NATIONAL COOPERATIVE DAIRY HERD IMPROVEMENT PROGRAM

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Standardization of NCDHIP Dairy Cattle Lactation Records

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Lactation records for cows are standardized so that yields of different cows can be compared. Currently, records of cows enrolled in the National Cooperative Dairy Herd Improvement Program (NCDHIP) in the United States are standardized for (1) number of times the cow was milked per day, (2) length of the lactation and (3) age of the cow and month of the year at calving.

Number of Milkings Per Day

Milking cows three times a day (3X) results in increased yield (Table 1) compared with milking two times a day (2X). (For additional information, see Fact Sheet I-2.) For evaluating genetic merit, this environmental effect must be removed so that cows milked 3X can be compared fairly with those milked 2X.

Records from cows milked on one or more sample days 3X can be adjusted to a 2X basis by

$$Y_{2X} = \frac{Y_{3X}}{1 + RI\left(\frac{DIM_{3X}}{DIM}\right)}$$

where Y_{2X} = equivalent 2X yield for the record, Y_{3X} = yield from record with 1 day or more milked 3X, RI = relative increase in production (see Table 1), DIM_{3X} = days of the record computed from 3X sample days, and DIM = total days in milk. For example, if a 2-year-old cow has a 305-day lactation record of 17,000 pounds of milk with 100 days milked 3X, her 2X standardized lactation yield would be

$$\frac{17,000}{1 + .2\left(\frac{100}{305}\right)}$$

or 15,954 pounds of milk.

If the days milked 3X is the same as the total days in milk, the formula simplifies to

$$Y_{2X} = \frac{Y_{3X}}{(1 + RI)}$$

If this cow had been milked 3X for her entire lactation, her equivalent 2X yield would have been 17,000/(1 + .2) or 14,167 pounds.

Length of Lactation

The accepted standard length for a lactation record is 305 days. This standard allows for a calving every 12 months with a 60-day dry period. The 12-month interval has been considered "ideal" for many years. If a cow is milked longer than 305 days, her yield for the first 305 days is taken as the lactation yield. Some cows are not milked for a full 305 days because they go dry or the lactation is terminated for any of several reasons. These short records are projected to a 305-day equivalent.

Projection Procedures for Milk and Fat

The procedure for projecting lactation records of less than 305 days to 305 days is based on the yield for the number of days the cow actually milked, plus an estimate for the remainder of the 305-day lactation derived from the last available sample-day yield. For records with less than 155 days in milk, the average mature-equivalent (ME)

Table 1. Relative increase[1] in yield from milking three times a day (3X) compared with milking two times a day (2X) by age of cow.

Age (years)	Relative increase
2	.20
3	.17
4	.15

[1]Increase from 3X milking divided by yield from 2X milking.

yield for cows freshening in the same herd 1 to 2 years prior to the record's last sample day also is required. This use of ME herd average increases the accuracy of the projection by providing information on the normal yield level of the herd.

Separate factors have been developed by trait (milk or fat), calving season, lactation number, region of the country and breed.[1] The four calving seasons are (1) December through February, (2) March through May, (3) June through August and (4) September through November. Lactations are grouped into (1) first lactations and (2) second or later lactations. For Ayrshires and Brown Swiss, national factors were developed; for Guernseys, Holsteins and Jerseys, the country was divided into three regions. Jersey factors are used for Milking Shorthorns, and Holstein factors are used for Red and Whites. Factors for Holsteins in the northern United States are reported in Table 2.

