Differences between primiparous and multiparous cows in voluntary milking frequency in an automatic milking system

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ABSTRACT

A total of four feeding experiments were designed to study the response of dairy cows to two different milking systems: a conventional auto-tandem milking parlor, and an automatic milking system (AMS, milking robot). The results were analyzed independent of the different feeding factors, because they were the same for all animals in both milking systems. The results, separately analyzed for first-lactating and multiparous cows, can be summarized as follows:

- First-lactating cows visited the automatic milking system more often (2.6 up to 3.5 times per day) than multiparous cows (2.5 up to 2.9 times per day), but the increased milking frequency did not positively affect milk yield.
- Although multiparous cows had a substantially higher FCM-yield (29.4 kg/day on average) than heifers (26.0 kg/day on average), they only went to the automatic milking system on average 2.6 times per day.
- The amount of time needed for first-lactating and multiparous cows to get used to the automatic milking system did not show a difference. They learned to visit the automatic milking system voluntarily after one week.
- During the course of lactation, differences in milking frequency were detected between first-lactating and multiparous cows. The milking frequency of multiparous cows was observed to be almost constant during the entire lactation, on average 2.5 times per day. However, first-lactating cows increase the milking frequency from the beginning (2.3 times per day) to the end of lactation (2.9 times per day), when the lactation is divided into three periods of 100 days each. The automatic milking system affects uncorrected milk yield positively. The increase of milk yield amounted up to 5.7% for primiparous cows in contrast to the multiparous cows with an increase of milk yield up to 3.1%.
- The FCM-yield for primiparous cows (25.8 kg/day and 26.0 kg/day) and for multiparous cows (30.3 kg/day and 29.4 kg/day) were lower than the uncorrected milk yield, because the milk fat content was significantly lower for cows milked in the AMS (4.03% in the AMS compared to 4.36% in the milking parlor).

Key words: Milk yield, Milking Frequency, Automatic milking system, First-lactating cows, Multiparous cows

RIASSUNTO

DIFFERENZE NELLA FREQUENZA DI MUNGITURA VOLONTARIA FRA VACCHE PRIMIPARE E PLURI-PARE IN UN SISTEMA AUTOMATICO DI MUNGITURA

Un totale di quattro prove di alimentazione sono state impostate per studiare la risposta delle vacche da latte a due diversi sistemi di mungitura: una sala di mungitura auto-tandem convenzionale, ed un sistema di mungitura automatico (robot di mungitura, AMS). I risultati sono stati analizzati indipendentemente dai diversi fattori alimentari, in quanto erano gli
stessi per tutti gli animali in entrambi i sistemi di mungitura. I risultati, analizzati separatamente per le vacche primipare e pluripare, possono essere riassunti come segue.

Le vacche primipare hanno visitato il sistema di mungitura automatico più spesso (dalle 2,6 alle 3,5 al giorno) delle vacche pluripare (dalle 2,5 alle 2,9 volte al giorno), ma l’aumentata frequenza di mungitura non ha influenzato positivamente la quantità di latte prodotto. Nonostante le vacche pluripare abbiano avuto un FCM significativamente più alto (29,4 Kg/giorno in media rispetto alle manze 26,0 Kg/giorno in media), esse sono andate al sistema di mungitura automatico in media solamente 2,6 volte al giorno. La quantità di tempo necessario per apprendere l’utilizzo del sistema automatico di mungitura non ha mostrato differenza per le primipare e le pluripare. Esse hanno imparato a visitare volontariamente il sistema automatico di mungitura dopo una settimana. Durante il periodo di lattazione sono state individuate differenze nella frequenza di mungitura fra le vacche primipare e pluripare. La frequenza di mungitura delle vacche pluripare è stata osservata essere praticamente costante durante l’intera lattazione, in media 2,5 volte al giorno. Diversamente, le vacche primipare hanno incrementato la frequenza di mungitura dall’inizio (2,3 volte al giorno) alla fine della lattazione (2,9 volte al giorno), considerata la lattazione suddivisa in tre periodi da 100 giorni ciascuno. Il sistema di mungitura automatico influenza positivamente la quantità di latte prodotto non corretto per il grasso. L’incremento nella quantità di latte è risultato del 5,7% per le vacche primipare, in contrasto con le vacche pluripare che hanno avuto un incremento nella quantità di latte del 3,1%. Queste differenze non sono tuttavia risultate significative. La quantità di FCM per le vacche primipare (25,8 Kg/giorno e 26,0 Kg/giorno) e per le vacche pluripare (30,3 Kg/giorno e 29,4 Kg/giorno) era più bassa della quantità di latte non corretto per il grasso, in quanto il contenuto di grasso nel latte era significativamente più basso per le vacche munte nell’AMS (4,03% nell’AMS rispetto al 4,36% nella sala di mungitura). Nessuna differenza è stata invece rilevata nella quantità di FCM e nel contenuto di grasso nel latte fra le vacche primipare e pluripare.

