

RELATIONS BETWEEN TEST-DAY MILK PRODUCTION OF HOLSTEIN COWS¹

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SUMMARY

Milk production on test day from 6,715 Holstein-Friesian HIR 2 × and 3 × records during 1952-54 was studied, to determine the relations between production for single months and cumulative production, and to develop factors for extending part production to a 305-day basis.

Correlations between milk produced on test days were largest for adjacent months and ranged from .38 to .89 for 2 × - cows under 3 yr.; from .23 to .88 for 2 × - 3 yr. and over; from .39 to .89 for 3 × - under 3 yr., and from .21 to .88 for 3 × - 3yr. and over.

Correlations between milk production on test day, and the sum of milk produced on ten test days, ranged from .71 to .93, were higher for the young cows, were similar for different milking frequencies in the same age group, and were highest during the 4th to 7th mo. The regressions of the sum of production for ten test days on single test-day production had relationships similar to the corresponding correlations.

Factors developed from the ratio of total to cumulative part production, and from the regression of total on part production, are presented. The ratio method may underestimate total production of low-producing cows and overestimate total production of high-producing cows, since the ratio method corrects only for the incompleteness of the lactation and does not take into account the incomplete repeatability of the parts of the lactation, which is a part of the regression method. This difference is largest during the early months.

Biased evaluation of a sire's transmitting ability may result from the selection of daughters and/or their records. Programs for proving sires allow dairy-men to determine at an early stage in lactation those cows which are unsatisfactory producers, and to remove these from their herds, in order not to lower the average production of a sire's daughters. If this procedure is common, and since injury and disease cause cows to leave herds prior to completion of lactations, perhaps some use should be made of information available in part lactations, which is not being utilized.

Associations between milk production at various stages in lactation have led workers (1, 4) to suggest that certain periods of the lactation may be more indicative of production for the entire lactation than are other periods. Several workers have developed factors for predicting total (305- or 365-day) production from single tests or cumulative parts of lactations (1, 5, 6, 9, 10). Few workers (6, 9, 10) have included age as an influence requiring joint consideration, although there has been general agreement for many years that younger cows are more persistent, but with lower maximum production, than older cows.

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part and total milk production were measured in this study. Factors were developed for extending incomplete production records to a 305-day basis. Age, milking frequency, and level of production were considered as influences which might affect the prediction factors obtained.

DATA AND METHODS USED

Monthly milk production recorded during 1952-54 for Holstein-Friesian Herd Improvement Registry (HIR) cows² throughout the United States was utilized. The first ten tests were used from lactations which had production recorded for at least ten different test days. Lactations with the same milking frequency ($2 \times$ or $3 \times$) throughout were utilized. Previous work (9) indicated that two age groups should be considered; namely, lactations which were initiated prior to 3 yr. of age and lactations initiated at 3 yr. and older. These same age groups have been used in the present study for several reasons: (1) When average monthly test-day production for year of age was plotted, the lactation curves for one- and two-year-olds were parallel, the curves for three-, four-, five-, and six-year-olds were parallel, but differed from the younger ages (one and two) by achieving a larger maximum but declining more rapidly, the curves crossing at about 9 mo. in production. (2) Average production on first test day for monthly age groups through 6 yr. of age differed significantly, and tests by Duncan's Multiple Range test (3) indicated means for ages under 3 yr.; and means for ages 3 yr. and older did not differ within groupings, i.e., overlapping within groups occurred, but overlapped between groupings only at 35 and 37 mo. of age. (3) When 3,930 Michigan DHIA-IBM Holstein records (8) were plotted by lactation number and age at freshening through 50 mo. of age (with age in months as the abscissa and per cent freshening at a given age for each lactation number as the ordinate), curves of the first and second lactation crossed between 35 and 36 mo. of age, and curves of the second and third lactation crossed between 47 and 48 mo. of age. That is, between 35 and 36 mo. of age the per cent of first lactations initiated was approximately equal to the per cent of lactations initiated. Twelve per cent of the second lactations were initiated prior to 36 mo. and 10% of the first lactations were initiated after 35 mo. Similar reasoning applies to the second and third lactations. Since HIR lactations would not be expected to start at an earlier age than DHIA lactations, and since the most important information lost pertains to incomplete first lactations, it seemed sufficient to proceed with the two age groups (under 3 yr., and 3 yr. and over).

