THE GLOBAL STANDARD
FOR LIVESTOCK DATA

Procedure 1 of Section 2 of ICAR Guidelines - Computing 24-hour Yields

Computing 24-hour Yields

Version May, 2022

Network. Guidelines. Certification.

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Change Summary

Date of Change	Nature of Change
July 17	Reformatted using new template.
Aug 17	Headings changed from Guideline B to Procedure 1.
Aug 17	Table numbers added with appropriate captions.
Aug 17	Equation numbers added to selected equations.
Aug 17	Index of Tables and Equations added to Table of Contents.
August 17	Stopped Track change sand accepted all previous changes.
August 17	Moved the file to the new template (v2017_08_29).
August 17	Edited short title. Updated version to August, 2017.
October 2017	Fixed some links and cross-references
May 2022	Update of Liu-method and adding the Kyntäjä-method.

1 Methods to calculate 24-hour yield for milk yield and fat percentage from a single milking

1.1 Method of Delorenzo and Wiggans (1986)

Daily milk (DMY) and fat yield (DFY) estimates are based on measured yield and milking frequency. An adjustment factor accounts for differences in the average milking interval (expressed in decimal hours) between the preceding milking and the measured milking, and the time of day of the measured milking (started in a.m. or p.m.). For 2X milking, an additional adjustment is applied to milk yield for the interaction between milking interval and stage of lactation, with mid lactation (158 DIM) set to zero. Milking interval does not affect protein and solids non fat (SNF) percentages and so the percentages for the sampled milking are used for test-day estimates. Protein yield is calculated from the measured percentage and the adjusted milk yield.

The prediction of DMY and DFY from single milking on morning or evening in herds milked twice a day requires factors, that are the reciprocal of the proportion of total yield expected from single milkings in relation to the milking interval.

We propose to derive these coefficients (intercept, slope, etc.) for each country separately.

1.1.1 Adjustment of milking interval

The milking interval is the interval between milking time for the observed milking and the milking time preceding the observed milking. The milking interval is divided into 15-minutes classes. Factors for milk and fat yields may be calculated to each class using Equation 1:

Equation 1. Factors for milk and fat yields.

$$\text{factor} = \frac{1}{[\text{Intercept} + (\text{slope} \times \text{milking interval})]}$$

1.1.2 Adjustment of lactation stage

Because the lactation stage of the cow has an influence on the effect of different milking intervals on milk production a second adjustment is made for every interval class through a covariate of days in milk as addition:

Covariate x (days in milk - 158)

1.1.3 Estimating sample day yields

Formulas for prediction sample day yields and percentages in herds with two milkings are:

Equation 2. Equation for predicting 24-hour milk yield.

$$\text{DMY} = \text{factor} \times \text{measured milk yield} + \text{covariate} \times (\text{days in milk} - 158)$$

Equation 3. Equation for predicting 24-hour fat percentage.

$$\text{daily fat percentage} = \text{factor for fat percentage} \times \text{measured fat percentage}$$

Equation 4. Equation for predicting 24-hour fat yield.

DFY = DMY x daily fat percentage

Equation 5. Equation for predicting 24-hour protein yield.

DPY = DMY x daily protein percentage

1.1.4 Practical Application

Two sets of factors are available for estimating DMY from a single milking, each for morning or evening milking sampling. The factors are calculated from the formula as described above and given in Table 1.

Table 1. Factor of milk yield and covariate for herds milked twice a day.