Parole chiave: Quantità di latte, Frequenza di mungitura, Sistema automatico di mungitura, Vacche primipare, Vacche pluripare.

Introduction

Technical innovations in animal production aim to contribute to improvements in the health and performance of animals and to facilitate labor. Accordingly, one of the major goals of milk production has been to improve the milking process. In the last 10 years “automatic milking systems” or “milking robots” were developed and are almost ready to be introduced into practice. The major benefit of those systems is saving of manual labor, but a contributory factor has been presumed to be an increase of milk yield due to a higher milking frequency, because cows are allowed to visit such milking systems up to four times and more per day. However, an essential prerequisite is that those systems be accepted by the animals. In this context, it is of interest whether there are differences between first-lactating and multiparous cows. To deal with this subject, four feeding trials were designed applying a two-factorial approach: one factor of the experiments was the different milking system; the other factor was concerned with investigations on feeding, e.g. different quality or composition of silage and concentrates. All these feeding factors had no influence on the investigations between primiparous and multiparous cows in the different milking systems, because in each milking system the number of animals in the different treatments was the same. The aim of these investigations was to study the advantage of such an automatic milking system in terms of acceptance, milking frequency and milk yield in comparison with an auto-tandem milking parlor with two milking times per day.

Material and methods

The four feeding trials involved in this study were conducted with dairy cows of the German Holstein Breed during the years 1999-2001 (FAL in Braunschweig, Germany). The two-factorial design of these experiments enabled an analysis of the data obtained on effects of the milking process. In each experiment the same number of animals were milked in a conventional milking parlor two times per day (5.30 h and 15.30 h) or had free access to the automatic milking system up to four times per day with a minimum interval of six hours.
Acceptance of an AMS by dairy cows

Housing

The cow housing in which the experiments were conducted comprises two equal barns with separate feeding and lying areas for 32 or 26 animals; the number of animals in the AMS-barn was reduced because of the AMS-installation. Roughage and water were provided ad libitum in computerized weight-troughs. The consumption was recorded individually by an electronic registration system. Concentrates were allotted to the cows by concentrate feeders according to milk yield or were given in the total mixed ration (TMR) during the experiment.

Milking Systems

A conventional milking system served the auto-tandem milking parlor, model 2 x 5, produced by Lemmer-Fullwood. Automatic milking was performed with a single unit AMS, named “MERLIN” produced by Lemmer-Fullwood as well. The unit is installed on the head of one barn with sufficient waiting area in front. The cows had free access to the robot over 23 hours; after 15 milking processes or 6 hours the automatic milking system was cleaned and one hour at night (between 2.00 h and 3.00 h) was left for general cleaning and collection of milk.

Experimental

Each feeding trial was carried out with more than 50 cows. The exact numbers involved in the four experiments, their stage of lactation and their distribution to the milking treatments are given in Table 1. As the milking behavior of first-lactating cows was considered to be different to that of multiparous cows, their data were separately collected and subjected to analysis. The experiments comprised different stages and periods of lactation.

Feeding varied in the four experiments; details are given in Table 2.

Table 1. Number of cows (first lactating-cows in brackets), days of lactation and duration of experiments

| Experiment | Milking parlor | AMS | Days of lactation at beginning | Duration of experiments (days) |
|------------|----------------|-----|-------------------------------|------------------------------|
| I          | 26 (7)         | 26 (7) | 70                           | 100                          |
| II         | 27 (8)         | 26 (8) | 70                           | 110                          |
| III        | 32 (5)         | 28 (6) | 10                           | 140                          |
| IV         | 32 (2)         | 28 (5) | 160                          | 80                           |

Table 2. Feeding variability in the four experiments

| Experiment | I                    | II                  | III                  | IV                  |
|------------|----------------------|---------------------|----------------------|---------------------|
| Roughage   | Wilted grass silage with different quality ad libitum | Wilted grass silage ad libitum | Grass-/Maize-silage or grass-/alfalfa-silage ad libitum | Grass silage in a total mixed ration (TMR) with stepwise reduction of roughage portion |
| Concentrate| Supply according to the recommendations of the GfE (2001) | Supply according to the recommendations of the GfE (2001), different levels of trace element cobalt | Supply according to the recommendations of the GfE (2001) | Supply according to the recommendations of the GfE (2001), Increasing of concentrate portion in the TMR during the experiment |
In the trials I, II and III the cows received wilted grass silage ad libitum in both milking systems and concentrates up to 4 kg per day during the milking process in the AMS; the remaining portion of concentrate were given by feeding automats. The cows which were milked conventionally received the total amount of concentrate only by feeding automats. In the automatic milking system, the concentrate was given in portions realized by a computer system, considering average milking frequency during the last ten days. Maximum and minimum consumption were set at 50% or 20% of the daily amount, corresponding to two or four daily visits in the automatic milking system.

