A method for continuous automatic monitoring of accuracy of milk recording equipment

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Summary

To minimize the costs of milk production the daily milk yield of each cow must known. Automatic milk recording systems have been developed for this purpose, b the accuracy of milk meters can be checked only over long periods. This pap proposes a method for continuous monitoring of milk meters that enables meter erro to be detected automatically. It is based on a comparison of expected and actual mi yields.
Keywords: milk recording equipment, error, monitoring.

Introduction

Under given economic conditions in EC successful milk production is possible only high milk yields can be reached with low production costs. As 50% and more of tl milk production costs are feeding costs (Landwirtschaftskammer Schleswig-Holstei 1992), the nutrient supply to the single cow has to be matched to the nutrient demar as exactly as possible. The nutrient demand of a cow is extremely dependent on tl milk yield. Therefore, for optimized feeding it is essential to know the daily mi yield.

Various automatic milk recording systems have been developed to measure the dai milk yield. At the moment, the number of systems installed on commercial farms the Federal Republic of Germany is probably below 1000, but the acceptance growing significantly. If milk meters are used for official yield recording, they have fulfil the specifications laid down by the International Committee for Anim Recording (ICAR, 1988-1991). According to these regulations, milk meters should b checked at least once a year and recalibrated if necessary. But manual checking is ver time-consuming and costly and, for this reason, it can only be done regularly at longe

intervals. So there is a need for a method which can check the accuracy of milk meters continuously and signal when the accuracy of meters worsens.

Method and material

The procedure to signal milk meter errors is based on a comparison of the expected and the actual milk yield of a cow (Dufter, 1988; Zenger, 1990) and assumes that the average deviations between the actual and expected yields of several cows are not significantly different from zero if milk meters are working correctly. If the average deviation for one milk meter is significantly different from zero during a longer period, a meter error is suggested.

The monitoring method assumes that:

1. The systematic error in measurement does not worsen at the same time on all milk meters.
2. If an error in measurement occurs it will drift in one direction (directed error).
3. The other milking equipment has no defects.

The discrepancy between actual and expected milk yield is calculate from formula 1.

$$d_{ikl} = m_{ikl} - M_{ik}$$

where

d_{ikl} = deviation of expected milk yield from actual milk yield of cow k on day i and meter l

m_{ikl} = recorded actual milk yield of cow k on day i and meter l

M_{ik} = expected milk yield of cow k on day i.

The reliability of the monitoring method depends strictly on the calculation of a realistic expected value. The expected yield and its standard deviation (Hyde et al., 1981) is calculated across the previous 7 days according to formulas 2 and 3. This ensures that only amounts of milk that have been recorded on at least 3 different meters (none of them the meter which has to be tested) are used.

$$M_{ik} = \frac{m_{i-7;k} + m_{i-6;k} + m_{i-5;k} + \ldots + m_{i-1;k}}{u_{ik}}$$

$$SM_{ik} = \sqrt{\frac{(m_{i-x;k} - M_{ik})^2}{u_{ik}}}$$

where

$m_{i-x;k}$ = recorded actual milk yield of cow k on day i-x
SM_{ik} = standard deviation of expected milk yield of cow k on day i
u_{ik} = number of available amounts of milk from cow k during the previous 7 day

To avoid possible time differences between morning and evening milk yield, a individual expected value is calculated for both yields. Since the daily amounts of mil fluctuate very stochastically (caused by external and internal influences), extrem values have to be identified and may not be used to calculate the expected value (Hyd et al., 1981; Walter, 1981). The following criteria are used to eliminate extrem values:

1. Only milk yield values from the 30th to the 300th days in lactation are used.
2. An expected value is valid only if the coefficient of variation $(SM_{ik} \times 100/M_{ik})$ below 20%.
3. If the standard deviation of the available amounts of milk is more than 1.0, only th amounts of milk in the range $M_{ik} \pm 2 \times SM_{ik}$ (i.e. 95.45% of normal distributio are used to calculate a new expected value.
4. Further, an expected yield is calculated only if at least 4 milk yield records a available across the previous 7 days, fulfilling the above mentioned conditions.
5. Finally, a deviation is only calculated if the actual milk yield is in the rang $M_{ik} \pm 2 \times SM_{ik}$.

The calculation of average deviation per milk meter and its standard deviation is do by formulas 4 and 5 with all available deviations from the previous 30 days.

$$D_{il} = \frac{d_{i-30;k;l} + d_{i-29;k;l} + d_{i-28;k;l} + \ldots + d_{i-i;k;l}}{x_{il}}$$

$$SD_{il} = \sqrt{\frac{\Sigma\ (d_{ikl} - D_{il})^2}{x_{il-1}}}$$

where

D_{il} = 30-day running average of deviations of meter l from the previous 30 days at time i

SD_{il} = standard deviation of deviations of meter l at time i

x_{il} = number of available deviations of all cows during the previous 30 (interval i-30 to i-1) on meter l

Additionally, it is assumed that the calculated deviations have a normal distribution. Therefore the hypothesis H_0 ($D_{il} = 0$) can be tested against hypothesis H_1 ($D_{il} \neq 0$) by using the Student's t-statistic (level of significance 0.1%). If the hypothesis H_0 is rejected over a period of seven running days, a milk meter error is signalled.