Length of milking interval in hours (minutes in decimal)	Morning milking		Evening milking	
	Factor	Covariate	Factor	Covariate
< 9.00	2.465	0.00710	2.594	0.00378
9.00-9.24	2.465	0.00710	2.534	0.00485
9.25-9.49	2.465	0.00710	2.477	0.00486
9.50-9.74	2.411	0.00716	2.423	0.00511
9.75-9.99	2.359	0.00726	2.370	0.00473
10.00-10.24	2.310	0.00458	2.321	0.00337
10.25-10.49	2.262	0.00399	2.273	0.00214
10.50-10.74	2.217	0.00294	2.227	0.00000
10.75-10.99	2.173	0.00223	2.183	0.00000
11.00-11.24	2.131	0.00000	2.140	0.00000
11.25-11.49	2.091	0.00000	2.099	0.00000
11.50-11.74	2.052	0.00000	2.060	0.00000
11.75-11.99	2.014	0.00000	2.022	0.00000
12.00	2.000	0.00000	2.000	0.00000
12.01-12.24	1.978	0.00000	1.986	0.00000
12.25-12.49	1.943	0.00000	1.951	0.00000
12.50-12.74	1.910	0.00000	1.917	0.00000
12.75-12.99	1.877	0.00000	1.884	0.00000
13.00-13.24	1.846	0.00000	1.852	-0.00190
13.25-13.49	1.815	0.00000	1.822	-0.00231
13.50-13.74	1.786	-0.00167	1.792	-0.00308
13.75-13.99	1.757	-0.00258	1.763	-0.00339
14.00-14.24	1.730	-0.00347	1.736	-0.00509
14.25-14.49	1.703	-0.00363	1.709	-0.00471
14.50-14.74	1.677	-0.00332	1.683	-0.00454
14.75-14.99	1.652	-0.00316	1.683	-0.00454
≥15.00	1.628	-0.00235	1.683	-0.00454

For estimating daily fat percentage there is only one table independent of morning or evening sampling – refer to Table 2.

Table 2. Factor of fat percentage for herds milked twice a day.

Length of milking interval in hours	Fat (percentage factor)
< 9.00	0.919
9.00-9.24	0.927
9.25-9.49	0.934
9.50-9.74	0.941
9.75-9.99	0.948
10.00-10.24	0.955
10.25-10.49	0.961
10.50-10.74	0.968
10.75-10.99	0.974
11.00-11.24	0.980
11.25-11.49	0.986
11.50-11.74	0.992
11.75-11.99	0.997
12.00	1.000
12.01-12.24	1.003
12.25-12.49	1.008
12.50-12.74	1.013
12.75-12.99	1.018
13.00-13.24	1.023
13.25-13.49	1.028
13.50-13.74	1.033
13.75-13.99	1.037
14.00-14.24	1.042
14.25-14.49	1.046
14.50-14.74	1.050
14.75-14.99	1.054
≥15.00	1.058

Milking-interval factors are calculated with the formula:

Equation 6. Equation for computing milking interval factors.

$$\text{Milking-interval factor} = \frac{1}{[\text{Intercept} + (\text{slope} \times \text{milking interval})]}$$

where the intercept and slope are as in Table 3.

Table 3. Slope and intercept for milk yield and fat yield.

Trait	Intercept		Slope
	For measured milking started in a.m.	For measured milking started in p.m.	
Milk yield	0.0654	0.0634	0.0363

Fat yield	0.1965	0.1939	0.0254

The milking interval has no significant influence on protein percentage. Therefore the protein percentage of the sampled milking is used as the daily protein percentage.

1.1.5 Calculation examples

1.1.5.1 Example of calculation of daily yields from morning milking

1.1.6

Table 4. Data for a cow from morning milking.

Begin of recording:	6:15	(Morning milking)
Start of preceding milking:	17:25	
Length of milking interval:	12 hours 50 minutes	(Expressed as decimal 12.83)
Milk results at morning:	12,0	Milk-kg
	4,12	Fat-percentage
	3,45	Protein-percentage
	120	Days in milk

Table 5. Factors for morning milking example.

The factor for milk yield from Table 1 is	1.877
The covariate is	0
The factor for fat percentage from Table 2 is	1.018

Table 6. Example calculations for morning milking.

The sample-day milk yield:	1.877 x 12,0 kg + 0 + (120 - 158) = 22,5 kg
The sample-day fat percentage:	1.018 x 4,12 = 4,19
The sample-day fat yield:	22,5 kg x 0,0419 = 0,94 kg
The sample-day protein yield:	22,5 kg x 0,0345 = 0,78 kg

1.1.6.1 Example of calculation of daily yields from evening milking

Table 7. Data for a cow from evening milking.