In Experiment IV, the cows were fed a total mixed ration ad libitum, based on wilted grass silage and concentrates. Additionally, concentrates up to 2 kg were given during the milking process in the AMS and in the conventional milking parlor by feeding automats.

In Experiments I and II total consumption of concentrate was related to FCM-yield (fat corrected milk) as follows:

- 20-25 kg FCM/day: 4.0 kg
- 25-30 kg FCM/day: 7.0 kg
- > 30 kg FCM/day: 10.0 kg

### Table 3. Milk yield in kg/day (mean value ± SD)

| Experiment | First-lactating cows | Multiparous cows | First-lactating cows | Multiparous cows |
|------------|----------------------|------------------|----------------------|------------------|
|            |                      |                  |                      |                  |
| I          | 22.2 ± 5.4 (7)       | 24.9 ± 5.2 (19)  | 22.8 ± 3.8 (7)       | 26.7 ± 4.2 (19)  |
| II         | 25.3 ± 3.3 (8)       | 29.0 ± 5.5 (19)  | 26.4 ± 3.9 (8)       | 28.8 ± 5.8 (18)  |
| III        | 27.3 ± 2.8 (5)       | 33.3 ± 5.3 (27)  | 29.9 ± 5.3 (6)       | 35.9 ± 6.3 (22)  |
| IV         | 23.6 ± 2.0 (2)       | 27.7 ± 7.4 (30)  | 25.2 ± 4.3 (5)       | 27.6 ± 7.3 (23)  |
| X          | 24.6 ± 3.4 (22)      | 29.0 ± 5.9 (95)  | 26.0 ± 4.3 (26)      | 29.9 ± 5.9 (82)  |

( ) = n.

### Table 4. Fat corrected milk (FCM)-yield in kg/day (mean value ± SD)

| Experiment | First-lactating cows | Multiparous cows | First-lactating cows | Multiparous cows |
|------------|----------------------|------------------|----------------------|------------------|
|            |                      |                  |                      |                  |
| I          | 23.4 ± 4.2 (7)       | 26.7 ± 5.0 (19)  | 22.5 ± 3.4 (7)       | 27.7 ± 4.0 (19)  |
| II         | 25.8 ± 2.7 (8)       | 31.4 ± 5.4 (19)  | 27.9 ± 3.4 (8)       | 32.8 ± 6.1 (18)  |
| III        | 29.1 ± 2.3 (5)       | 34.1 ± 4.6 (27)  | 27.8 ± 3.3 (6)       | 33.0 ± 6.1 (22)  |
| IV         | 25.8 ± 2.3 (2)       | 28.7 ± 7.3 (30)  | 25.6 ± 4.0 (5)       | 27.5 ± 6.7 (23)  |
| X          | 25.8 ± 2.9 (22)      | 30.3 ± 5.6 (95)  | 26.0 ± 3.5 (26)      | 29.4 ± 5.7 (82)  |

( ) = n.

### Table 5. Average milk fat content in % (mean value ± SD)

|                     | Conventional milking parlor | Automatic milking system |
|---------------------|-----------------------------|--------------------------|
|                     | First-lactating cows | Multiparous cows | First-lactating cows | Multiparous cows |
|                     |                       |                       |                       |                  |
| I                   | 4.37a ± 0.50           | 4.35a ± 0.59           | 4.08a ± 0.49          | 3.98a ± 0.48     |

a < b; P < 0.05
In Experiment III energy supply from roughage was assumed to meet the requirements for 10 kg FCM and for each kg FCM exceeding amount additionally 0.5 kg concentrate.

**Statistical Analysis**

The data were subjected to statistical analysis applying SAS® (Statistical Analysis System), version 6.12, for WINDOWS®. Differences between primiparous and multiparous cows were proved by the t-test procedure. The results are presented as means ± standard derivation. Different superscripts symbolize statistically significant differences at least on a confidence level of p < 0.05.

