March 1967

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Abstract

Whether to select for longer life in the herd or shorter calving interval depends on the genetic and phenotypic relationships among herd life, amount of milk in first lactation, and calving interval. Herd life and average calving interval are essentially phenotypically uncorrelated. The phenotypic and genetic correlations of herd life and milk in first lactation ranged from .19 to .25 and from .54 to .77, respectively. The phenotypic correlation of average calving interval and milk in first lactation ranged from .19 to .21. Estimates of the heritability of herd life ranged from .05 to .14. This heritability was reduced by 30% when the influence of milk in first lactation was eliminated. Selection of females for longer herd life or shorter calving interval would not be advantageous, but some consideration of the herd life of half-sisters and close ancestors could be of value in choosing young sires for testing.

The early studies of longevity or herd life were made using records from one or a few herds, and inferences were limited by specific management and disease conditions and by small numbers of animals. Rendel and Robertson (6) pointed out that with only a moderate margin between salvage value and cost of replacement the main economic advantage to be gained from a long productive life arises from the increase in selection intensity for milk production and, conversely, that the major economic loss due to a shortened herd life results from the inability to cull low producers. Van Vleck (10) studied Dairy Herd Improvement Association (DHIA) records in New York and found that cows with high milk production in their first lactations not only produced more than their herdmates in later lactations, but also had a higher survival rate in each of the first four lactations. White and Nichols (11) studied daughters of artificial insemination (AI) sires in Pennsylvania and found the heritability of number of lactations completed to be .13, but found little increase in herd life after production exceeded 5,000 kg in the first lactation.

The current study was initiated to investigate the importance of longevity in selection of dairy cattle.

Data and Methods

Dairy Herd Improvement Association milk records at the Dairy Records Processing Laboratory at Cornell University were used where the first lactation recorded for a cow sired by artificial insemination was begun at less than 35 months of age. A total of 100,280 cows was included.

The records were divided into opportunity groups, to enable comparisons of herd life before all cows had died. Seventeen months from the date of first calving was considered adequate opportunity to begin a second lactation. Each subsequent 15-month period completed before April 1, 1964, was recorded as an additional opportunity. Herd life was then measured as the number of recorded lactations truncated at the number of opportunities. Each cow was also included in every opportunity group smaller than her largest number of opportunities.

Milk production was measured as the deviation of the 305-day, 2×, mature equivalent (ME) milk record from the adjusted herdmate average (8). Incomplete records were extended to 305 days. These deviations were stratified into deciles by normal probabilities, with approximately equal numbers in each group.

Calving interval was the number of days between reported calvings. Limits of 270 days and 600 days were imposed to eliminate abortions, skipped lactations, and recording errors.

A one-way classification by sire groups was used to estimate components of variance and covariance in each opportunity group for all pairs of the traits, herd life, milk production, and calving interval. The heritabilities, phenotypic correlations, and genetic correlations were computed as outlined by Falconer (4) for a half-sib analysis. Only sires with 50 or more daughters were used in estimating the components of variance.

Two methods were used to eliminate the effects of selection for milk production on herd

Received for publication March 6, 1967.

TABLE 1
Average herd life [a] in each production level for each opportunity group

	Decile [b]	Opportunities for lactation								
		2	3	4	5	6	7	8	9	10
High	1	1.88	2.58	3.09	3.38	3.52	3.61	3.79	3.89	4.02
	2	1.87	2.56	3.03	3.34	3.54	3.71	3.89	3.98	3.96
	3	1.85	2.49	2.95	3.22	3.42	3.54	3.73	3.84	3.86
	4	1.85	2.49	2.92	3.17	3.36	3.46	3.62	3.89	3.87
	5	1.84	2.46	2.89	3.14	3.27	3.34	3.51	3.61	3.70
	6	1.82	2.40	2.78	3.00	3.10	3.22	3.36	3.40	3.40
	7	1.81	2.36	2.73	2.94	3.07	3.14	3.32	3.42	3.64
	8	1.78	2.29	2.61	2.76	2.83	2.95	3.06	3.18	3.04
	9	1.72	2.19	2.49	2.67	2.73	2.79	2.88	2.98	3.04
Low	10	1.54	1.83	2.00	2.09	2.13	2.19	2.27	2.33	2.39
St. error [c]		+.00	.01	.02	.03	.03	.04	.06	.08	.13
Avg		1.79	2.36	2.74	2.95	3.08	3.17	3.31	3.42	3.42

[a] Herd life in lactations and truncated at number of opportunities.
[b] Decile of deviation from herd mates of milk in the first lactation.
[c] Approximate standard error for each mean in the body of the table in the respective column.

life. The herd life records were adjusted by the simple regression of herd life on milk production and used to recompute components of variance. The heritability of herd life was also estimated within each decile for milk production, then averaged to estimate heritability of herd life for cows with approximately the same level of milk production. Sires with ten or more daughters in each opportunity group were used in the analyses within deciles.