Begin of recording:	16:48	Evening milking
Start of preceding milking:	6:35	
Length of milking interval:	13 hours 47 minutes	Expressed as decimal 13.78
Milk results at evening:	14,0	Milk kg
	4,00	Fat percentage
	3,40	Protein percentage
	120	Days in milk

Table 8. Factors for evening milking example.

The factor for milk yield from Table 1 is	1.763
The covariate is	-0,00339
The factor for fat percentage from Table 2 is	1.037

Table 9. Example calculations for evening milking.

The sample-day milk yield:	1.763 x 14,0 kg - 0,00339 x (120 - 158) = 24,8 kg

The sample-day fat percentage:	1.037 x 4,00 = 4,15
The sample-day fat yield:	24,8 kg x 0,0415 = 1,03 kg
The sample-day protein yield:	24,8 kg x 0,0340 = 0,84 kg

1.1.6.2 Herds with alternate recording of components and milk yield at both milkings

For this plan only the sample-day fat yield has to be calculated with regard to milking interval. The milk yield is the sum of evening and morning milk results.

Table 10. Example data for a cow from both milkings.

Begin of recording evening:	17:25	
Milk results at evening:	10:00	Milk kg (only milking-yield)
Begin of recording morning:	6:15	
Milk results at morning:	12:00	Milk kg
	4:20	Fat percentage
	3:50	Protein percentage

Table 11. Factor for fat percentage.

Length of milking interval:	12 hours 50 minutes (expressed as decimal 12.83)
The factor for fat percentage from Table 2 is	1.018.

Table 12. Example calculation of daily yields.

The sample-day milk yield:	10,0 kg + 12,0 kg = 22,0 kg
The sample-day fat percentage:	1.018 x 4,20 = 4,28
The sample-day fat yield:	22,0 kg x 0,0428 = 0,94 kg
The sample-day protein yield:	22,0 kg x 0,0350 = 0,77 kg

1.1.6.3 Calculation for 3X Milking

For 3X herds, a single milking or two consecutive milkings may be weighed. The sample may be collected at one or both of these milkings. Stage of lactation × milking interval adjustments are not used for greater than 2× milking. These AM/PM factors for estimating daily yields in 3X herds should not be confused with factors that adjust 3X records to a 2X basis. Milking-interval factors are calculated using the same formula with the intercept and slope as in Table 13.

Table 13. Slope and intercept factors for 3X milking.

	Intercept			
Trait	**For measured milking started between 2 a.m. and 9:59 a.m.**	**For measured milking started between 10 a.m. and 5:59 p.m.**	**For measured milking started between 6:00 p.m. and 1:59 a.m.**	**Slope**
Milk yield	0.077	0.068	0.066	0.0329
Fat yield	0.186	0.186	0.182	0.0186

When two milkings are included for sampling, the intercepts and intervals for both milkings are included in determining a factor for calculated estimated milk yield that is applied to the total yield from both milkings as in Equation 7.

Equation 7. Milking interval factor for 3X milking.

$$\text{Milking-interval factor} = \frac{1}{[(\text{Intercept 1} + \text{Intercept 2}) + [\text{Slope} \times (\text{Milking Interval 1} + \text{Milking Interval 2})]]}$$

Milk and fat percent factors are calculated separately based on the number of milkings weighed or sampled.

1.1.6.4 Calculation for 4X - 6X Milking

The intercept terms for calculating 3X factors (0.077, 0.068, and 0.066) are multiplied by the factor [3 / (milkings per day)] for use in calculating factors for milking frequencies greater than 3X.

1.2 Method of Liu et al. (2019)

A multiple regression method (MRM) is used for estimating 24-hour daily milk yield (DMY), daily fat yield (DFY) and daily protein yield (DPY) based on partial yields from either morning (AM) or evening (PM) milking. Fat percentage (DFP) or protein percentage (DPP) on a 24-hour daily basis are then derived using the estimated 24-hour daily yields. The MRM can be used as a reference method for estimating daily yields and component percentages.

The method of Liu et al. (2019) is an updated version of the method of Liu et al. (2000). The model is only used for farms with 2 time milkings during 24 hours.