Records with less than 305 days in milk can be projected by

$$\hat{Y}_{305} = Y_{DIM} + (\hat{\bar{Y}}_D)(305 - DIM)$$

where $\hat{Y}_{305}$ = projected 305-day yield, Y_{DIM} = yield for the partial record, $\bar{Y}_D$ = estimated average daily yield for the remainder of the lactation, and $(305 - DIM)$ = days remaining. For records with more than 155 days in milk, average daily yield for the remainder of the lactation can be estimated as

$$\hat{\bar{Y}}_D = [\alpha_S + \beta_S(DIM)](Y_S) + \alpha_F + \beta_F(DIM)$$

where α = intercept, S = sample day, β = slope, Y_S = sample-day yield, and F = factor. Example values of sample-day and factor intercepts and slopes are shown in Table 2. For records with 155 days in milk or less, the ME herd average is included in estimating average daily yield:

$$\hat{\bar{Y}}_D = [\alpha_S + \beta_S(DIM)](Y_S) + \left[\frac{\alpha_H + \beta_H(DIM)}{1,000}\right](Y_H)$$

where H = herd average and Y_H = herd-average yield. The herd-average intercepts and slopes in Table 2 were multiplied by 1,000 to simplify presentation. This multiplication must be reversed in the formula; thus, the herd-average intercept and slope are divided by 1,000.

For example, a first lactation Holstein cow that calved in December in the northern United States has a record in progress of 44 days. Her total yield for the record is 1,800 pounds of milk and 60 pounds of fat; her last sample-day milk yield at 44 days is 40 pounds of milk and 1.5 pounds of fat. Her herd's ME average is 17,000 pounds of milk and 610 pounds of fat. The factors for projecting the record are in Table 2. Her projected 305-day milk yield would be

$$1,800 + \{[.453 + (.00296)\,44]\,40$$
$$+ \left[\frac{1.314 + (-.01538)(44)}{1,000}\right] 17,000\}\,(305 - 44)$$
$$= 1,800 + (34.16336)\,(261)$$

or 10,717 pounds. Her projected 305-day fat yield would be

$$60 + \{[.316 + (.00340)\,44]\,1.5$$
$$+ \left[\frac{1.536 + (-.01149)(44)}{1,000}\right] 610\}\,(305 - 44)$$
$$= 60 + (1.32697)\,(261)$$

or 406 pounds.

Projection Procedures for Protein and Solids-Not-Fat (SNF)

Protein yield is projected by adjusting either last sample-day or average protein percentage and then multiplying by the estimated milk yield from the end of the partial record until 305 days in milk. This estimate is added to the partial record for protein to give the projected protein record.

Separate protein factors have been developed for calving season, breed and stage of lactation. The calving seasons are the same as those for milk and fat. Breeds are grouped into (1) Holstein, Milking Shorthorn, and Red and White and (2) Ayrshire, Brown Swiss, Guernsey and Jersey. Lactations are divided into four stages: (1) 6-49 days in milk, (2) 50-139 days in milk, (3) 140-239 days in milk and (4) 240-304 days in milk.

Protein factors can be represented as a function of days in milk by a quadratic equation:

$$F_P = a_1 + a_2(DIM) + a_3(DIM^2)$$

where F_P = protein factor and the a's are the coefficients in Tables 3 and 4. Records with 240 or more days in milk are projected with last sample-day protein percentage if available and within limits of 1 to 7 percent:

$$\hat{Y}_{305} = Y_{DIM} + \left(\frac{P\%_{LS}}{100}\right)(F_P)\,(\hat{Y}_R)$$

where $P\%_{LS}$ = last sample-day protein percentage, F_P is calculated with the a's in Table 3, and Y_R = estimated remaining milk yield. If last sample-day protein percentage is not available or is outside limits or the record has less than 240 days in milk, average protein percentage is used:

$$\hat{Y}_{305} = Y_{DIM} + \left(\frac{\overline{P\%}}{100}\right)(F_P)\,(\hat{Y}_R)$$

where $\overline{P\%}$ = average protein percentage = 100 (protein yield/milk yield) and F_P is calculated with the a's in Table 4.

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[1] Wiggans, G.R. and R.L. Powell. 1980. *Projection Factors for Milk and Fat Lactation Records.* **USDA Dairy Herd Impr. Ltr.** 56(1):1-15.

Table 2. Projection factors for Holsteins in the northern United States.

