minimizing variation in concentrate consumption, and 2) reducing feed costs due to the lower cost per unit of nutrient in the PMR compared with the concentrate. Assuming that the DM consumption per cow would adjust to remain iso-energetic at different target concentrate allowances at the AMS, PMR consumption was corrected to complete the energy required (i.e., cows would consume more PMR if a lower concentrate allowance was offered at the AMS). Target levels of concentrate varied proportionally to the known individual cow level of consumption (i.e., relative distribution of consumption of AMS concentrate remained among herd mates). For example, using an average concentrate allowance at the AMS for primiparous cows of 2 kg/cow.d (min=0.51, max=3.86) would result in an IOFC improvement from €7.85 to €8.14/cow.d, a gain of €0.29/cow.d or €6,710 for 64 primiparous cows in 1 yr. For multiparous cows, using an average concentrate allowance at the AMS of 3 kg/cow.d (min=1.02, max=5.78) would generate an IOFC improvement from €10.03 to €10.30/cow.d, a gain of €0.27/cow.d or €6,748 for 70 multiparous cows in 1 yr. Overall, in the whole farm, targeting the consumption of AMS concentrate to 52% for primiparous (2 kg/cow.d) and to 64% for multiparous (3 kg/cow.d) of what was actually being fed, would improve overall IOFC by €100.4/cow.yr or 13,449/herd.yr. Feed cost decreased as the amount of AMS concentrate consumed decreases because of the cost differential per unit of nutrient in the PMR. For instance, the cost for each energy unit is €0.06/Mcal of NEI for the AMS versus €0.13/Mcal of NEI for the PMR concentrate. On the other hand, in a scenario that would maintain the consumption of energy at the same level (iso-energetic intake), CP consumption would barely be affected: it would decrease from 3.44 kg/cow.d (min=1.66, max=4.48) to 3.40 (min=1.64, max=4.40) for primiparous and from 4.25 kg/cow.d (min=1.78, max=5.24) to 4.19 (min=1.74, max=5.17) for multiparous cows, which likely would not affect production performance. However, a more precise protein feeding would likely decrease N excretion.

3. Precision feeding. These economic returns could even be greater if a dynamic feeding approach was implemented, that is, combining 2 concentrates (energy and protein) at the AMS in different amounts and proportions at the AMS. Precision feeding provides, in theory, only the exact amount of nutrient required because the supplement changes in composition as needed, whereas conventional supplementation, because of a fixed profile of nutrients, provides some of those in excess without additional benefits and incurring in economic inefficiencies.
Following the previous case study, we assumed that cow productivity would remain constant and economic gains would result for nutrient savings: precision feeding provides only the exact amount of nutrient required, whereas conventional supplementation, because of a fixed profile of nutrients, provides some of those in excess without additional benefits. As previously, we calculated, according to NRC (2001), the cow-specific DMI, and NEI and CP requirements and then targeted the level of supplementation as before (2 and 3 kg in average for primiparous and multiparous cows, respectively). Next, we calculated individual and overall IOFC by either using conventional supplementation or precision supplementation. We found that using precision feeding would improve IOFC (€/cow.d) by 1.30 (min=1.02, min=1.56) and 1.56 (min=0.62, max=1.83) for primiparous and multiparous cows, respectively. Overall, in the whole farm, precision feeding would have a potential of improving IOFC by 192€/d or 70,080€/yr on the illustrated farm of 134 cows with 2 AMS.

Conclusions economic considerations

**Reducing number of animals per AMS could improve IOFC if production does not decline**

**Precision feeding to meet cow-specific nutrient requirements may greatly improve IOFC**

**Restricting concentrate allowance to kg/cow.d** 3 (PMC) and 4 (MPC) improves IOFC and minimizes variation nutrient intake

**Keeping concentrate allowance low** help to reduce digestion problems, feed costs, concentrate refusals, and milking regularity

References


