Analysis of the accuracy of lactation qualification methods and use of weighting factors for genetic evaluation

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Summary

In France, the Dairy Cattle Milk Recording Guidelines allows 8 protocols, each with 6 levels of recording intervals (between 4 to 9 weeks), approved by ICAR. The percentage of cows recorded with A protocol has decreased by 42 points during the last twenty years (from 92% in 2000 to 48% in 2020). Milk Recording Organizations have indeed wished to adapt and simplify protocols in keeping with the changes in measuring equipment, new services, etc.

The aim of this study was to determine the effect of all qualification methods on prediction accuracy of 305-day production traits milk yields, fat yields, protein yields, fat%, protein% (a lactation model is used for the French genetic evaluation) and to calculate and/or update the different weighting factors applied to each method in genetic evaluation.

Two datasets have been created: one with 19047 lactations reference-305 days A4 method, another with 8250 lactations reference-305 days R4 method.

The methodology used for this study has consisted in simulating T4, Z4, C*4, Z*4 methods from reference A4 method and R*4 method from reference R4 method.

A8, T8, Z8, C*8, Z*8, R8, R*8 methods have been obtained by taking into account only one out of two test-day per lactation.

The 305-day production traits estimated for each simulated method were compared to those of the reference method. The accuracies of the other methods (5, 6, 7 and 9) have been extrapolated by means of a linear regression model. The calculation of the weighting factors for all methods took into account the coefficient of determination (R^2) and the repetability level of each trait.

The results of accuracy (R^2, bias and standard deviation of bias) underlined the fact that R^2 is lower for all traits for 8 methods compared to 4 methods.

For example, R^2 is equal to 0.945 and 0.861 for fat yields and percent for T8 method compared to 0.989 and 0.962 for T4 method. Moreover the loss of accuracy is lower for R8 method compared to A8 method.

The comparison between the old and the new weighting factors for each lactation qualification method brought out an overall underestimation for milk yields, fat yields and protein yields and an overestimation for fat%, protein% with the old factors.

For example, the new milk yields weighting factor for A8 method is equal to 0.95 compared with 0.93 previously. The weighting factors obtained for new methods are

low, mainly for fat% for which it is equal to 0.44 for C*9 method. The weighting factors will have an impact on the accuracy of the cows' index, low weighting factors leading to reduced accuracy.

Keywords: Milk recording, protocols, accuracy, weighting factors.

Introduction

In France, the percentage of dairy farms which uses A protocol is for the first time below 50% in 2020 with exactly 48% of herds. This percentage decreases each year.

Alternated one-milking recording (T) and one-milking sampling with milk weights from more than one milking (Z) represent 27% of herds, AMS protocols 13% and B protocols by farmers represent 12% of herds.

In this context, French Milk Recording Organizations (MRO) wish to answer expectations of farmers, changes in measuring equipment, new services…, and to simplify, reduce the cost of milk recording by using ICAR standard and method, with a quality level for genetic evaluation and cow management.

Many protocols and methods are proposed in France and the aim of this study is to evaluate the accuracy of these protocols and methods:

- on lactation reference-305 days from relevant data sets in comparison with A4, AR4 methods (gold standard) by calculation R2, bias, standard deviation of bias on criteria milk yields, fat%, fat yields, protein%, protein yields for each method,
- and to calculate weighting factors for genetic evaluation.

A lactation model is used in France for genetic evaluation and it was necessary to update and to calculate weighting factors from new relevant data sets.

Material and methods

Description of the datasets

Data were collected by Milk Recording Organizations, from herds in A4 scheme with use of Electronic Milk Meter Lactocorder and recording of one milk weight, one sample at each milking (pm and am) and from herds in R4 scheme with use Automatic Milking System with recording of samples for at least two milkings per test day.

Several criteria have been used to select raw data from both datasets.

For the A4 scheme dataset, recordings with missing information, with too large a difference in milk weight between milkings, before 5 and after 399 days in milk (DIM), from lactation ranks greater than 10 and with daily recorded values out of permitted range (defined in ICAR Guidelines, 2017) were excluded. 208 204 test-day records from Holstein cows were thus retained.