Calving season	Days in milk	Milk Sample day Intercept	Milk Sample day Slope	Milk Factor/herd average Intercept	Milk Factor/herd average Slope	Fat Sample day Intercept	Fat Sample day Slope	Fat Factor/herd average Intercept	Fat Factor/herd average Slope
		Intercept	Slope	Intercept	Slope	Intercept	Slope	Intercept	Slope
First lactation									
December–February	7- 55	.453	.00296	1.314	−.01538	.316	.00340	1.536	−.01149
	56-105	.570	.00085	.599	−.00238	.412	.00166	1.170	−.00483
	106-155	.536	.00117	.787	−.00416	.453	.00126	1.064	−.00383
	156-205	.547	.00148	4.866	−.03418	.399	.00209	.495	−.00226
	206-255	.376	.00232	9.545	−.05700	.361	.00228	.665	−.00309
	256-305	.502	.00182	−8.621	.01424	.485	.00179	.165	−.00113
March–May	7- 55	.367	.00364	1.487	−.01787	.272	.00334	1.623	−.01157
	56-105	.511	.00101	.578	−.00134	.361	.00174	1.146	−.00291
	106-155	.355	.00250	.981	−.00518	.138	.00386	1.783	−.00897
	156-205	.420	.00219	12.811	−.06840	.444	.00208	.701	−.00337
	206-255	.314	.00271	14.562	−.07694	.470	.00195	.599	−.00288
	256-305	.797	.00082	−10.551	.02154	.656	.00122	−.033	−.00040
June–August	7- 55	.437	.00312	1.268	−.01269	.328	.00308	1.529	−.00817
	56-105	.466	.00260	.844	−.00499	.323	.00316	1.511	−.00784
	106-155	.583	.00149	.699	−.00360	.455	.00190	1.241	−.00527
	156-205	.734	.00088	5.054	−.03293	.726	.00070	.320	−.00135
	206-255	.508	.00198	12.628	−.06988	.477	.00192	.698	−.00320
	256-305	.755	.00101	−3.981	−.00475	.728	.00094	.181	−.00117
September–November	7- 55	.494	.00286	1.234	−.01355	.336	.00350	1.577	−.01143
	56-105	.578	.00134	.661	−.00314	.391	.00250	1.321	−.00677
	106-155	.620	.00094	.619	−.00274	.530	.00117	.979	−.00352
	156-205	.737	.00039	7.600	−.03672	.690	.00039	.408	−.00145
	206-255	.278	.00263	24.020	−.11682	.245	.00256	1.071	−.00469
	256-305	.403	.00214	−12.652	.02699	.220	.00266	.113	−.00093
Second and later lactation									
December–February	7- 55	.379	.00197	1.615	−.01498	.250	.00297	1.849	−.01328
	56-105	.418	.00124	1.075	−.00517	.317	.00175	1.487	−.00670
	106-155	.380	.00161	1.273	−.00705	.335	.00158	1.452	−.00636
	156-205	.175	.00314	20.017	−.12387	.120	.00328	.939	−.00498
	206-255	.223	.00291	3.584	−.04371	.154	.00311	.592	−.00329
	256-305	.599	.00143	−37.383	.11694	.565	.00150	−1.103	.00336
March–May	7- 55	.346	.00149	1.693	−.01406	.253	.00172	1.832	−.00857
	56-105	.332	.00175	1.269	−.00636	.242	.00193	1.714	−.00642
	106-155	.269	.00235	1.360	−.00722	.071	.00356	2.271	−.01172
	156-205	.199	.00306	16.995	−.09916	.226	.00285	.878	−.00458
	206-255	.016	.00395	12.222	−.07588	.039	.00376	.663	−.00353
	256-305	.973	.00020	−35.230	.11021	.878	.00049	−1.099	.00338
June–August	7- 55	.362	.00161	1.520	−.01202	.238	.00240	1.893	−.01015
	56-105	.314	.00247	1.248	−.00706	.221	.00270	1.851	−.00939
	106-155	.233	.00325	1.436	−.00886	.062	.00421	2.231	−.01301
	156-205	.360	.00254	14.446	−.09237	.428	.00214	.543	−.00322
	206-255	.339	.00264	7.166	−.05686	.435	.00211	.316	−.00211
	256-305	.977	.00014	−31.780	.09587	.758	.00084	−.787	.00221
September–November	7- 55	.416	.00194	1.430	−.01329	.260	.00291	1.856	−.01247
	56-105	.409	.00208	1.042	−.00622	.253	.00304	1.751	−.01056
	106-155	.455	.00164	.957	−.00541	.314	.00246	1.492	−.00810
	156-205	.459	.00165	15.972	−.09260	.522	.00122	.556	−.00288
	206-255	.196	.00293	15.710	−.09132	.240	.00259	.663	−.00340
	256-305	.305	.00251	−30.126	.08843	.007	.00350	−.452	.00097