Results and Discussion

Herd life. Average herd life for each opportunity group in each decile of first lactation production is listed in Table 1. In nearly every case the average herd life increased as first lactation milk increased. It is doubtful that many cows from the top six or seven deciles were culled for low milk production, yet herd life continued to increase as first lactation production increased. The greatest difference occurred between Deciles 9 and 10, where most of the culling for low production took place. The proportion of the total range among decile means accounted for by the difference between Deciles 9 and 10 decreased as more opportunities were added. This indicates that milk produced in the first lactation became less important in culling as the cow became older, as reported by Allaire (1). In opportunity groups 6, 7, 8, and 9 the second decile has a slightly longer average herd life than the highest producing group, indicating that extremely high production in the first lactation may have some detrimental effect on herd life after five lactations. These individual differences are not significant by the "t" test.

The means in the opportunity groups are low, because all cows have not yet been culled. Also, some herds had discontinued testing. These herds lower the average herd life in all opportunity groups, but should not bias heritability estimates if daughters are randomly distributed among herds.

The mean herd life of the daughters of each sire with 50 or more daughters in opportunity group 6 ranged from 2.60 to 3.72 lactations.

TABLE 2
Heritability of herd life, calving interval, and milk production

	Opportunities for lactation								
	2	3	4	5	6	7	8	9	10
No. of cows [a]	92,340	65,569	49,081	38,438	29,545	20,495	14,603	8,452	3,209
No. of sires [a]	245	185	140	103	78	52	48	35	25
Heritability									
herd life									
Unstratified	.05	.09	.10	.08	.07	.09	.10	.14	.10
Within decile	.05	.07	.07	.06	.05	.06	.07	.11	.04
Adjusted	.04	.06	.07	.06	.05	.06	.06	.10	.07
Calving interval	.04	.04	.04	.04	.03	.03	.03	.02	.03
Milk production	.22	.24	.23	.22	.21	.22	.22	.20	.19

[a] The numbers of sires and cows is about 25% less for calving interval and somewhat smaller for the heritabilities pooled within deciles.

This difference of more than a lactation between the best and worst sire average is equivalent to a difference of approximately 11% in the annual replacement rate for cows.

Heritability estimates for the three methods are listed in Table 2. Values in the unstratified row are estimates of the heritability of herd life as measured in this study. The heritability of this trait is low and shows little tendency to increase as the cow is given more opportunities for added lactations. There is a slight increase between the 2 and 3 opportunity groups, but heritability remains fairly constant after the 3 opportunity group. The intraclass correlation was tested in the 10 opportunity group and was significantly different from zero at the 5% probability level. The other estimates were not tested, because they were estimated from larger samples and would also be significant.

Low milk production is one of the traits frequently listed (3, 5) as a reason for culling cows. Since the additive genetic variance of milk production is well established, phenotypic selection for milk production must cause this genetic variance to be included in the additive genetic variance for herd life. Estimation of the heritability of herd life within decile groups eliminates most of the influence of selection for milk production and gives an estimate of the heritability of herd life eliminating the effects of selection for first lactation milk production. Correction of the data by the regression of herd life on milk production performs essentially the same function as estimation within groups, but more completely eliminates the effects of milk production if the relationship between milk production and herd life is nearly linear. The heritability of herd life was reduced by an average of 28% when computed within deciles and by 30% when the data were corrected by regression. The heritabilities were smaller in the central deciles, where the range of milk production was smaller. The heritabilities of herd life in the lowest decile were noticeably higher than in the other deciles, probably due to more intense selection for milk production within this decile.

Calving Interval

The average calving interval was 381.5 days, somewhat lower than most estimates in the literature, even though abortions were not included. The limit of 600 days imposed to omit clerical errors may have caused some bias downward, but examination of the omitted records indicated that most were truly in error.

The average calving interval of each decile group for milk included all available calving intervals but, of course, did not consider the length of the terminal lactation, which would likely be long if the cow was culled for breeding problems. These means are listed in Table 3.

There is a direct relationship between milk produced in the first lactation and a longer calving interval. Since milk production was measured as deviation from herd mates, this shows that the highest producers within the herd have longer calving intervals than their contemporaries producing less milk. The genetic and environmental covariances of these traits show that the association must be mostly environmental. Some increase in milk production is expected, because of the shorter period carrying calf during the first lactation. Another cause could be more intense culling of low producers that do not breed right back. Also, there is some evidence (9) that cows in high production may not return to estrus as quickly after parturition as lower producers. The low phenotypic correlation (0.05 to 0.08) between 90-day production and days open reported by Smith and Legates (7) indicates that much of this relationship may be extra production of milk, due to more days in milk.

The averages in the deciles are confounded with age, since the higher producers lived longer and had more calving intervals. The mean calving interval within each parity group is shown in Table 4. An analysis of variance found differences among these means at the .01 level, but the differences are small and could easily result from confounding with level of milk production.

Estimates of the heritability of the length of calving interval were consistently low, ranging from .02 to .04, as shown in Table 2. The sire component of variance was significantly different from zero at the .05 level in all cases, but the estimates were so low that much of the genetic variance could arise from inherited differences in length of gestation period (2).