The following formula is used to estimate DMY, DFY, DPY based on partial yields (PMY, PFY,PPY) from either morning (AM) or evening (PM) milking:

Equation 8. Model for predicting 24-hour yield.

$$y_{ijk} = a + b_{ijk} * x_{ijk}$$

where:

y_{ijk} is the estimated 24-hour daily yield (DMY, DFY or DPY);

x_{ijk} is AM or PM partial daily yield on a test day (PMY, PFY, or PPY).

Subscript ***i*** represents class of parity effect with 2 levels: first and higher parities.

Subscript ***j*** represents class of length of preceding milking interval with 8 levels for AM milking: < 720 minutes, < 740 minutes, < 760 minutes, < 780 minutes, < 800 minutes, < 820 minutes, < 840 minutes, >= 840 minutes and 8 levels for PM milking: < 600 minutes, < 620 minutes, < 640 minutes, < 660 minutes, < 680 minutes, < 700 minutes, < 720 minutes, >= 720 minutes.

Subscript ***k*** represents class of lactation stage with 7 classes: < 60 days, < 120 days, < 180 days, < 240 days, < 300 days, < 360 days, >= 360 days.

a is the estimated intercept for the combination of parity class (i), milking interval class (j) and lactation stage class (k) for either AM or PM milking for the given trait.

$\boldsymbol{b}_{ijk}$ is the estimated slope for the combination of parity class (i), milking interval class (j) and lactation stage class (k) for either AM or PM milking for the given trait.

The factors for $\boldsymbol{a}$ and $\boldsymbol{b}_{ijk}$ can be found in Appendix 1.

For a given yield trait a total number of 112 formulae are to be estimated for calculating 24-hour daily yield based on partial yield from either AM or PM milking. Component percentage for fat (DFP) and protein (DPP), on a 24-hour basis is calculated by dividing estimated fat or protein yield by estimated daily milk yield:

$$\mathrm{DFP} = \frac{\mathrm{DFY}}{\mathrm{DMY}} \times 100, \text{ and } \qquad \mathrm{DPP} = \frac{\mathrm{DPY}}{\mathrm{DMY}} \times 100.$$

1.2.1 Calculation example with method of Liu et al. (2019)

Table 14. Data from an evening milking.

Date of milk testing:			23.04.2020					
Milking time :(AM/PM):			16:29 (PM)					
Length of preceding milking interval:			629 minutes, previous milking time 06:00 (AM)					
Cow ID	**Calving date**	**Lactation number**	**Milk yield (kg)**	**Fat content (%)**	**Protein content (%)**	**Fat yield (kg)**	**Protein yield (kg)**	**Index[1]**
A	01.01.2020	1	25,0	3,98	3,33	0,995	0,8325	1132
B	01.01.2020	2	25,0	3,98	3,33	0,995	0,8325	1232
C	27.03.2020	1	33,1	4,03	3,36	1,3339	1,1122	1131
D	27.03.2020	2	33,1	4,03	3,36	1,3339	1,1122	1231

[1] Index is marked in the Appendix table.

Table 15. Calculation of 24-hour daily yield and components for evening milking.

Date of milk testing:			23.04.2020		
Milking time :(AM/PM):			16:29 (PM)		
Length of preceding milking interval:			629 minutes, previous milking time 06:00 (AM)		
Cow ID	**DMY (kg)**	**DFY (kg)**	**DPY (kg)**	**DFP (%)**	**DPP (%)**
A	3,47396+25,0 * 1,98268 = 53,0401 ≈ **53,0**	0,2135+0,995 * 1,68050 = 1,8855975	0,10471+0,8325 * 1,99092 = 1,7621509	1,8855975 / 53,04096*100 ≈ **3,55**	1,7621509 / 53,04096*100 ≈ **3,32**
B	4,15080+25,0* 1,98520 = 53,7808 ≈ **53,8**	0,3635+0,995 * 1,47515 = 1,8312743	0,13952+0,8325 * 1,97074 = 1,7801611	1,8312743 / 53,7808*100 ≈ **3,41**	1,7801611 / 53,7808*100 ≈ **3,31**
C	2,80244+33,1 * 2,02183 = 69,72501 ≈ **69,7**	0,17663+1,3339 * 1,72438 = 2,4767805	0,11078+1,1122 * 1,96422 = 2,2953855	2,4767805 / 69,725013*100 ≈ **3,55**	2,2953855 / 69,725013*100 ≈ **3,29**
D	3,85525+33,1 * 2,00429 = 70,19725 ≈ **70,2**	0,27991+1,3339 * 1,62403 = 2,4462036	0,12863+1,1122 * 1,98973 = 2,3416077	2,4462036 / 70,7197249*100 ≈ **3,48**	2,3416077 / 70,7197249*100 ≈ **3,34**

