Computerized solutions for periodic checking of electronic milk meters

C. Allain[1], M. Trinderup[2], M. Burke[3], E. Rouzaut[1], S. Sievert[4], E. Schuiling[5], J. Lassalas[6]

[1] Institut de l'Elevage, 149 Rue de Bercy, 75595 Paris, France

[2] Agrotech, Agro Food Park 15, 8200 Aarhus, Danemark

[3] ICBF, Highfield House, Shinagh, Bandon, Co. Cork, Ireland

[4] Quality Certification Services, 421 S. Nine Mound Road, Verona, WI 53593, USA

[5] Animal Sciences Group Wageningen UR, P.O. Box 65, 8200 AD Lelystad, The Netherlands

[6] INRA, UMR 1080 Production du Lait, Domaine de la Prise, 35590 Saint Gilles, France

Abstract

For a use in official milk recording, on-farm electronic milk meters require an installation and an annual calibration checking. These periodic controls are still done manually and are consequently restrictive and costly. To simplify this work, an international ICAR project group was built with the objective to review, test and validate the existing alternative solutions based on the use of data recorded by the milk meters. Several statistical models or computerized algorithm have been found in the literature, for both multi-stands milking parlours and automatic milking systems. Some of these methods were applied on the field on experimental farms. The deviations estimated by these alternative solutions were compared to measured deviations performed on milking tests. For milking parlours, three different methods gave good results but with more or less easiness of implementation on the field. They were respectively based on a comparison of the recorded milk yield with the cow expected yield, a comparison of the yield average per stand with the overall average (use of a Dynamic Linear Model) or an estimation of the residuals from a lactation modeling. For automatic milking systems, the use of a comparison between measured and collected milk was also satisfactory and easy to implement. In conclusion, these selected methods were usable as helpful tools to complement the current periodic checking. They can be run continuously instead of once a year and reduce substantially the manual labour. Nevertheless, these selected alternative methods have some requirements: reliable cow identification and a link between the milk meters and a computer are indispensable. Furthermore, they are not suitable for small milking parlours and multi-stands automatic milking systems.

Keywords: electronic milk meters, monitoring, automatic milking system, milking parlour.

Introduction

In the main European and North American countries producing milk, 2 % to 25 % of the farms are equipped with electronic milk meters to record milk production (De Koning, 2008). For a use in official milk recording and to ensure a reliable data collection, on-farm electronic milk meters require an installation and an annual calibration checking (ICAR Guidelines Section 11, 2011). The periodic controls of these devices are still done manually by using water in most of the cases. They are consequently very restrictive and costly.

In the past ten years, several statistical alternative solutions based on the use of data recorded by the milk meters appeared to simplify this work. These computerized algorithms give a lot of potential benefits like replacing the water tests and allowing a continuous remote control instead of once a year on the farm. But most of them are not used in the field and were never validated on more farms.

At the end of 2010, an ICAR working group was built in order to review, test and validate these alternative methods. The final objective was to update ICAR guidelines to provide standardized statistical models for validating accuracy of electronic milk meters and to encourage their use on the field by manufacturers or ICAR members.

The aim of this paper is to present the final results of this project group work.

Materials and methods

Milking data

Data from the experimental farm of the INRA (Institut National de la Recherche Agronomique) in Méjusseaume was used to test the methods for multi-stand installations. Milk yields were gathered from 1st January 2011 to 30th June 2011. In average 159 cows were milk twice a day on a 28 stands rotary. In average 5.7 cows were milked per stand and per session. This represents 55327 milk yields. Milkings with zero yields were excluded from the data set, as well as sessions with missing values.

Each electronic milk meter was checked three times between April to June 2011 in order to calculate its deviation level. Each checking consisted on a milking test where the values measured by the milk meter on five cows were compared to the amount of milk weighted on an electronic scale which represented the reference. According to ICAR guidelines, the milk meter was considered as faulty when the deviation was lower than -3% or higher than 3%.

In order to see if the alternative methods would be able to detect punctual deviations, three milk meters were voluntarily set up to be out of calibration from the 15th to the 25th of May. This was done by changing their calibration value from respectively 3, 5 and -10 %.