RESULTS AND DISCUSSION

The number of lactations satisfying the above conditions are presented (in Table 1), with the corresponding average production on various test days. Approximately equal average production for the young and older groups is noted at the 9th mo., with the young cows exceeding the older cows at the 10th mo. Somewhat more variability is in the "under 3" group than in the "3 and over" group and in the $3 \times$ than in the $2 \times$. Curves of average monthly production

² These data were provided by the Holstein-Friesian Association of America, Brattleboro, Vermont.

TABLE 1
Average test-day milk production^a

Milking frequency	2 ×		3 ×	
Age	Under 3 yr.	3 yr. and over	Under 3 yr.	3 yr. and over
No. records	1,662	4,037	254	762
Test day	(lb.)			
1	41.3	56.7	46.3	59.1
2	42.0	57.0	47.0	61.5
3	39.3	52.4	45.0	57.5
4	37.1	47.6	42.9	52.5
5	35.3	43.6	40.9	48.5
6	33.7	40.0	39.6	45.2
7	32.3	36.9	38.5	42.1
8	30.6	33.3	36.4	38.6
9	28.4	29.3	34.4	34.7
10	25.3	24.2	31.1	30.5
Ranges of standard errors	.19 to .21	.15 to .18	.53 to .59	.36 to .46

^a Average milk production for a test day multiplied by 30.5 estimates monthly production. The sum of the ten monthly values estimates milk production for 305 days.

for 2 × and 3 × for the same age appear parallel, with the 3 × production larger than 2 × production. Since these curves are parallel, the same factors might be useful for extending 2 × and 3 × lactations; i.e., perhaps milking frequency is not an important factor to consider.

Single test-day relations. Milk produced each single test day is correlated with the amount produced every other test day for the two milking frequencies and two age groups in Table 2. As expected, adjacent months are correlated more closely than nonadjacent months. In general, these correlations are higher for the "under 3" than the "3 and over" groups, with only small differences between frequencies of milking. The lowest correlations between adjacent months appear between first and second, illustrating the increased variability of production on first test day, due in part to the varying stage of lactation at first test. Since these records were computed on a calendar-month basis, it was not possible to ascertain average days in production attributed to first test day. Michigan DHIA-IBM Holstein data (8) averaged 33.5 days for first test period, ranging from 4 to 56 days.

In order to ascertain which single test days are most closely associated with total production, correlations between single test-day milk production and the sum of milk production for the ten test days were computed. These correlations (presented in Table 3) were highest for the 5th mo., but high also for the 4th, 6th, and 7th mo. Since correlations between part and whole are partially automatic, one might expect the highest correlation between that single month which is the largest part of the whole, i.e., the month of maximum production. However, variability must be considered also and the single months 4 to 7 have the lowest variability and, therefore, are correlated more closely with the total production than are the months of maximum production (1st to 3rd mo.). As expected from the data in Table 2, correlations are higher for the "under 3" than for the "3 and over" groups, but are about the same for the two milking frequencies.

