Estimating the Lactation Curve on a.m./p.m. Milkings in Dairy Cows

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Abstract
A pilot study was conducted in order to assess the effect of a.m./p.m. milkings on the shape of the lactation curve during a normal lactation. Data from a.m. and p.m. milkings from 86 Romanian Spotted cows were used. Cows calved during January, February and March 2011 and concluded their lactations by the end of February 2012. Results showed that there was a difference between morning and evening milkings regarding the shape of the lactation curve. The shape of the lactation curve for morning milking was more resembling to the shape of the lactation curve for total daily milk. Modelling the lactation curve with gamma incomplete function led to a milk production estimate very close to the real production, although the model overestimated the yield in early lactation and underestimated it in middle lactation. If alternative milkings are going to use for milk yield estimation it is preferable to measure the evening milking at the beginning.

Keywords: am/pm milkings, cows, lactation curve, Romanian Spotted

1. Introduction

Alternate strategies for sampling yield traits in the dairy industry have been implemented. Variations in strategies include frequency of testing and whether the sample is obtained by an official tester or by the herd owner [1]. Alternate month a.m.-p.m. sampling was proposed and this was considered a promising method [2,3]. Therefore it was introduced as a method for calculating milk production per lactation [4]. The use of estimated daily yields from morning or evening milkings has a smaller impact on estimated breeding values of bulls than cows, and the difference in the weights between estimated and true daily yields decreases as lactation progresses [5].

Selection for milk production in dairy cattle has been based primarily on total milk yield, but the knowledge of the shape of the lactation curve is important because the pattern of how a cow produces milk over time could determine her biological and economical efficiency [6]. Similarly to the lactation milk production, it was found that the shape of the lactation curve is affected by various environmental and genetic factors such as season of calving, parity, year of calving, days open, service period, herd level of milk production lactation length, breed, population etc [7].

The aim of the paper was to assess the shape of the lactation curve for the a.m. and p.m. milk yield during a normal lactation and try to find the similarities and differences to the lactation curve shape of the total daily milk yield. Also, the best predictor of the milk yield per lactation was assessed by using a mathematical model for the lactation curve.
2. Materials and methods

The study was carried out on 86 Romanian Spotted cows reared at the dairy farm of the Research and Development Station for Bovine Raising in Arad. Cows calved in January, February and March 2011 and concluded their lactations by the end of February 2012. The morning (a.m.) and evening (p.m.) milk yield was recorded individually, and the daily milk yield was obtained by summing up the two partial yields. Milk production was recorded using the A4 method, every 28 days, and every milking. The first 11 controls were used for each cow in order to calculate the milk production per normal lactation. The length of the first control period was calculated taking into account the calving date and the date the first control was performed. For each cow and control, the proportion of a.m. and p.m. milkings milk yield was calculated from the daily milk yield, as well as the ratio between a.m. and p.m. yields.

Averages were calculated for days in milk, daily, a.m. and p.m. milk yield, as well as for a.m. and p.m. percentage, and a.m./p.m. ratio. Using these averages, the real lactation curves were drawn. The lactation curve was modelled using gamma incomplete function \[8\] for daily, a.m. and p.m. milk yield, with the following equation:

\[y_n = an^b e^{-cn}\]

where \(y_n\) is the milk yield at moment \(n\) from calving, \(a\) is the initial milk yield, \(b\) is the model parameter that shows the daily milk increase up to the peak and \(c\) is the model parameter that shows the daily milk decrease after reaching the peak production.

Using the real days in milk and model parameters the modelled lactation curves were drawn. A comparison of the daily, a.m. and p.m. shapes of the lactation curve was carried out, for both actual and modelled curves.

The milk yield was estimated from the gamma incomplete function using the parameters \(a\), \(b\), and \(c\), as well as the days in milk. The following equations were used:

- For maximum daily milk yield
  \[y_{max} = a(b/c)^b e^{-b}\]

- For days in milk when the maximum daily yield is achieved
  \[n = b/c\]

- For the total milk yield per normal lactation
  \[Y_{tot} = a\sum n^b e^{-cn}\]

For the actual milk yield the real percentages for a.m. and p.m. milkings were used in order to estimate the normal lactation milk yield.

Lactation curve modelling was performed using the Statistica software.

3. Results and discussion

Table 1 presents the averages and SEM for the actual milk yield obtained during the morning and evening milkings, as well as the overall daily yield.

The first milk record was performed on average at 18 days in milk (DIM), when the average daily production was 13.9 kg milk. During the whole normal lactation the morning yield obtained was higher than the milk yield obtained in evening milking. The difference between the two milkings was low at the beginning of lactation, a.m. milk yield representing 52.4% of the total milk, while p.m. milking being 47.6% from the daily milk production. This difference increased as lactation advanced, reaching a maximum of 56.5% for the morning yield and 43.5% for the evening milk yield at 214 DIM.