Data from the experimental farm of Institut de l'Elevage in Derval was used to test the method for automatic milking systems installations. Milk yields and bulk tank collections data were gathered from the 1st January 2011 to the 30th June 2011. In average, 71 cows were milked and there were 144 milkings per day on a one box milking robot. The data set contains 26048 milk yields. 24949 of them were identified as sent to the tank and 1099 were separated. Milk collections were done every 2 or 3 days and 64 collections occurred in this period with an average collection of 5341 litres.

The electronic milk meter was checked four times with a milking test between February to June 2011 by using the same procedure as described above.

Tested models

The main principles of the tested models are presented below. Some of them are the original models as found in the literature or provided by their author and some were adapted or simplified from their original form.

Use of expected milk yield (from the method used in the USA)

A comparison between expected milk yield and milk yield recorded by the milk meter is used to estimate whether a milk meter is out of calibration or not. Several steps are followed to estimate the milk meter's deviation.

First, the expected yield for each cow is calculated. Several calculations are possible from the milk yields of the previous days or the previous milkings and corrected or not by a herd factor. In this case, the expected yield for one cow was calculated as following (example for a morning milking).

Expected yield = Cow ave. yield for the last 5 morning milkings * (Herd ave. yield for the current milking / Herd ave. yield for the last 5 morning milkings) **(1)**

Then, for one milking and one cow, the difference between the expected milk yield and the yield recorded by the milk meter is calculated as presented below.

Cow Deviation (kg) = Measured yield (kg) – Expected yield (kg) **(2)**

For each milk meter and for one milking deviation is calculated from the individual cow deviations.

$$\text{Deviation (\%)} = \frac{\Sigma \text{ cow deviations (kg) for this milk meter}}{\Sigma \text{ expected yields (kg) of these cows for this milk meter}} \times 100 \quad (3)$$

Finally, the average deviation for one milk meter is calculated from a minimum of at least 10 milkings.

Use of a Dynamic Linear Model (from De Mol and André, 2009)

This method uses a Dynamic Linear Model (DLM, West & Harrison, 1989).
The average milk yield per stand and milking session is calculated over all milkings on that stand. The resulting stand average is compared with the overall average. The deviation will be close to zero for a properly working meter. A DLM is based on a comparison per milking session of the average per stand with the overall average. This model is described here:

$$Deviation_{ms} = AveYield_{ms} - AveYield_{m} \quad (4)$$

with:
$Deviation_{ms}$: deviation for milking session m and stand s (kg)
$AveYield_{ms}$: average milk yield for milking session m and stand s (kg)
$AveYield_{m}$: average milk yield for milking session m (kg)

It is assumed that the stand deviation is a factor relative to the average milk yield for a milking session:

$$Deviation_{ms} = \mu_{ms} \times AveYield_{m} \quad (5)$$

The stand deviation factor μ_{ms} will be close to zero if the milk meter is recording correctly, positive if the milk meter recordings are too high or negative if the milk meter recordings are too low.

This model was adapted from the original one, by using the UCM procedure from SAS (version 9.2).

Lactation model from Trinderup (2009)

The effect of different factors (date, milking time and days in milk) on milk yield is estimated. A statistical treatment on the residuals reveals if a milk meter is out of calibration or not. The model is described as following:

$$Y_i = \alpha_1(Date_i) + \alpha_2(Milking_i) + \beta_1{*}DIM_i + \beta_2{*}DIM^2_i + \beta_3{*}DIM^3_i + \beta_4{*}1/DIM_i + \beta_5(Milking_i){*}DIM_i + \beta_6(Milking_i){*}DIM^2_i + \beta_7(Milking_i){*}DIM^3_i + \beta_8(Milking_i){*}1/DIM_i + a(Cow_i) + \varepsilon_i \quad (6)$$

with:

Y_i: observed milk yield (kg)
Cow_i: cow identification
$date_i$: date of milking
DIM_i: days in milk
$Milking_i$: classification of milking according to time of day (two times: am/pm; three times: am/pm/night)
ε_i: residual (kg)

Then, the residuals per milk meter are smoothed as an average over a period of 4 days. The deviation between the mean residuals of any given milk meter and the mean residuals of all other milk meters is calculated. The deviation will be close to zero if the milk meter is recording correctly, positive if the recordings are too high and negative if the recordings are too low.

The model was developed in SAS (version 9.2) using the procedure Mixed.

Method for automatic milking systems: comparison with collected milk

A comparison between the milk weight collected in the tank and the sum of milk weights measured by the milk meter of the robot and identified as sent to the tank between two milk collections is used for estimating the milk meter's deviation.