Note that intercepts and slopes of the applied regression formulae are underscored.

1.2.2 Fat correction for equal measure sampling

With Equal measure sampling, it is advisable to use Equation 9 (or the like) to correct fat contents:

Equation 9. Fat correction for equal measure sampling.

Fat, % = Analysed fat, % + 0.69 – 1.3 x (morning milk/ 24-hour milk)

The relation of morning milk to 24-hour milk is to be calculated to at least four decimals.

1.3 Method of Kyntäjä and Nokka (2021): 24-hour correction factors for fat percentage

This method can be applied to calculate 24-hour correction factors for fat percentage, in case the milk recording is based on two milkings, with at least one known milk yield and one sample. A 24-hour recording day is assumed.

The conventional way to calculate correction factors is based on a data set where all milkings have been recorded and analysed separately. This approach requires a lot of effort and extra analysis, and is not cheap to organise. Organisations that have access to a large number of records may be able to use those data to calculate correction factors even if they have no extra analysis.

Requirements for the data set:

1. The data set has to be large enough. Every single factor needs to be based on at least 10,000 or, even better, 100,000 observations.
2. Each individual data set must contain at least one preceding milking interval, milk weight, and analysed sample. If it contains more milk weights, intervals etc. that is even better. It is also good to include breed, lactation number, days in milk and other data that may have an effect on the factors.

1.3.1 Calculation example of the method of Kyntäjä and Nokka (2021)

1.3.1.1 The accumulated data set

Since 2003, Finland had accumulated a data set of 7.5 million recordings with data on the time of the sampled and preceding milking as reported by the farmer, the lab analysis results, and the 24-hour milk yield. Grouped according to the preceding interval, the analysed fat content gives a nice sigmoid curve with the highest fat content found after a 540 to 630 minutes' interval (9 to 10.5 hours) and the lowest at 810 to 930 minutes (13.5 to 15.5 hours).

Table 16. Average analysed milk fat percentage by preceding interval class, 2003 – 2020.

Interval before Sampling (minutes)	Number of samples	Median interval in the class	Average fat content analysed (%)
<510	93,577	495	4.20
510-539	19,523	525	4.70
540-569	111,268	555	4.79
570-599	253,807	585	4.83
600-629	1,461,587	615	4.75
630-659	919,968	645	4.66
660-689	1,168,683	675	4.56

690-719	223,877	705	4.42
720-749	517,447	735	4.28
750-779	212,428	765	4.16
780-809	924,014	795	4.12
810-839	698,463	825	4.09
840-869	1,104,778	855	4.07
870-899	154,561	885	4.05
900-929	77,024	915	4.07
>929	26,977	945	4.13

The results were also divided into subgroups according to lactation number, phase of lactation, and breed. The effect of the preceding milk interval on milk fat seems to be bigger with older cows and in the beginning of lactation. It was also bigger with Ayrshire cows as compared with Holsteins. At this point, however, the decision was made not to take these factors into account when calculating new correction factors.

1.3.1.2 Calculation of new factors

The results above were turned into a simple set of correction factors, dependent solely on the preceding interval. In order to do this, two assumptions were made:

1. A 24-hour recording day was assumed. This way, we can deduce the second milking interval from the one we know and mirror the fat percent for that milking.
2. Milk secretion rate was assumed to be constant around the 24-hour period. This allows us to deduce the share of the 24-hour yield produced at each milking.