Cows tended to have higher milk yield at the a.m. milking (a.m.-p.m. effect) even when the interval between milkings is equal [9], although other authors found out that 92% of the cows had longer milking interval before the a.m. milking than before the p.m. milking [10]. Differences between a.m. and p.m. milk yield were primarily a function of milking interval and the number of days in lactation [11-13]. It was found that for every hour increase in the p.m. to a.m. interval past 12 hours, the milk yield increased by 1.3 kg in a.m. milking [14].

When the a.m./p.m. ratio was performed the same trend was observed. The lowest ratio was obtained at the beginning of lactation (1.099 at 46 DIM), then an increasing tendency of this ratio was observed until the maximum ratio of 1.305 between morning and evening yield was obtained at 213 DIM. After that, a slow decrease of the ratio was obtained.
The maximum daily milk yield was 23.6 kg which occurred at 158 DIM, distributed as 12.8 kg in the morning milking (54.4%) and 10.8 kg in the evening milking (45.6%).

Table 2 presents the parameters of the lactation curve after applying the gamma incomplete function to the raw data.

The determination coefficient was high (r between 0.826 and 0.868) which showed that this equation fitted relatively well to the raw data.

Comparing the lactation curve parameters for a.m. and p.m. milkings we could observe that for the morning milkings the initial level of the milk yield (parameter a) was lower, with a higher increase to the peak (parameter b) and a higher decrease after the peak yield (parameter c). While for evening milking the initial level was higher, with a slower increase of production to the peak and a lower rate of decrease of production after the peak. These differences resulted in steeper lactation curve for the morning milking and flatter curve for evening milking.

The shape of the lactation curve for the total daily milk yield was intermediate to those obtained for morning and evening milkings.

After modelling the data for lactation curve the daily, a.m. and p.m. milk yields were calculated using the equations parameters a, b, and c. Results are presented in Table 3.

Compared to actual data presented in Table 2 we could observe that the milk yield at the beginning of lactation was underestimated by the mathematical model (13.9 kg real and 11.1 kg modelled), as well as the milk yield at peak (23.6 kg real and 21.9 kg modelled). In the same time the milk yield at the end of lactation was overestimated by the mathematical model (12.8 kg real and 15.2 kg modelled, at the 298 DIM). These differences resulted in flatter lactation shapes
obtained after modelling compared to the actual lactation shapes, both for daily, a.m., and p.m. production.

As in the real data, the a.m./p.m. ration of milk production was low at the beginning of lactation, the estimated milk yield was almost the same in morning and evening milkings (5.6 kg and 5.5 kg, respectively). This ratio increased with lactation, reaching the maximum level at the end of lactation, 1.203 at 298 DIM, where in the morning was estimated to be produced 8.3 kg and in the evening 6.9 kg milk.

The differences between the actual and modelled lactation shapes could be better observed in Figures 1 to 3. For all the three situations, daily, a.m., and p.m. milk yield, the mathematical model overestimated the milk production during the first 100-130 DIM, underestimated the milk production between 130 and 240 DIM, and then was followed again by a slight overestimation. Thus, the modelled curves were flatter, reached the peak production earlier, with lower daily milk yield, and ended up at higher levels than the actual curves.

The closest modelled lactation curve to the actual curve was obtained for evening milking (Figure 3), where the determination coefficient for the mathematical model used was the highest $(r=0.868$, Table 2).

The actual milk production obtained by A4 method, taking into account both milkings was 5569 kg. When the model was used to estimate the milk production taking into account both milkings resulted a production with 18.8 kg higher, that is 0.34% more milk.

When applied to the actual data, the estimation of milk production using only morning milkings resulted in almost the same production, 5567.5 kg compared to 5569 kg. The difference of 1.5 kg (0.03%) per lactation was reduce and negligible.

When only the evening milkings were taken into account to estimate the normal lactation production a slightly higher yield resulted, 5574.3 kg compared to 5569 kg. The small amount of 5.3 kg (0.1%) was considered insignificant.

Using the lactation curve parameters of the mathematical model, we obtained the same estimation of production per normal lactation.

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**Figure 1.** Lactation curve for actual and modelled daily milk yield

**Figure 2.** Lactation curve for actual and modelled morning milked milk yield

**Figure 3.** Lactation curve for actual and modelled evening milked milk yield
(5585.2 kg) either using the morning or the evening milkings. The difference compared to the production estimated by taking into account both milkings was low, 2.6 kg and represented less milk by 0.05%. Compared to the actual milk yield these methods overestimated the production by 16.2 kg, which represents 0.29%.