TABLE 2
Correlations between single test-day milk production ^a
month of test

Month of test	2	3	4	5	6	7	8	9	10	2	3	4	5	6	7	8	9	10
1	.79	.72	.68	.64	.62	.58	.54	.49	.38	.76	.67	.64	.59	.60	.53	.50	.47	.39
2		.86	.82	.78	.74	.69	.65	.59	.49		.84	.82	.78	.75	.69	.63	.63	.53
3			.88	.84	.80	.74	.70	.63	.52			.86	.83	.81	.74	.70	.69	.56
4				.89	.85	.80	.75	.68	.56				.89	.84	.78	.73	.73	.61
5					.89	.85	.81	.74	.62					.87	.84	.78	.79	.68
6						.89	.85	.78	.65						.89	.81	.78	.64
7							.89	.80	.68							.86	.83	.70
8								.87	.74								.83	.71
9									.84									.85
1	.73	.64	.58	.54	.48	.43	.35	.30	.23	.70	.61	.57	.53	.48	.44	.38	.29	.21
2		.82	.76	.71	.63	.55	.48	.41	.33		.82	.77	.69	.62	.57	.50	.41	.32
3			.85	.80	.72	.65	.56	.48	.39			.85	.76	.71	.65	.57	.49	.38
4				.87	.79	.73	.65	.56	.45				.85	.77	.73	.64	.56	.44
5					.87	.80	.73	.64	.51					.85	.80	.71	.65	.52
6						.87	.80	.70	.57						.88	.78	.69	.56
7							.88	.79	.65							.86	.77	.64
8								.87	.73								.85	.72
9									.86									.85

^a All correlations differ significantly from zero at $P < 0.01$.

Regressions of total production on single test-day production are presented in Table 4 and, as in Table 3, the largest values occurred during the 4th to 7th mo.

Cumulative test-day relations. Since most routine production testing programs provide "total-to-date" production, the data in this study also were considered in a cumulative manner. Correlations between cumulative test-day production and the sum of production for ten test days are presented in Table 5. These correlations become larger as the cumulative part becomes an increasingly larger part of the total production, and in all groups are .9 by the 4th mo. of cumulative production.

To ascertain if different extension factors are required for low- or high-producing cows, quadratic regression equations of total on cumulative part production were fitted for the various age-milking frequency groups. The resulting multiple correlation values were within .006 of the correlation values presented in Table 5. These small differences indicate that the same relationship between part and whole production exists for low as for high producers, as has been noted previously (7).

TABLE 3
Correlations between single test-day milk production and the sum
of milk production for the ten test days^a

Milking frequency	2 ×		3 ×	
	Under 3 yr.	3 yr. and over	Under 3 yr.	3 yr. and over
Test day				
1	.75	.67	.71	.66
2	.86	.80	.86	.80
3	.89	.86	.89	.85
4	.92	.89	.91	.89
5	.93	.91	.93	.90
6	.93	.90	.92	.89
7	.91	.88	.91	.88
8	.90	.84	.87	.84
9	.85	.78	.88	.78
10	.74	.68	.77	.67

^a All correlations differ significantly from zero at $P < 0.01$.

TABLE 4
Regression of the sum of milk production for ten test days on
single test-day milk production

Milking frequency	2 ×		3 ×	
	Under 3 yr.	3 yr. and over	Under 3 yr.	3 yr. and over
Test day				
1	6.24	4.84	6.16	4.78
2	6.95	5.74	7.43	5.69
3	7.40	6.40	7.34	6.12
4	7.96	7.06	7.88	7.04
5	8.31	7.66	7.93	7.48
6	8.36	7.80	7.78	7.87
7	8.24	7.81	8.22	7.82
8	8.03	7.58	7.91	7.62
9	7.56	7.12	7.90	7.16
10	6.28	5.84	6.46	5.78

TABLE 5
Correlation between cumulative test-day production and total production^a

Cumulative months	2 ×		3 ×	
	Under 3 yr.	3 yr. and over	Under 3 yr.	3 yr. and over
1	.75	.67	.71	.66
2	.85	.79	.84	.79
3	.90	.85	.90	.86
4	.93	.90	.93	.90
5	.95	.93	.96	.93
6	.97	.95	.97	.95
7	.98	.97	.98	.97
8	.99	.99	.99	.99
9	1.00	1.00	1.00	1.00

^a All correlations differ significantly from zero at $P < 0.01$.

After deciding to use two age groups, one must develop appropriate factors for extending incomplete records to a 305-day basis. Some workers (1, 2, 9, 10) have obtained factors by the ratio method, where the ratio of total to cumulative part production provides a factor for extending the part to the total basis. Other workers (6, 7, 9, 10) have used a regression equation, whereby cumulative part production is multiplied by the regression, (b), of whole on part and added to an appropriate constant, (a), to estimate total production.