These assumptions allow us to create the new correction factors by mirroring the milk yield and milk fat content in the milking whose actual data we have not got. This way, we get the following formula:

Equation 10. Correction factor.

$$\text{Correction factor} = \frac{[(sampled\ milk \times sampled\ fat) + (mirrored\ milk \times mirrored\ fat)]}{(sampled\ milk + mirrored\ milk)}$$

Table 17. Calculation of the mirrored milking and the correction factors

Interval before sampling (minutes)	Average fat in the sampled milking (%)	Share of 24-hour milk in the sampled milking	Mirrored interval (minutes)	Average fat in the mirrored milking (%)	Calculated 24-hour average fat(%)	Correction factor
<510	4.21	0.34	>929	4.14	4.16	0.989
510-539	4.77	0.36	900-929	4.08	4.33	0.907
540-569	4.82	0.39	870-899	4.05	4.35	0.903
570-599	4.84	0.41	840-869	4.07	4.38	0.906
600-629	4.76	0.43	810-839	4.09	4.37	0.919
630-659	4.66	0.45	780-809	4.12	4.36	0.936
660-689	4.56	0.47	750-779	4.16	4.35	0.953

690-719	4.43	0.49	720-749	4.29	4.36	0.984
720-749	4.29	0.51	690-719	4.43	4.36	1.016
750-779	4.16	0.53	660-689	4.56	4.35	1.046
780-809	4.12	0.55	630-659	4.66	4.36	1.059
810-839	4.09	0.57	600-629	4.76	4.37	1.070
840-869	4.07	0.59	570-599	4.84	4.38	1.076
870-899	4.05	0.61	540-569	4.82	4.35	1.073
900-929	4.08	0.64	510-539	4.77	4.33	1.062
>929	4.14	0.66	<510	4.21	4.16	1.006

2 Standard methods to calculate 24-hour yields in Automatic Milking Systems

2.1 Using data on more than one day (Lazenby *et al.*, 2002)

An average of most recent milk weights is used for estimating 24-hour daily milk yield collected from Automatic Milking Systems (AMS). The average of most recent milk weights can be calculated using a number of preceding milkings or a number of preceding days. If number of milkings is used, the optimal estimate of the milking rate is obtained using an average of current milking together with the 12 most recent milkings back in time. The optimal estimate is the maximum value of the difference curve at which the correlation with the 'true' 24-hour milk yield is greatest and the variance across milkings is minimized. If number of days is used, the optimal estimate of the milking rate is obtained using an average of all milkings occurred in the last 96 hours (4 most recent days). In Table 18 the percent of maximum difference for various number of milkings and days is reported. The optimal estimate is independent from stage of lactation and parity.

Table 18. Percent maximum for different number of days and milkings.

Days	Percent Max.	Current milking + most recent milkings	Percent max.
1	49.38	10	97.85
2	77.26	11	99.08
3	92.34	12	99.70
4	98.91	13	99.81
5	98.50	14	99.40

2.1.1 Example for calculating 24-hour milk yield

Table 19. Data for milk volume from 12 previous milkings for AMS.

Date	Milk yield (kg) y_i	Time (hrs) t_i
2000-12-26	$y_i = 10.7$	$t_i = 6.50$
	$y_i = 10.1$	$t_i = 6.03$
	$y_i = 13.2$	$t_i = 7.80$
2000-12-25	$y_i = 9.6$	$t_i = 6.00$
	$y_i = 12.5$	$t_i = 7.02$
	$y_i = 11.9$	$t_i = 6.50$
	$y_i = 10.4$	$t_i = 6.20$
2000-12-24	$y_i = 11.7$	$t_i = 6.77$
	$y_i = 11.0$	$t_i = 6.38$
	$y_i = 10.1$	$t_i = 6.45$
	$y_i = 8.5$	$t_i = 5.13$
2000-12-23	$y_i = 13.7$	$t_i = 4.32$
	$y_i = 6.0$	$t_i = 6.90$
	$y_i = 10.5$	$t_i = 6.90$
	$y_i = 9.5$	$t_i = 6.30$

Current milking (first row)
12 milkings back (rows 2–13)
4 days (all rows)

Therefore, 24-hour yield estimation using most recent milkings (1+12) is computed using Equation 11.