Table 4. Actual and modelled milk production per lactation, calculated based on daily, morning and evening yield

<table>
<thead>
<tr>
<th></th>
<th>Actual</th>
<th>Modelled</th>
<th>Difference</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total/day</td>
<td>5569.0</td>
<td>5587.8</td>
<td>18.8</td>
</tr>
<tr>
<td>a.m.</td>
<td>5567.5</td>
<td>5585.2</td>
<td>17.7</td>
</tr>
<tr>
<td>Difference from total</td>
<td>1.5</td>
<td>2.6</td>
<td>-</td>
</tr>
<tr>
<td>p.m.</td>
<td>5574.3</td>
<td>5585.2</td>
<td>10.9</td>
</tr>
<tr>
<td>Difference from total</td>
<td>-5.3</td>
<td>2.6</td>
<td>-</td>
</tr>
</tbody>
</table>

Further, the milk production estimation was simulated using the alternative method when the first control was carried out in the evening or in the morning. For the actual data, when the first control was carried out in the evening the estimated milk production was 5579.1 kg, 10.1 kg more than real production of 5569 kg. While in the case of first control carried out in the evening the production was 5562.7 kg, 6.3 kg lower than the real milk production. We consider that both deviations (0.18% and 0.11%, respectively) were low and insignificant.

When the model parameters were used for estimating the milk production starting the first control in the morning the result obtained was 5699.8 kg, and when the first control was carried out in the morning the result was 5663.2 kg. Differences from the real production were 100.8 kg and 94.2 kg, respectively, representing 2.35% and 1.69% deviations from the real production. This could be important deviations, and could be higher at higher level of production.

We could state that estimating milk production per normal lactation either by using the lactation curve parameters or/and using the a.m. and p.m. milkings is providing similar results, at an average production of 5569 kg. Differences were low and insignificant, varying from 0.03 to 0.35%. This is particularly important for reducing the costs with the official control of milk performance in cows. It could be of interest to find out if this conclusion stands with higher or lower milk productions.

Tables 5 and 6 show the same results as those in Table 4, but in these tables the peak milk yield and for DIM when the peak milk is attained are presented.

Table 5. Actual and modelled milk production at peak, calculated based on daily, morning and evening yield

<table>
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<th></th>
<th>Actual</th>
<th>Modelled</th>
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<tbody>
<tr>
<td>Total/day</td>
<td>23.6</td>
<td>22.0</td>
<td>-1.6</td>
</tr>
<tr>
<td>a.m.</td>
<td>23.0</td>
<td>22.0</td>
<td>-1.0</td>
</tr>
<tr>
<td>Difference from total</td>
<td>0.6</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>p.m.</td>
<td>23.6</td>
<td>21.8</td>
<td>-1.8</td>
</tr>
<tr>
<td>Difference from total</td>
<td>-</td>
<td>0.2</td>
<td>-</td>
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</table>

The actual daily milk yield at peak was 23.6 kg, while the model yielded a peak production of 22 kg (Table 5). This is quite a difference if we take into consideration that 1 kg difference at peak could yield 200-230 kg difference per total lactation given the same shape of the lactation curve [15].

When the peak milk was estimated using only a.m. milkings a lower values was obtained, 23 kg, while estimating peak production based on p.m. milkings yielded the same value, 23.6 kg. Big differences were observed when the moment of peak milk is occurring was taken into account. Thus for the actual lactation the peak yield occurred at 158 DIM, while for the modelled lactation the peak yield was obtained 38 days earlier, when both milkings were taken into consideration.

For the real data, the peak yield occurred at 172 DIM when it was calculated based only on the morning milkings and at 158 DIM when only evening milkings were considered.

Table 6. Actual and modelled days in milk at peak, calculated based on daily, morning and evening yield

<table>
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<th></th>
<th>Actual</th>
<th>Modelled</th>
<th>Difference</th>
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<tbody>
<tr>
<td>Total/day</td>
<td>158</td>
<td>120</td>
<td>-38.0</td>
</tr>
<tr>
<td>a.m.</td>
<td>172</td>
<td>124</td>
<td>-48</td>
</tr>
<tr>
<td>Difference from total</td>
<td>-14.0</td>
<td>-4</td>
<td>-</td>
</tr>
<tr>
<td>p.m.</td>
<td>158</td>
<td>115</td>
<td>-43</td>
</tr>
<tr>
<td>Difference from total</td>
<td>-</td>
<td>5</td>
<td>-</td>
</tr>
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</table>

There were differences for the peak moment when a.m. and p.m. milkings were considered in modelled lactations, but the variation was lower, from 4 to 5 days.
4. Conclusions

Cows produced more milk in a.m. than in p.m. milking, difference that was maintained during the whole lactation. The difference between a.m. and p.m. production was low at the beginning of lactation and higher at the mid-end of lactation. The a.m./p.m. ratio was 1.099 at 46 DIM, and increased up to 1.305 at 213 DIM. The actual peak was attained at 158 DIM with 23.6 kg milk.

Applying the gamma incomplete function to the raw data, a highly significant determination coefficient was obtained (0.84). The model overestimated the milk yield at the beginning of lactation, from 50 to 100 DIM, and underestimated it at the mid-end lactation, from 130 to 300 DIM.

Estimating milk production per normal lactation either by using the lactation curve parameters or/and using the a.m. and p.m. milkings was providing similar results with actual data. The peak production was 7% lower and was reached 30-40% earlier with the modelled lactation.

More consistent results were obtained by using modelled lactations in terms of lactation milk yield, peak yield and days in milk at peak compared to actual data.

References

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