For the R4 scheme dataset, recordings with missing information, with daily recorded values out of permitted range (defined in ICAR Guidelines, 2017), without 24-hour reference and during a sampling period of less than 12 hours were excluded, as well as protein and fat percent from sampled milkings carried out within 4 hours of a previous sampled milking. 380 170 test-day records were thus retained, from Holstein (74%), Montbeliarde (22%), Normande, Simmental and Brown cows breed.

Estimation of the lactation accuracy for each recording method

Firstly, the data sets were used to estimate 24-hour milk yields, fat percent and fat yields, protein percent and protein yields for each recording method.

The A4 prrotocol data set was used to simulate A4 (reference method), T4 and Z4 (adjustment of milk yield and/or fat and protein yields with the ICAR approved Liu's method) and C*4 (constant one-milking recordings with adjustment of milk, fat and protein yields with the Liu's method) method. It's a new protocol used in France since 2020 (Leclerc. *et al.*, 2019).

The R4 protocol dataset was used as a reference and to simulate a R*4 method by adjusting fat percent with the ICAR approved Peeters and Galesloot's method (Peeters, R., Galesloot, P.J.B., 2002) for recordings with only one single sample during the sampling period. It's a new protocol used in France since 2019 (Minery., *et al.*, 2018).

The R*4 dataset was obtained by selecting the first sampled milking as well as the two previous non-sampled milking per cow per test day, leaving 319 076 first sampled milkings.

The A4 and R*4 data sets were split into two independent data sets: a training data set (138 222 and 212 522 records for the A4 dataset and the R*4 dataset respectively), used to estimate the Liu's and Peeters and Galesloot's regression coefficients and a validation dataset (69 982 and 106 554 records records for the A4 data set and the R*4 data set respectively) on which the regression coefficients were applied to calculate 24-hour production traits for each method.

In order to estimate 305-day production traits for each method with a 4 week-interval between recordings, each lactation had a minimum of 7 test day records separated by less than 95 days, a first record before 60 DIM and a last record after 280 DIM (and before 399 DIM for the R4 and R*4 data sets).

19 047 lactations for the A4 data set, 8 250 lactations for the R4 data set (Table 1) and R*4 data set respectively fulfilled these conditions.

For each method with a 8 week-interval between recordings, only one out of two recordings were taken into account to estimate 305-day production traits, starting from the first or the second lactation record and the same conditions were required, except for the minimum of test day records which was lowered to 4.

The statistical analysis was carried out by comparing the 305-day lactation traits thus obtained for every method to the reference 305-days lactation traits (R4 for R8, R*4 and R*8 and A4 for every other methods). The results of the accuracy (R^2, mean bias, standard deviation of bias) published for each method correspond to the lowest R^2 value and the highest mean bias values (in absolute value) obtained for each method on the validation data sets.

Table 1. Description of the initial datasets for analysis on lactation

Criteria	A4 Data set	R4 Data set
# 305-day lactations	19 047	8 250
# Cows	14 396	7 889
Average milk yields (kg)	9 172	9 495
Average fat%	3.85	3.84
Average fat yields (kg)	351	361
Average protein%	3.12	3.21
Average protein yields (kg)	285	303

The R^2 of the other methods (5, 6, 7 and 9) have been extrapolated from the 4 and 8 methods results by means of a linear regression model.

Weighting factors for genetic evaluation

In the French genetic evaluation of production traits, each trait is weighted according to the lactation number (1 for a first lactation and lower for future ones) and according to its coefficient of determination (R^2) and its repeatability level (Rep.). The aim of the study was to estimate the latter weighting factor for each method, according to the following formula:

$$\text{Weighting factor} = 1 - \text{Rep.} / [1 - \text{Rep} + (1 - R2 / R2)]$$

with Rep= 0.5 for all yields and 0.7 for fat and protein percent.

Example: A8 method for milk yields

R^2= 0.972 and Rep.= 0.5

weighting factor= 1 - 0.5 / [1 - 0.5 + (1 - 0.972 / 0.972)] = 0.95 (applied for this lactation on genetic evaluation).