Equation 11. 24-hour yield estimation using 12 previous milkings from AMS.

$$\text{24 Hour Milk Yield} = \left(\frac{\sum_{i=1}^{13} y_i}{\sum_{i=1}^{13} t_i} \right) * 24 = \left[\frac{(10.7 + 10.1 + 13.2 + \cdots + 8.5 + 13.7 + 6.0)}{(6.5 + 6.03 + 7.8 + \cdots + 5.13 + 4.32 + 6.9)} \right] * 24 = 40.8$$

and, 24-hour yield estimation using all milkings occurred in the last 96 hours (most recent 4 days), all milking in the last 4 days are included is computed using Equation 12.

Equation 12. 24-hours yield estimation using milkings from last 96 hours from AMS.

$$\text{24 Hour Milk Yield} = \left(\frac{\sum_{i=1}^{15} y_i}{\sum_{i=1}^{15} t_i} \right) * 24 = \left[\frac{(10.7 + 10.1 + 13.2 + \cdots + 6.0 + 10.5 + 9.5)}{(6.5 + 6.03 + 7.8 + \cdots + 6.9 + 6.9 + 6.3)} \right] * 24 = 40.2$$

2.1.2 Advantages and disadvantages of this method

In terms of Milk Yield, this method leads to a better accuracy of the estimation of the true performance than a performance estimated on a 24-hour basis only. However, problems of disconnection between milk weights and contents may arise if contents are recorded on one day only. Moreover, some cows may begin or finish their lactation during the period of recording. In this case the computation of milk yield must be adapted. The number of data that need to be validated is higher (for instance, contents have short interval between two milkings)

2.2 Using data on 1 day (Bouloc *et al.*, 2002)

When the number of milkings is reduced to milkings obtained during one day only, the accuracy of the estimation of the true performance is the same as classical milk recording methods with the same interval between two test days. For instance, Milk Yield estimated from all the milkings recorded during 24 hours, and with an interval between two test days of four weeks has the same accuracy as A4.

2.3 Estimation of fat and protein yield (Galesloot and Peeters, 2000)

Calculation of fat and protein percent must be based on milk weights at time of sampling. The 24-hour protein percentage can be predicted by the protein percentage of the sample without adjustment. However, the 24-hour fat percentage is more difficult to predict, as levels of fat percent are inversely proportional to the amount of milk yield. It is important then to have a close connection between time of samples and actual milk yields. The best prediction of 24-hour fat percentage should include fat percentage, protein percentage, milk yield and milking interval of the sampled milking, milk yield and milking interval of the preceding milking, and the interaction between milking interval and the ratio of fat to protein percentage of the sampled milking. After the estimation of 24-hour fat and protein percentages, 24-hour fat and protein yield are computed using the preceding 24-hour average milk yield. Under defined restrictions (correct matching, interval at least 4 hours, no interrupted milking) one sampled milking suffices to get a satisfactory estimate for the test day fat yield.

A disadvantage of this procedure is that a 24-hour milk yield computed using an average of the last day is subject to a higher degree of variability.

A possible solution could be to use the optimal estimate of 24-hour yield (12 milkings or 4 days) accounting for the negative relationship between fat and protein percent and milk yield as in Equation 13.

Equation 13. Fat percent estimate adjusted for negative relationship between fat percent and milk yield.

$$Fat\%_{est} = Fat\%_{obs} + b * (Milk_{est} - Milk_{obs})$$

Where $Fat\%_{obs}$ is the observed fat percent at time of sample/s, $Milk_{est}$ is the optimal estimate of 24-hour milk yield, $Milk_{obs}$ is the observed milk yield at the time of sample/s, and ***b*** is a linear or curvilinear regression of milk yield on fat percent. Further research is needed to estimate a ***b*** specifically for each population/breed.