Table 3. Coefficients (a's) for calculating protein projection factors for records with 240 or more days in milk and last sample-day protein percentage available and within limits (1 to 7 percent).

Breed	Calving season	a_1	a_2	a_3
Holstein Milking Shorthorn and Red and White	December-February	1.352	−.001890	.000002400
	March-May	1.006	.000262	−.000000921
	June-August	1.006	.000262	−.000000921
	September-November	.583	.003470	−.000006880
Ayrshire, Brown Swiss, Guernsey and Jersey	December-February	1.583	−.003570	.000005440
	March-May	1.023	−.000128	.000000169
	June-August	1.023	−.000128	.000000169
	September-November	.629	.002910	−.000005550

Table 4. Coefficients (a's) for calculating protein projection factors for records with less than 240 days in milk or records with last sample-day protein percentage missing or outside limits (1 to 7 percent).

Breed	Calving season	Days in milk	a_1	a_2	a_3
Holstein, Milking Shorthorn and Red and White	December-February	6- 49	.723	.009780	−.00008580
		50-139	.923	.001780	−.00000582
		140-239	1.103	−.000787	.00000335
		240-304	−.029	.008650	−.00001630
	March-May	6- 49	.740	.009850	−.00008300
		50-139	.928	.002310	−.00000762
		140-239	1.047	.000617	−.00000155
		240-304	1.295	−.001450	.00000275
	June-August	6- 49	.757	.010000	−.00008900
		50-139	.959	.001930	−.00000800
		140-239	1.173	−.001130	.00000291
		240-304	.488	.004580	−.00000898
	September-November	6- 49	.732	.009510	−.00008490
		50-139	.928	.001660	−.00000641
		140-239	1.098	−.000759	.00000223
		240-304	.868	.001160	−.00000176
Ayrshire, Brown Swiss, Guernsey and Jersey	December-February	6- 49	.760	.008910	−.00007600
		50-139	.930	.002100	−.00000800
		140-239	1.198	−.001730	.00000569
		240-304	−.437	.011900	−.00002270
	March-May	6- 49	.776	.009350	−.00007790
		50-139	.950	.002360	−.00000800
		140-239	1.080	.000512	−.00000139
		240-304	.841	.002510	−.00000554
	June-August	6- 49	.805	.009350	−.00008080
		50-139	.979	.002390	−.00001110
		140-239	1.287	−.002000	.00000457
		240-304	.238	.006740	−.00001370
	September-November	6- 49	.783	.008380	−.00007460
		50-139	.951	.001640	−.00000724
		140-239	1.162	−.001380	.00000355
		240-304	.457	.004500	−.00000870

For example, for this Holstein cow, the protein factor would be

$$.723 + .00978(44) + (-.0000858)(44^2)$$

or .987. If her protein yield was 56 pounds, then her average protein percentage would be 56/1,800 or 3.11 percent. Her estimated remaining milk yield was 8,917 pounds; therefore, her projected 305-day protein yield would be

$$56 + (.0311)(.987)(8,917)$$

or 330 pounds.