Factors for extending part production to a 305-day basis are presented in Table 6, where c represents the ratio of total to cumulative part production,

TABLE 6
Regression and ratio factors for extending cumulative test-day production to a 305-day basis

Cumulative months	Under 3 yr.			3 yr and over		
	a^a	b^a	e^b	a	b	c
			2 × Milking frequency			
1	87.68	6.24	8.36	146.46	4.84	7.42
2	38.76	3.68	4.15	72.64	3.06	3.70
3	20.02	2.65	2.82	39.74	2.30	2.53
4	9.40	2.10	2.16	21.19	1.87	1.97
5	2.19	1.76	1.77	9.54	1.60	1.64
6	-1.62	1.52	1.51	0.89	1.41	1.42
7	-4.04	1.34	1.32	-4.62	1.27	1.26
8	-4.27	1.20	1.18	-6.80	1.16	1.14
9	-3.16	1.09	1.08	-5.94	1.08	1.06
			3 × Milking frequency			
1	117.14	6.16	8.69	185.22	4.78	7.89
2	42.06	3.86	4.31	97.41	3.08	3.88
3	18.02	2.78	2.91	62.13	2.29	2.64
4	6.59	2.18	2.22	41.52	1.86	2.03
5	1.79	1.80	1.81	25.27	1.59	1.68
6	2.11	1.53	1.54	12.17	1.41	1.45
7	-2.37	1.35	1.34	5.12	1.27	1.28
8	-4.59	1.21	1.20	-0.06	1.16	1.16
9	-3.39	1.09	1.08	-2.42	1.08	1.07

^a b represents the regression of whole on cumulative part production and a represents the appropriate constant in the regression method.

^b c represents the ratio of whole to cumulative part production.

and a and b are appropriate constants for the regression equation. These are utilized as follows:

(a) Ratio method: The ratio factor multiplied by total-to-date production estimates 305-day production. From Table 1, cumulative 4 mo. $2\times$ —under 3 yr. production would be $(41.3 + 42.0 + 39.3 + 37.1)$ times 30.5, or 4,871 lb. This, multiplied by 2.16 (from Table 6) would be the estimated 305-day production (10,521), which must conform to the sum of all values in Column 1 of Table 1, multiplied by 30.5, since this is an average situation.

(b) Regression method: Using the same production data as above, but a and b values from Table 6, total-to-date production (4,871) multiplied by 2.10 and added to 30.5, times 9.40, equals 10,516 lb.

Regressions of total on cumulative part production (Table 6) were tested for differences between milking frequencies within age groups. The regressions for 1st mo. for young cows differed significantly. No other comparisons differed significantly, indicating that milking frequency is not of major importance in extending part production.

The ratio method may underestimate total production of low-producing cows and overestimate total production of high-producing cows (10), since the ratio method corrects only for the incompleteness of the lactation and does not take into account the incomplete repeatability of the parts of the lactation which is included in the regression method. The amounts of this difference and of the increased variance of the difference between estimated and actual total production have been presented by Harvey (7). The difference is $(b - c)(X - \bar{x})$, where b represents the linear regression of total on cumulative part, c represents the ratio of total to part, and X and \bar{x} represent cumulative and mean cumulative part production. Empirically (7, 10), and as reported previously (10), this difference $(b - c)$ is negative and largest ($c > b$) during the early (1-3) cumulative months, least during the center (4-6) ($c \geq b$), and positive and small during the longer (7-9) cumulative parts. The increased variance of the difference between estimated and actual total production becomes $(b - c)^2 \sigma x^2$, where σx^2 equals the variance of cumulative part production.

The choice between methods (ratio versus regression) depends on the purpose for which the method is to be used and the ease of use. The ratio method may appeal intuitively to many and is easier to develop and use. The variation in the total production estimated by ratio is more nearly like the variation in actual total production. In addition to the adjustment for incompleteness accomplished by the ratio method, the regression method adjusts also for unidentified sources of variation which make the part larger or smaller than average, and the total estimated by regression varies less than the actual total. As noted above, the differences between estimates by the two methods are largest during the early months.

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