**Results**

**Milk yield**

Milk yield as dependent on the factors analyzed, i.e., milking system and first-lactating/multiparous cows, are summarized as average of groups in Table 3.

The results indicate that the automatic milking system affects uncorrected milk yield positively. Apart from Experiment I, this effect was more pronounced in first-lactating cows. In Experiment III the maximum increase of milk yield amounted up to 9.5% in contrast to the multiparous cows with an increase of milk yield up to 7.8%. But all these differences proved not to be significant. The uncorrected milk yield of primiparous cows was 26.0 kg/day on average in the AMS compared to 24.6 kg/day in the milking parlor. The milk yield of multiparous cows was similar for both milking systems (29.9 kg/day in the AMS and 29.0 kg/day in the conventional milking system). The FCM-yield was lower for cows milked automatically in most of experiments (Table 4), because the milk fat content was significantly lower for cows milked in the AMS (Table 5).

This effect was higher for multiparous cows with an average FCM-yield of 29.4 kg/day in the AMS compared to 30.3 kg/day in the milking parlor, whereas the FCM-yield of first-lactating cows was 26.0 kg/day, when they were milked automatically, and 25.8 kg/day for those cows milked in the parlor. Only in Experiment II the FCM-yield of first-lactating cows increased up to 8.1% (27.9 kg/day to 25.8 kg/day), in Experiment I the FCM-yield of multiparous cows increased up to 3.7% (27.7 kg/day to 26.7 kg/day), when they were milked automatically.

**Influences of lactation rank on the milking frequency in the automatic milking system**

The acceptance of the automatic milking sys-
Table 7. Modified milking frequency (mean value ± SD) depending on lactation rank

| Experiment | I       | II      | III     | IV      |
|------------|---------|---------|---------|---------|
| First-lactating cows | Multi-parous cows | First-lactating cows | Multi-parous cows | First-lactating cows | Multi-parous cows |
| (n.=7) | (n.=19) | (n.=8) | (n.=7) | (n.=13) | (n.=5) |
| Milking frequency | 3.5 ± 0.4 | 2.9 ± 0.6 | 2.8 ± 0.2 | 2.7 ± 0.3 | 2.6 ± 0.4 | 2.5 ± 0.5 | 2.7 ± 0.5 | 2.6 ± 0.5 |

a < b; P < 0.05

Table 8. Average duration (mean value ± SD) up to a voluntary visit of the automatic milking system (Exp. III)

|                      | First-lactating | Multiparous |
|----------------------|-----------------|-------------|
|                      | (n.=6)          | (n.=22)     |
| Duration up to voluntary milking days | 6.7 ± 3.9       | 7.3 ± 7.9   |

Figure 1. Milking frequency (mean ± SD) during the course of lactation (averages from Exp.I-IV)
The system of first-lactating and multiparous cows is shown in Table 6.

These results indicate that the milking frequency was higher for first-lactating (2.9 milking per day on average) than for multiparous cows (2.6 milking per day on average). But this effect was significant only in Experiment I (p < 0.05). The milking frequency for first-lactating cows was 3.5 milking per day in contrast to a milking frequency of only 2.9 milking per day for multiparous cows in the automatic milking system. One of the reasons for this more pronounced effect might be that only cows without any previous experience with the automatic milking system were involved in this experiment, whereas in Experiments II – IV some of the multiparous cows were already accustomed to this milking system.

To eliminate this fact, those cows which were already milked in previous lactations with AMS were omitted. The corresponding results (Table 7) demonstrate no severe differences to those obtained in Table 6, leading to the conclusion that multiparous cows respond in terms of milking frequency to the automatic milking system in the same way, whether they are accustomed to the system or not. These data do not support a learning process for multiparous cows.

During the course of lactation, differences in milking frequency were detected between first-lactating and multiparous cows. The milking frequency of multiparous cows was observed to be almost constant during the entire lactation, on average 2.5 times per day. However, first-lactating cows increase the milking frequency from the beginning to the end of lactation, when the lactation is divided into three periods of 100 days each, as illustrated in Figure 1.

**Influences of lactation rank on the milking interval**

As expected, the substantial difference of milking frequency between first-lactating and multiparous cows as observed in Experiment I had consequences on the milking interval, which is illustrated as box-plot diagram in Figure 2.

The milking interval for 50% of the first-lactating cows was observed to be in the range of 349 min and 442 min, whereas the range for multiparous cows was registered between 417 min and 617 min. Obviously, the milking interval of first-lactating cows proved to be...
more constant as compared to that of multiparous cows. This is supported by the observation that the maximum milking interval of cows with several lactations was 1129 min in contrast to 766 min for first lactating cows. The minimum interval was nearly the same for both groups lasting 329 min or 338 min.