Procedures to project SNF records have not been developed yet. The procedure for protein could be applied to SNF and would provide usable results.

Projection Procedures for 3X Records

Because the projection formula for milk and fat includes ME herd average or a factor based on 2X yield, 3X records must be adjusted to a 2X basis before projection. If the days milked 3X are equal to the total days in milk or the last sample day is reported as 3X, last sample-day yield and the record are adjusted to a 2X equivalent and then projected. Otherwise, only the record is adjusted before projection. Fat percentage is not adjusted.

For example, assume the Holstein cow above had a 3X record in progress of 68 days. Her total yield for the record was 3,800 pounds of milk; her last sample-day milk yield at 68 days was 60 pounds of milk. Her 2X milk yield would be 3,800/(1+.2) or 3,167 pounds; her last sample-day 2X milk yield would be 60/(1+.2) or 50 pounds. Her projected 305-day, 2X milk yield would be calculated as

$$3,167 + \{[.570 + (.00085)\,68]\,50$$
$$+ \left[\frac{.599 + (-.00238)(68)}{1,000}\right] 17,000\} (305-68)$$
$$= 3,167 + (38.82172)(237)$$

or 12,368 pounds. If days milked 3X had been less than total days in milk and last sample day had not been reported 3X, last sample-day yield would not have been adjusted.

Use of Projected Records for Genetic Evaluations

All lactation records with fewer than 305 days in milk are projected to 305 days for use in genetic evaluations calculated by USDA. Research[2] has shown that projecting lactation records to 305 days in milk for cows reported as having gone dry results in better estimates of the heritable portion of differences among cows and, therefore, better predictions of genetic merit. The rationale for this is that any cows that conceive extremely early in lactation must be dry before 305 days in milk although still milking well to allow for a sufficient dry period. Therefore, these cows were penalized unfairly by not being permitted to complete a 305-day lactation. Even if the records for some cows may not deserve projection because the cows went dry naturally, projection of the records will not result in credit for much additional yield because last sample-day yield will be quite low.

Projected lactation records are not given quite as much emphasis as a completed 305-day record because shorter records contain less information on the cow's performance and, therefore, are less reliable. A set of factors for assigning relative weighting to incomplete records of various lengths is shown in Table 5. Projected records that are used in genetic evaluations are weighted according to these factors.

Age and Month at Calving

The third adjustment made to standardize lactation records is for age of the cow and calendar month at calving. Yield is standardized to the yield that the cow would have produced if she had calved at a mature age in an environmentally average month. Such an ME record *cannot* predict what a cow will produce in the future because many things may happen to a cow before she reaches mature age, and environmental conditions that affect her future records may be quite different. The ME factors also should not be taken as an indication that heifers mature slower in some regions of the country or that cows are genetically superior in other regions. Breed and regional differences are caused by the many genetic and environmental effects that determine the yields of cows of different ages.

Adjustment factors for age and month of calving for cows in the United States were published in 1974 for milk and fat,[3] and adjustments factors for protein and SNF were published in 1979.[4] These factors were developed from a national set of NCDHIP lactation records with a statistical procedure that estimated the interaction of age of the

[2] Norman, H.D., F.N. Dickinson and J.R. Wright. 1985. *Merit of Extending Completed Records of Less Than 305 Days.* J. Dairy Science 68:2646.

[3] Norman, H.D., P.D. Miller, B.T. McDaniel, F.N. Dickinson and C.R. Henderson. 1974. *USDA-DHIA Factors for Standardizing 305-Day Lactation Records for Age and Month of Calving.* ARS-NE-40, 91 pp.

[4] Norman, H.D., B.G. Cassell, A.L. Kuck and F.N. Dickinson. 1979. *Factors for Standardizing 305-Day Protein and Solids-Not-Fat Records for Age and Month of Calving.* **USDA-DHIA Milk Components Sire Summary, Prod. Res. Rpt.** 178:11-21.