Results

Analysis of the lactation accuracy for each recording method

The analysis of the coefficients of determination (R^2) on 305-day lactation traits for the different methods shows (Table 2):

- a lower R^2 for fat yields and percent compared to the other traits;
- a lower R^2 for all traits for 8 methods compared to 4 methods. For example, R^2 is equal to 0.945 and 0.861 for fat yields and percent for T8 method compared to 0.989 and 0.962 for T4 method;
- a higher loss of accuracy for adjusted constant one-milking recording (C) compared to alternated milking. For example, R^2 for C*4 method is obtained with adjusted constant one-milking recording. It is equal to 0.853 for fat% compared to 0.962 for fat% for T4 method;
- a lower loss of accuracy for R8 method compared to A8 method.

The analysis of the mean bias on lactation traits for the different methods shows (Table 3) that as for R^2, bias are higher for 8 methods compared to 4 methods.

The different R^2 and bias between R and R* methods for non-adjusted traits (such as milk and protein yields and percent) are due to the fact that the records taken into account per lactation could differ between R and R* data sets, leading to different 305-days lactation traits.

Moreover, the lowest R^2 value and the highest mean bias values obtained for 8 methods correspond mostly to 305-day lactation traits estimated from lactation starting from the second record.

Table 2. Coefficient of determination (R^2) for each method.

Recording method	Milk yields	Fat yields	Protein yields	Fat%	Protein%
A4, R4	1	1	1	1	1
Z4	1	0.968	0.987	0.976	0.989
T4	0.997	0.989	0.997	0.962	0.997
R*4	0.997	0.954	0.997	0.878	0.997
C*4	0.966	0.940	0.971	0.853	0.955
A8	0.972	0.955	0.966	0.902	0.946
R8	0.980	0.970	0.979	0.941	0.963
Z8	0.972	0.934	0.956	0.876	0.927
T8	0.967	0.945	0.963	0.861	0.940
R*8	0.979	0.930	0.978	0.845	0.961
C*8	0.925	0.876	0.928	0.749	0.894

Table 3. Maximum mean bias (standard deviation of bias) for each method.

Recording method	Milk yields (kg)	Fat yields (kg)	Protein yields (kg)	Fat% %	Protein% %
A4, R4	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)
Z4	0 (0)	0.10 (13.3)	0.27 (6.23)	0.00 (0.14)	0.00 (0.06)
T4	11.1 (155)	0.85 (12.2)	0.39 (4.34)	0.01 (0.10)	0.00 (0.02)
R*4	30.6 (107)	0.06 (15.7)	0.88 (3.4)	-0.01 (0.15)	0.00 (0.01)
C*4	21.3 (263)	1.11 (18.4)	0.48 (7.5)	0.01 (0.18)	0.00 (0.03)
A8	-34.0 (238)	-2.32 (15.1)	-0.14 (10.1)	-0.02 (0.15)	0.01 (0.03)
R8	-149.4 (285)	-6.11 (12.5)	-3.13 (8.6)	0.01 (0.06)	0.01 (0.04)
Z8	-34.0 (238)	-2.22 (18.3)	0.30 (10.0)	-0.03 (0.18)	0.01 (0.07)
T8	28.6 (321)	1.74 (15.5)	0.44 (9.0)	0.03 (0.14)	0.01 (0.04)
R*8	-124.4 (291)	-5.75 (19.6)	-2.38 (8.9)	0.00 (0.16)	0.01 (0.04)
C*8	46.2 (407)	1.83 (22.3)	0.55 (12.7)	0.04 (0.21)	0.01 (0.06)

Table 4. New weighting factors for each method.