Between two milk collections, the deviation is calculated as following:

$$\text{Deviation (\%)} = 100 \times \frac{\Sigma \text{ yields measured by the milk meter and sent to the tank (kg)} - \text{Collected yield (kg)}}{\text{Collected yield (kg)}} \quad (7)$$

A DLM using also a comparison between yields measured by the milk meter and the collected milk in the tank was proposed by De Mol and André (2009) for AMS. But the previous approach is more simple and only that one is presented here.

Other methods

Other methods does exist for multi-stand installations but won't be presented here. One of them is an iterative algorithm proposed by Lefcourt (1999) and based on the comparison of the milk yields for one cow on one milk meter with her average yield on the other milk meters. The meter is considered faulty and excluded from the calculations if the ratio of these two yields differs significantly from 1. Another one provided by Delaval (Olsson, 2011) is a method using expected milk yield, very close from the first one presented in this paper.

Results

Methods for multi stands milking parlours

Figure 1 shows the deviation evolution of 4 of the 28 milk meters from the installation of Méjusseaume between the 1st of April and the 30th of June 2011. Continuous calculated deviations with the three alternative tested methods and the punctual measured deviations are presented.

According to the computerized methods, milk meters n° 2 and 21 are working properly with an average deviation inside the acceptance limits of +/- 3%. Nevertheless, deviation of milk meter n°21 is close from the lower acceptance limit. The results are identical for all of the three methods with more or less variability and these conclusions are confirmed by the three milking tests in both cases.

Milk meter n°1 is detected as faulty by all of the alternative methods from the 1st of April to the 6th of May. This was confirmed by the first milking test. On the 6th of May, this meter was unfortunately broken by a cow on a milking session and was only changed on the 20th of May. The new device was also out of calibration and was fixed two days later. This fixing is detected by two of the alternative methods as well as by the third milking test. The model from Trinderup does not detect the fixing immediately probably because of the smoothing but tend to reach the acceptance limits after a few days.

Milk meter n° 15 was voluntarily got out of calibration from 5% on the 15th of May and fixed again on the 25th. This punctual deviation is detected by the method using expected yield but not by the two other ones.

Figure 2 shows the correlation between deviations calculated by each of the methods and the punctual measured deviation values. All the deviations estimated by the alternative methods are positively correlated to the measured deviations, with a R^2 from 0.48 to 0.64. These R^2 values reach 0.6 for all of the methods if the three punctual provoked deviations are excluded from the data set.

These results show that all of the three methods seem efficient to detect well calibrated milk meters and high deviating milk meters with higher deviations than 5 %. For moderate deviation between 3 and 5 %, all of them are not detected by the alternative methods.

Method for automatic milking systems

Figure 3 shows the continuous calculated deviation in comparison with the collected milk and the four punctual measured deviations of the AMS milk meter of Derval farm between the 1st January and the 30th June 2011.

From January to the end of April, the calculated deviation was inside the acceptance limits of +/- 3%. This was confirmed by a milking test on the 3rd of March. By the end of April, the meter started to overestimate the production, which was detected by the alternative method and confirmed by the second milking test.

Two months later, the situation was still the same and on the 23rd of June the meter was fixed. It appeared that a corn grain was blocked inside the meter’s canal. This fixing was directly detected by the alternative monitoring method and confirmed by the last milking test checking.