Table 5. Factors for weighting records used in genetic evaluations.

Days in milk	All milkings weighed on sample day		AM–PM testing plans	
	Record in progress	Terminated[1] record	Record in progress	Terminated[1] record
First lactation				
15- 45	.47	.70	.36	.65
46- 75	.58	.70	.49	.65
76-106	.67	.70	.60	.65
107-136	.75	.75	.69	.69
137-167	.81	.81	.78	.78
168-197	.87	.87	.85	.85
198-228	.92	.92	.90	.90
229-258	.96	.96	.94	.94
259-289	.99	.99	.97	.97
290-305	1.00	1.00	.98	.98
Second and later lactation				
15- 45	.40	.70	.30	.65
46- 75	.53	.70	.44	.65
76-106	.64	.70	.57	.65
107-136	.74	.74	.68	.68
137-167	.82	.82	.77	.77
168-197	.89	.89	.84	.84
198-228	.94	.94	.90	.90
229-258	.98	.98	.95	.94
259-289	.99	.99	.97	.97
290-305	1.00	1.00	.98	.98

[1]Terminated records with less than 107 days in milk receive more weight than records in progress so that poor daughters culled early will retain significant influence on their sire's evaluation.

cow and calendar month at calving on yield. For all breeds except Milking Shorthorn, factors were calculated on a regional basis and also were pooled on a national basis. Because of the limited data available for Milking Shorthorns, only national factors were computed. Holstein factors are applied to Red and White lactation records. Milk and fat yields are standardized to an ME basis by multiplying 305-day yield by the factor corresponding to the cow's age and calendar month at calving for the appropriate breed, region of the country, and yield trait. Fat factors are used to adjust protein yield for all breeds except Holstein, and to adjust SNF yield for all breeds except Guernsey,

Holstein and Jersey. For those breeds, multiplication of the fat factor by an additional adjustment is necessary. Example age and month factors for adjustment of yield of Holstein cows in New York are reported in Table 6.

If a Holstein cow calved in New York in January at an age of 18 months and her 305-day milk yield was 14,000 pounds, her ME milk yield would be 14,000 multiplied by 1.49 (the adjustment factor from Table 6) or 20,860 pounds. If her 305-day protein yield was 460 pounds, then her ME protein yield would be 460 multiplied by 1.49 (the adjustment factor for fat in Table 6) multiplied by .8974 (the protein adjustment in Table 6) or 615 pounds.

Table 6. Adjustment factors for New York dairy cows calving in January by breed and selected ages at calving.

Breed	Age at calving (months)	Adjustment factor for:		Adjustment to fat factor for:	
		Milk	Fat	Protein	Solids-not-fat
Ayrshire	18	1.39	1.36	1.0000	1.0000
	24	1.21	1.18	1.0000	1.0000
	36	1.10	1.08	1.0000	1.0000
	48	1.02	1.01	1.0000	1.0000
Brown Swiss	18	1.56	1.52	1.0000	1.0000
	24	1.42	1.38	1.0000	1.0000
	36	1.20	1.17	1.0000	1.0000
	48	1.06	1.04	1.0000	1.0000
Guernsey	18	1.27	1.27	1.0000	.9308
	24	1.19	1.18	1.0000	.9721
	36	1.07	1.06	1.0000	.9997
	48	1.00	.99	1.0000	1.0027
Holstein	18	1.49	1.49	.8974	.9837
	24	1.30	1.30	.9751	.9827
	36	1.13	1.14	.9758	.9899
	48	1.04	1.04	.9921	.9941
Jersey	18	1.41	1.40	1.0000	1.0146
	24	1.26	1.25	1.0000	.9940
	36	1.10	1.08	1.0000	1.0050
	48	1.01	1.00	1.0000	1.0094

Summary

Differences among cows (such as herd, breed, region, milking practices, length of lactation, age and season) often make comparison difficult. Standardization of records allows for more accurate comparisons between cows and the evaluation of their sires.