Recording method	Milk yields	Fat yields	Protein yields	Fat%	Protein%
A4, R4	1	1	1	1	1
A5, R5	0.99	0.98	0.98	0.92	0.96
A6, R6	0.97	0.96	0.97	0.85	0.92
A7, R7	0.96	0.93	0.95	0.79	0.88
A8, R8	0.95	0.91	0.93	0.73	0.84
A9, R9	0.93	0.89	0.92	0.68	0.81
Z4	1	0.94	0.97	0.92	0.96
Z5	0.99	0.92	0.96	0.85	0.92
Z6	0.97	0.91	0.95	0.79	0.87
Z7	0.96	0.89	0.93	0.73	0.83
Z8	0.95	0.88	0.92	0.68	0.79
Z9	0.93	0.86	0.90	0.63	0.76
T4	0.99	0.98	0.99	0.88	0.99
T5	0.98	0.96	0.98	0.82	0.95
T6	0.96	0.94	0.96	0.76	0.90
T7	0.95	0.92	0.95	0.70	0.86
T8	0.94	0.90	0.93	0.65	0.83
T9	0.92	0.88	0.91	0.6	0.79
R*4	1	0.91	0.99	0.68	0.99
R*5	0.99	0.90	0.98	0.67	0.96
R*6	0.97	0.89	0.98	0.65	0.93
R*7	0.96	0.88	0.97	0.64	0.91
R*8	0.95	0.87	0.96	0.62	0.88
R*9	0.93	0.86	0.95	0.61	0.86
C*4	0.93	0.89	0.94	0.64	0.86
C*5	0.92	0.86	0.92	0.59	0.82
C*6	0.90	0.83	0.90	0.55	0.79
C*7	0.88	0.81	0.89	0.51	0.75
C*8	0.86	0.78	0.87	0.47	0.72
C*9	0.84	0.75	0.85	0.44	0.69

Weighting factors for genetic evaluation

The comparison between the new weighting factors (Table 4) and the previous ones (Table 5) for each method brought out an overall underestimation for milk, fat and protein yields and an overestimation for fat and protein percent with the previous factors.

For example, the new milk yield weighting factor for A8 method is equal to 0.95 compared with 0.93 previously and the new fat% weighting factor for A8 method is equal to 0.73 compared with 0.78 previously.

The weighting factors obtained for new C* protocol are low mainly for fat percent for which it is equal to 0.44 for C*9 method.

Discussion and conclusions

Regarding the context in milk recording, the willingness of France Genetics Breeding (FGE) is to propose all the protocols and methods approved by ICAR to the farmers. The wish is to simplify and to reduce the cost of Milk Recording mainly in big herds and AMS Robots.

After analyzing the results of French studies (2018 and 2019) about respectively, a new AMS protocol with only one sample (R*), a new constant one-milking recording protocol (C*), the FGE board has proposed a program of implementation of these protocols in the dairy cattle milk recording Guidelines by the end of 2019 with conditions:

- to use the Liu's method for estimating 24-hour yields with C* protocol;
- to use the Peeters and Galesloot's method for estimating 24-hour fat percent and yields with R* protocol;
- to describe Standard Operating Procedure (FGE Guidelines, 2019);

Table 5. Previous weighting factors for each method.

Recording method	Milk yields	Fat yields	Protein yields	Fat%	Protein%
A4, R4	1	1	1	1	1
A5, R5	0.99	0.98	0.99	0.96	0.98
A6, R6	0.98	0.96	0.98	0.92	0.96
A7, R7	0.96	0.93	0.95	0.85	0.93
A8, R8	0.93	0.87	0.91	0.78	0.89
A9, R9	0.90	0.81	0.87	0.71	0.85
Z4	1	0.96	0.99	0.94	0.99
Z5	0.99	0.94	0.98	0.90	0.97
Z6	0.98	0.91	0.96	0.85	0.95
Z7	0.96	0.85	0.94	0.76	0.92
Z8	0.92	0.81	0.90	0.71	0.88
Z9					
T4	0.99	0.96	0.99	0.94	0.99
T5	0.98	0.94	0.98	0.90	0.97
T6	0.97	0.91	0.96	0.85	0.95
T7	0.96	0.85	0.94	0.76	0.92
T8	0.92	0.81	0.90	0.71	0.88
T9					

- to define weighting factors (for milk yields, fat percent, fat yields, protein percent, protein yields) among the level of individual lactation qualification model use by FGE and applied for genetic evaluation.

It was necessary to update the old weighting factors from new relevant datasets and to calculate factors for all protocols and methods.

The new weighting factors will have an impact on the accuracy of the cows' index, low weighting factors leading to reduced accuracy, the main goal is to improve the quality of genetic evaluation in accordance with ICAR Guidelines.

Regarding changes and evolutions in ICAR Guidelines, another FGE study project is scheduled in 2021 about the implementation of the new Liu's method (Kuwan and Bunger, 2019).

List of references

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