2.4 Sampling period (Hand *et al.*, 2004; Bouloc *et al.*, 2004)

Given the high variability of milking frequency within and across cows during a 24-hour period, the best estimate of fat and protein percentages could be then calculated when samples are taken through the complete period. However, a 24-hour sampling is not always a feasible solution for milk recording agencies due to higher cost of this procedure. A less than 24-hour sampling period could be sufficient for a reasonable estimation of fat and protein percentages. Comparison of different protocols suggests collecting all samples (adjusted or unadjusted for covariates) on a 16-hour test day is the optimal protocol when estimating 24-hour yields of fat and protein. Table 20 illustrates differences in concordance correlations at various lengths of sampling periods.

Table 20. Percent fat, concordance correlations and 95% tolerance intervals.

Sampling hours	Adjusted for covariates			Unadjusted for covariates		
	Concordance correlation	Lower limit	Upper limit	Concordance correlation	Lower limit	Upper limit
10	0.887	-0.668	0.678	0.886	-0.772	0.770
12	0.836	-0.833	0.843	0.905	-0.707	0.700
14	0.922	-0.584	0.579	0.921	-0.645	0.626
16	0.936	-0.607	0.493	0.938	-0.573	0.545
18	0.953	-0.462	0.458	0.953	-0.503	0.467

Estimation of milk contents: It is recommended to select only milkings which took place at least 4 hours after the previous milking.

2.5 Milking events collected by the data recording system

All the milking events and milk yields (i.e., raw data) should be recorded by the data recording system. The computation of the 24-hour performance is done by the Milk Recording Organization, not via the AMS software in order to guaranty the harmonization of the method of calculation of performance between AMS.

3 Standard methods to calculate 24-hour yields from stationary milk meters

3.1 Using data on more than one day (Hand *et al.*, 2006)

An average of most recent milk weights is used for estimating 24-hour daily milk yield collected from Electronic Milk Meters. The average of most recent milk weights can be calculated using a number of preceding days. Table 21 reports the concordance correlations for a range of multiple-day averages. As soon as at least the 3 preceding days are used in the calculation, the concordance correlation reaches a high value of at least 0.981. There are no significant differences between 3,4,5,6 and 7-day averages. The correlations are independent from stage of lactation and parity. Thus, 24-hour yields can be the average of from 3 to 7 daily milkings previous to the test day when fat and protein samples were taken.

Table 21. Concordance correlations for different multiple-day averages.

Multiple-day average	Concordance correlation
1	0.957
2	0.975
3	0.981
4	0.981
5	0.982
6	0.981
7	0.981
10	0.979
14	0.977

3.1.1 Example for calculating 24-hour milk yield

Table 22. Example data for Calculating 24-hour milk yield using 5 day average.

Date	Milk yield (kg) y_i	24-hour milk yield (kg)
2007-11-10	y_i = 21.5 y_i = 21.0	m24 = 42.5
2007-11-09	y_i = 22.5 y_i = 23.0	m24 = 45.5
2007-11-08	y_i = 24.0 y_i =17.0	m24 = 41.0
2007-11-07	y_i = 25.0 y_i =22.0	m24 = 47.0
2000-11-06	y_i = 26.5 y_i =16.5	m24 = 43.0

Therefore, 24-hour yield estimation averaging over 5 days is given by Equation 14.

Equation 14. 24-hour yield estimation averaging over 5 days.

$$\text{24 Hour Milk Yield} = \left(\frac{\sum_{i=1}^{5} m24_i}{5} \right) = \left[\frac{(42.5 + 45.5 + 41.0 + 47.0 + 43.0)}{5} \right] = 43.8$$

3.1.2 Advantages and disadvantages of this method

Concerning Milk Yield, this method leads to a better accuracy of the estimation of the true performance than a performance estimated on a 24-hour basis only. However, problems of disconnection between Milk weights and contents have been shown. The estimation bias increases proportionally to the number of days use to compute the 24-hour average. Thus, this method is recommended only if milk weight is the only variable of interest. If milk contents are of interest then the milk weight should be calculated using the milkings from the same day of sampling.

3.2 Estimation of 24-hour fat and protein yield

Fat and protein yields should be determined from the 24-hour yield on the day of sampling, and not the averaged value.

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