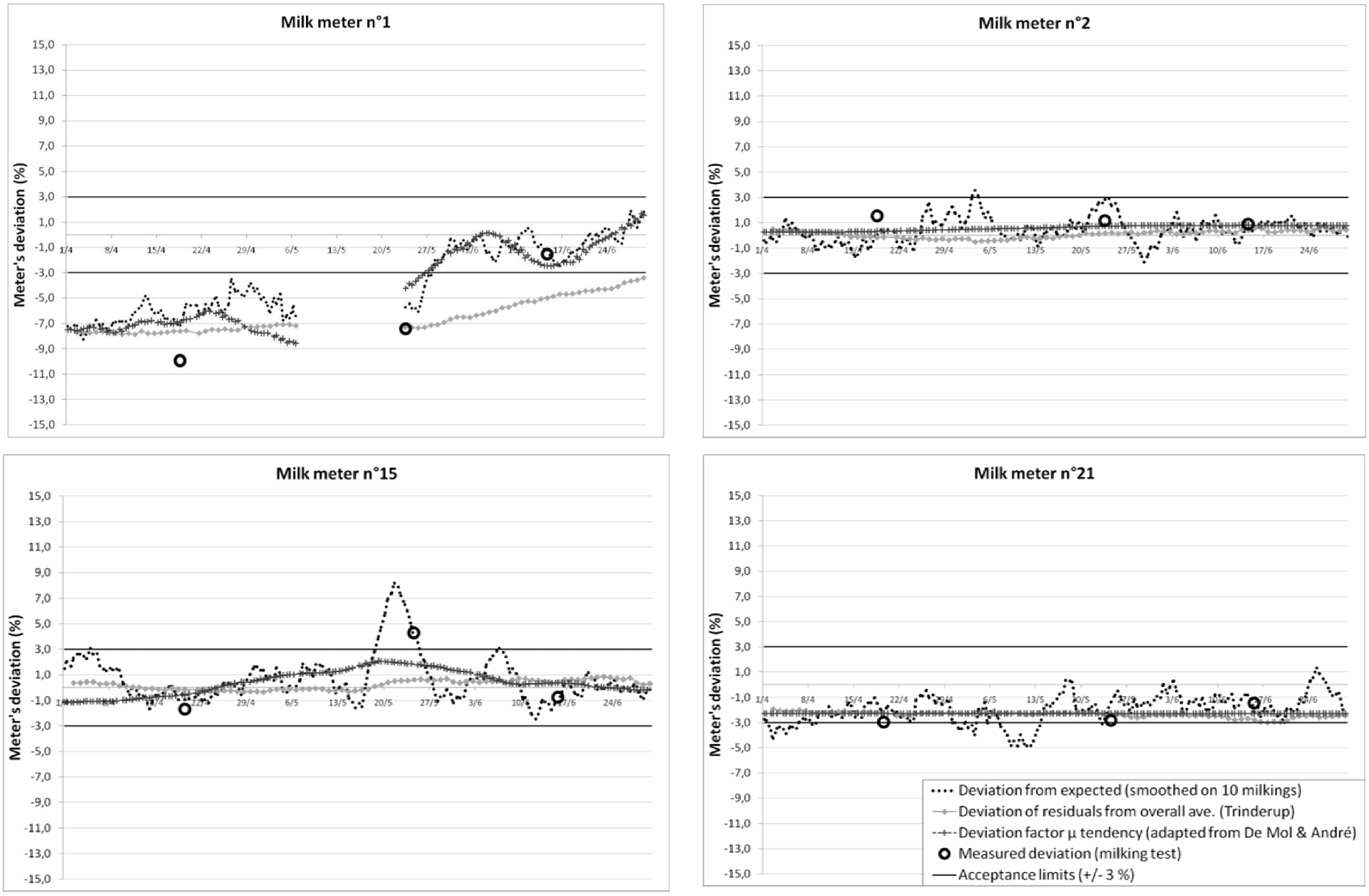

Figure 1: deviations for meters n° 1, 2, 15 and 21 from Méjusseaume Farm (INRA)

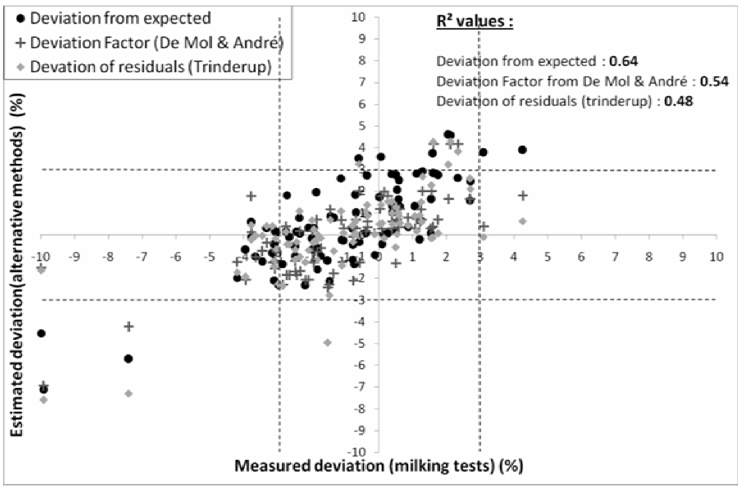

Figure 2: correlations between measured and estimated deviations for all milk meters from Méjusseaume farm