The data base used to develop the monitoring method is described in table 1.

Table 1. Description of data base.

Investigated farm	dairy farm (34 ha)
Type of parlour	2 × 4 herringbone with identification on each stall
Number of milk meters	8
Measuring principle	volumetric, continuous, variable portions
Available data	455 days (1 March 1988 to 31 May 1989)
Number of cows	34
Available amounts of milk	
morning	10 735 [illegible]
evening	10 585 [illegible]

Results

Expected value for single milk yield

The monitoring method must be able to calculate the expected value. The expected yield should be as robust as possible against short-term random variations. Figure 1 shows the daily morning milk yields and the calculated expected yields for one cow.

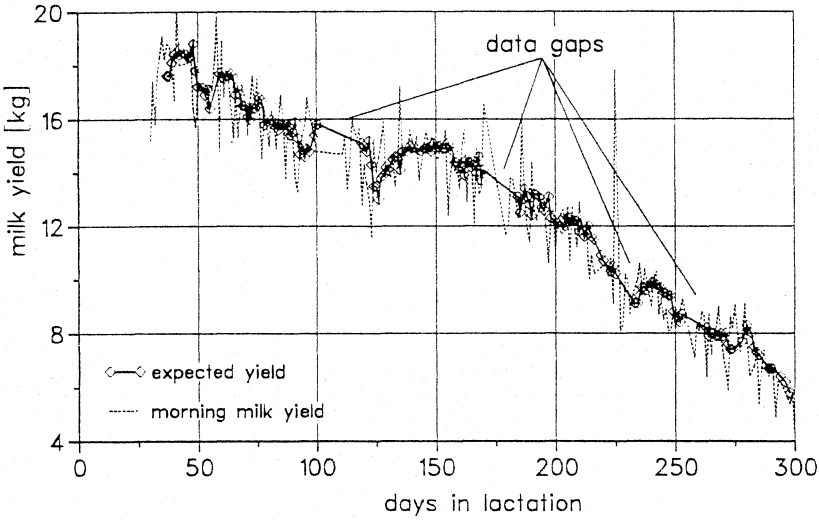

Figure 1. Lactation curve of cow no. 85 (4th lactation, morning milk yield).

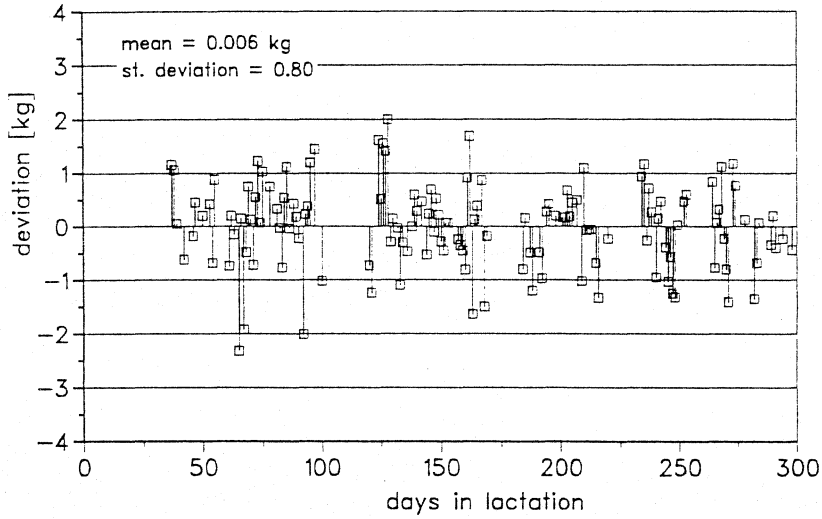

Figure 2. Deviation of the real and expected milk yield for cow no. 5 (4th lactation, morn milk yield).

Clearly, the daily milk yield varies greatly. The method for calculating the expected value has to ensure that obvious extreme values (for instance on the 225th day of lactation) are eliminated. This enables the course of the expected value to be adapted to the real lactation curve comparatively well, but it lags slightly behind the real development because it is extrapolated from the past to the future.

The discrepancy between the expected and actual milk yield for the same cow is represented in Figure 2. All deviations are below ± 2 kg except one, and vary with a standard deviation of 0.8 around zero. The size of deviations is independent of the stage of lactation.

Deviations per milk meter

If the deviations of all cows are sorted by the single milk meter and its 30-day running average is calculated, the accuracy of the meter can be estimated from the trend of the average. Figure 3 shows the single deviations and the running average for milk meter no. 5 for a period of 15 months. The deviations move symmetrically around zero during the investigation period. A significant difference from zero point cannot be determined. But on other meter devices a significant difference does appears on several periods. This signals a malfunctioning milk meter.