Differences of time for adaptation to the automatic milking system

As only Experiment III started with cows in the early stage of lactation, it was qualified to study the adaptation time necessary for cows to voluntarily visit the automatic milking system. The other experiments were regarded as less appropriate as they started on lactation day 70 or 160 (Table 1) and the milking process up to that time was presumed to have an effect on the milking behavior.

During the experiment, those cows which had to be edged to the AMS were registered. This was done eight hours after the last milking procedure in a way that should help the cows learn to visit the AMS voluntarily as soon as possible. Table 8 gives the average time for a voluntary AMS visit for first-lactating and multiparous cows.

The results do not show substantial differences between the two groups (6.7 or 7.3 days), but the variation between individuals within the multiparous cows was found to be very high.

A differentiation between cows with or without AMS-contact before the experiment leads to the conclusion that the effect of training cannot be neglected (Table 9).

The time for acceptance of the automatic milking system was about six days for cows that already had contact with this system before the start of this experiment, whereas adaptation time was about one day longer when the cows engaging in their first contact with AMS.

Considering the fact that two cows did not show any progress in learning voluntary milking (they were edged to the milking robot over a period of three weeks), although they had already contact with this system before the experiment, the mean adaptation time for the residual animals in this group was found to be only two days.

Discussion

The results of these investigations show differences between first-lactating and multiparous cows, in agreement with a study by Fübbeker and Kowalewsky (2000), which was based on the experience of 35 farms operating with automatic milking systems. According to the evaluation of these data, only 20% of the multiparous cows visited the milking robot voluntarily after an adaptation time of three days; the percentage of first-lactating cows was 46. Correspondingly the change over to an automatic milking system seems to be easier and less complicated with first-lactating than with multiparous cows. Within a period of four weeks, 90% of multiparous cows visited the milking robot voluntarily; the rate for first-lactating cows was 80% within one week (Fübbeker and Kowalewsky, 2000).

This effect was not so pronounced in our own investigations, which have shown that the learning effect of multiparous cows should not be underestimated, especially when cows had already had contact with this system (Table 9). In our own experiments, the time for adaptation of first-lactating or multiparous cows was found to be one week with a high variance for multiparous cows (Table 8). Similar results concerning voluntary visits to the milking robot were published by Kremer and Ordolff (1992). According
to these investigations, 49% of the first-lactating cows visited the AMS voluntarily, 56% of those of the second lactation too, and 35% of the cows with more than two lactations. Also, cows in the first and second lactation period visited the AMS more often than cows with more lactation, which were satisfied with two milking procedures per day.

It was reported very often that the milk yield increased after the introduction of an automatic milking system as a consequence of the higher milking frequency. The effectiveness of the increasing milk yield varied from 3% (Svennersten et al., 2000) up to 23% (Bohlsen et al., 2000). In contrast to this Scholz et al. (2001) reported that milk yield varied extremely between decreases of 9% up to an increase of 18%. Additionally, effects on milk yield due to a raised milking frequency were observed to be different for first-lactating and multiparous cows. Hillerton and Winter (1992) reported an increase of milk yield between 15 and 25% for first-lactating and between 10 and 15% for multiparous cows, when three milking procedures per day were carried out. This milk increase is substantially higher than found in our own experiments with a rate of 6% for first-lactating and 4% for multiparous cows (Table 3). In contrast to these results, De Peters et al. (1985) reported a higher increase of milk yield for multiparous cows (17 and 13%) than for primiparous (6%), when they were milked three times per day. A milk increase in the range between 3.3 and 3.5 kg/day was also reported by Erdman and Varner (1995), who reviewed 19 publications on raising the milking frequency in a conventional milking parlor. Corresponding results are observed by Jahneke and Wolf (1998) as well. In this experiment multiparous cows showed the maximum milk yield in the second month of lactation, amounting to 113%. The first lactating cows had the maximum in the third month with 116%, related to milk yield at the start of lactation (=100%). These improvements are on the same level as found in our own AMS-investigations.

Conclusions

From these experiments it can be concluded that the installation of an automatic milking system does not improve milk yield due to a higher milking frequency in the expected range of 15% (Hillerton and Winter, 1992). The results indicate a substantially higher improvement for first-lactating cows only. This leads to the conclusion that the improved effects of these systems are only limited. The principal advantage seems to be the saving of labor. Additional studies are necessary to improve their effectiveness, especially with regard to performance.

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