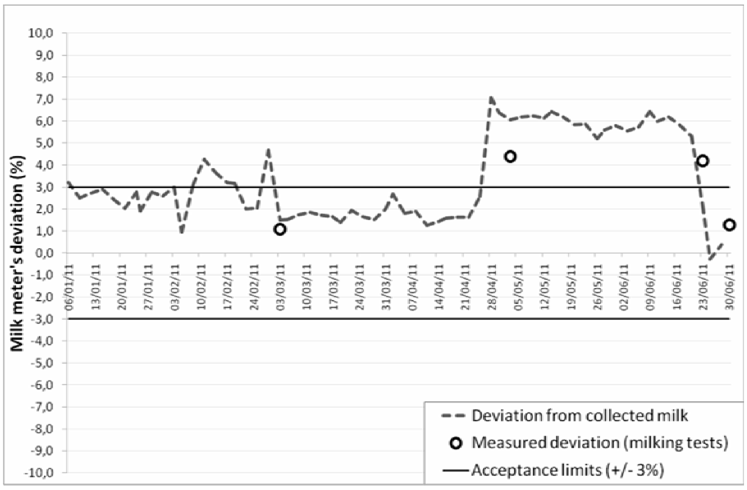

Figure 3: milk meter's deviation on the AMS farm of Derval.

Discussion

For multi stands milking parlours, all of the methods detected properly working meters and high deviating meters. For moderate deviations, between 3 and 5 %, deviation values were sometimes different between the measured and the estimated ones.

This can partially be explained by the fact that for practical reasons, measured deviations performed on milking tests were calculated on only 5 cows for each meter and on each milking test, with sometimes a high variability of the deviation values between animals. Therefore, these milking tests only give a good idea of the meters deviation level but cannot be considered as a golden standard. Another reason is that the deviations for a current milking estimated with alternative methods are calculated with data from the last days and compared with current measured deviations.

Even if all the methods gave quite similar results, some differences were noticed between them. For the algorithm based on a comparison of the recorded milk with the expected milk yield, more variability was observed in the deviation values than for the statistical methods that give a stable deviation tendency. Nevertheless, this basic algorithm is very simple to implement in a software and easy to use on the field.

For all of these three methods some requirements are needed for an outstanding use. Particularly, reliable cow identification, a link between the electronic milk meters and a computer, and a milking parlour of at least 8 stands are indispensable. For smaller milking parlours of 6 or 4 stands, some simulations not presented here showed that influence of a faulty device is too high.

For AMS farms, the method tested here seems precise and efficient. Calculations are furthermore very simple to implement. However, it requires to respect some conditions, like knowing milk destination from the robot, recording precisely milk collection date and time and controlling private milk collection. Furthermore, this method cannot be used as an official accuracy test for AMS with more than one box. Indeed, in theory the deviation from one meter could be compensated by the meter from another box, with no overall difference in comparison with the tank.

In this case, another method shall be developed. In extreme cases were 8 boxes or more would be used with no animal lots, methods for multi stands milking parlours could be performed.

Conclusions

It appears that these alternative computerized methods could be used as very useful tools to improve labour intensity and to replace the restrictive routine test activity. In that case, they could be used at least once per year but for best practice in quality assurance it is recommended to run this more frequently throughout the year, for instance at time of milk recording visits.

Easy solutions are possible and must be used in the near future by manufacturers or milk recording organizations. Of course other methods than the ones presented here can be subjected but must be approved by ICAR.

References

De Koning, K., Huijsmans, P., 2008. Quality assurance for milking machines and recording devices. ICAR Technical Series n°13, p59-63

De Mol, R., André, G., 2009. Automated monitoring of milk meters. Precision Livestock Farming 09, p 63 – 70.

Lefcourt, A., 1999. Method to monitor the precision of milk yields recorded at individual milking stalls on a daily basis. Journal of Dairy Science vol. 82, p 953 – 956.

Olsson, T., 2011. Calibration of MM25 and MM27 in ALPRO Windows. Delaval Report.

Trinderup, M., 2009. Application of statistical methods for online control of data from automatic milkmeters. Thesis, Master of Applied Statistics . Faculty of Agricultural Sciences, Aarhus University.