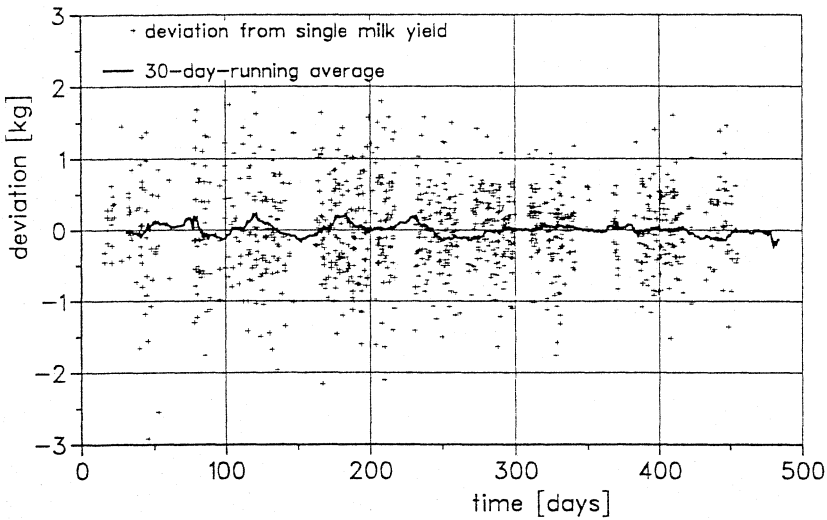

Figure 3. Deviation of real and expected milk yield for milk meter no. 5 (34 cows, 1 March 1988 to 31 May 1989).

Verification of monitoring method

The sensitivity of the monitoring method is checked by increasing the milk y recorded at a specific milk meter. Therefore the daily milk yields recorded on r meter no. 5 are increased by 5% between the 300th and 400th days in lactation. Do that assumes that milk meter no. 5 has no systematic error in measurement. change caused is shown in Figure 4. A significant difference from zero is appa between the 316th and 418th days in lactation and this indicates that the milk meter worse. The time lag between starting and the detection of meter error (about 2 we is caused by the 30-day average. The longer this period is chosen to be, the lat meter error is detected, but the security of identifying the error increases as the risl a wrong decision decreases.

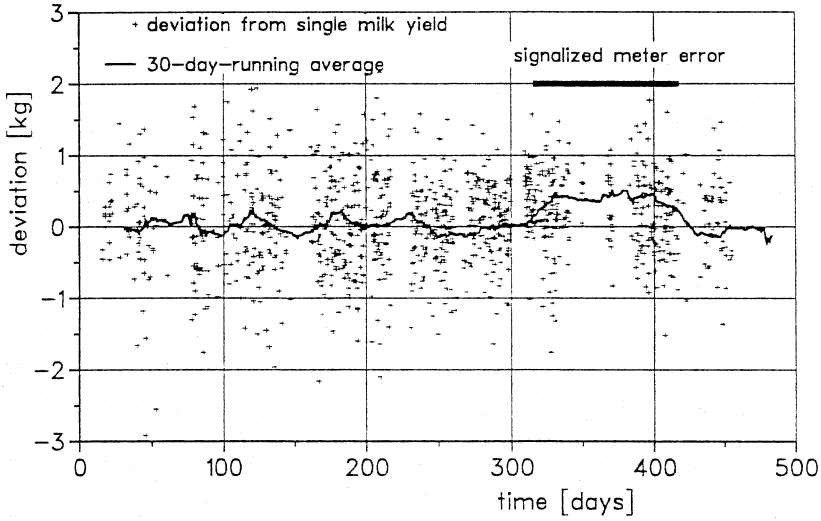

Figure 4. Deviation of actual (increased by 5% between 300 and 400 days) and expected yield for milk meter no. 5 (34 cows, 1 March 1988 to 31 May 1989).

Conclusion

The software-aided method developed seems to be a suitable and cost-effective procedure for monitoring the accuracy of milk meters. A very critical point of the method is the calculation of a good expected yield. Further research is necessary for optimizing and verifying:

- the method for calculating expected yield (running average or weighted running average or exponential smoothed average);
- the criteria for eliminating extreme values;
- the length of periods for making the average and
- the criteria for testing significance.

In a future practical test the software-aided monitoring method will be checked and verified by a manual monitoring. For that, the method will be implemented on the on-farm computer and it will be continuously monitored to see if deviations from the expected yield differ significantly from zero.

This method can be adapted to automatic milking if the time that has elapsed since the last milking is entered into the calculation of the expected yield. Therefore an expected yield for milk production per hour must be calculated and multiplied by the number of hours that have elapsed since the last milking. Obviously a basic requirement is that at least 2 automatic milking units are available.

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