TABLE 3
Average calving interval in each decile

Production decile	High 1	2	3	4	5	6	7	8	9	Low 10
Average C. I. (*days*)	394	388	386	383	381	380	377	376	372	369
No. of cows	9,138	8,321	7,956	8,305	8,228	8,194	8,022	7,668	7,267	6,261

TABLE 4

Average calving interval in each parity group

	Between lactations							
	1-2	2-3	3-4	4-5	5-6	6-7	7-8	8-9
Average C. I. (*days*)	382	380	381	383	385	387	392	389
No. of C. I.	75,578	37,587	20,357	10,466	4,936	2,129	953	336

Phenotypic and genetic correlations among these traits are shown in Table 5. The phenotypic correlation between herd life and milk production ranged from .25 to .19 and tended to decrease slowly as the cow was given more opportunities. This decline supports the earlier conclusion that milk in the first lactation becomes less important in deciding which cows are culled in later lactations. The genetic correlation between these traits was much higher than the phenotypic correlation, the estimates ranging from .54 to .77. This high genetic correlation arises both from pleiotropy and from selection for milk production. Because of this confounding, the genetic correlation is a measure of both selection intensity for milk production and the genetic association of milk production with the physiological mechanisms causing shortened herd life. These parts could not be separated using the usual techniques of analysis.

Herd life and calving interval were essentially unrelated, the phenotypic correlations being virtually zero. The genetic correlations are fairly large but have little significance, since the genetic variance of calving interval is such a small part of the phenotypic variance. Interpretation of these relationships is restricted, because the terminal lactation does not result in a calving interval measurement.

The phenotypic correlation between milk production and calving interval ranged from .19 to .21 and showed no trend. The genetic correlations were high, but contribute only a small part of the phenotypic association because of the low heritability of calving interval.

Conclusions

Selection for herd life or calving interval would not be effective because of their low heritabilities. Automatic selection resulting from a larger number of daughters of long-lived cows has placed a lower limit on selection for herd life, and moderate additional selection would not likely change much the mean of the selected group. The late stage of life at which a desirable herd life is expressed, coupled with automatic selection, makes further selection of female breeding animals utilizing herd life information a futile effort, except in certain unusual types of pedigree selection.

Many aspects of natural selection which limit the number of progeny of cows do not apply to sires. Artificial insemination allows a few bulls to service a large number of cows each. The high genetic correlation of herd life with milk production in the first lactation indicates that if these bulls are highly selected for genetic merit for high milk production, this should result in an increase in the average herd life. This increase in herd life will usually not be realized, however, since the average herd life is dependent only on the proportion of the herd replaced in a given unit of time which, in turn, is usually dependent on the number of heifer calves born and the success in raising them to milking age. What will be realized is an increase in the genetic merit for the traits which lead to long herd

TABLE 5

Phenotypic and genetic correlations among herd life (HL), average calving interval (CI), and first lactation milk production (MP)

	Opportunities								
	2	3	4	5	6	7	8	9	10
Phenotypic correlations									
HL and MP	.23	.25	.24	.23	.22	.21	.21	.21	.19
HL and CI	....	+ .00	− .01	+ .00	.01	+ .00	+ .00	.01	.01
CI and MP	....	.20	.19	.20	.19	.20	.20	.21	.19
Genetic correlations									
HL and MP	.54	.63	.62	.61	.65	.68	.74	.77	.76
HL and CI	....	.24	.34	.40	.59	.72	.62	.44	1.02
CI and MP	....	.43	.48	.47	.51	.55	.52	.51	.65

life, accompanied by a longer useful life for the better cows and more culling for low production.

The "genetic correlation" measured in this study, however, is partly a measure of the amount of selection for milk production and, as such, is dependent on the intensity of involuntary selection for traits other than milk production. If, for example, intense selection for milk production caused a correlated sharp increase in the rate of involuntary culling, then the intensity of selection for production in the next generation would decrease, and so would the "genetic correlation" between herd life and milk production.

The really useful correlation for prediction is the genetic correlation between milk production and some variable (wearability) which indexes causes of culling other than genetic merit for milk production. This correlation will be difficult to obtain. Estimation from a population where there is no culling for milk production may give an approximate estimate, but there are undoubtedly many factors, such as udder breakdown, which exert their effects as low milk production after several lactations but would not cause culling in the unselected population.

Estimation of the heritability of herd life within decile groups and from the corrected records gives biased estimates of the heritability of wearability (i.e., herd life eliminating the effects of milk production), but tells little about the genetic correlation of wearability with milk production.

The evidence in this study indicates that selection of sires primarily on the basis of the milk production of their daughters in the first lactation should not decrease the herd life of the daughters. However, it seems prudent to continue to screen dams of potential young sires, not only for high production but also for wearability, because of the unknown genetic correlation of wearability and milk production. It would also be valuable to have available the survival rates of tested daughters of AI sires on a lactation-to-lactation basis. These survival rates would measure the acceptance of daughters by their owners at each stage of their life and, when compared with the milk and fat proofs, could be valuable in choosing sires from which sons are desired for use in a young sire testing program.

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