FACTORS RELATED TO WEIGHT GAIN OF DAIRY CALVES [1]

T. G. MARTIN,[2] N. L. JACOBSON, AND L. D. McGILLIARD [3]
Department of Animal Science

AND

P. G. HOMEYER [4]
Department of Statistics
Iowa State University, Ames

SUMMARY

Growth data on 659 dairy calves were used to determine the effects of breed, sex, season of birth, inbreeding, ration, and birth weight on weight gains of dairy calves to 8 wk, six months, and 1 yr of age. Breed, sex, degree of inbreeding, and ration were found to be significant sources of variation. Effects of season of birth were significant in the analysis of weight gains to 1 yr. Correlations of birth weight with weight gains were all less than .40. Early rate of gain had little or no effect on later gains, age at calving, and milk production. Although calf nutrition experiments should be designed to prevent confounding breed, sex, and inbreeding effects with ration effects, a portion of these effects can be removed by using birth weight as the independent variable in an analysis of covariance.

Body weight increase has been used as a measure of the adequacy of numerous calf rations and managerial systems. A number of factors in addition to ration have been shown to affect calf growth. Rathore (23) found sex and breed differences in growth rate of dairy calves, and Rollins and Guilbert (25) found that sex and season of birth affected growth of beef calves. There are many other similar studies on beef calves. Baker et al. (3) and Nelson and Lush (19) observed that growth rate decreased as inbreeding increased.

The relationship between birth weight and early growth rate has not been reported on large samples of dairy cattle. Forshaw et al. (13) observed a correlation of 0.46 between birth weight and weaning weight of Duroc pigs. Dawson et al. (6) and Arizona workers (1) have reported growth of beef calves to be associated postively with birth weight.

Correlations of milk production with birth weight, six-month body weight, mature body weight, and growth reported by Straus (26), Bailey and Broster (2), Plum et al. (20), Blackmore et al. (4), and Holtz et al. (15) were generally small and positive. Results reported by Reid (24) showed no significant differences in first lactation production between heifers underfed and normally fed prior to their first lactations. Since there were differences in growth rate, these results imply that there is little or no relationship between growth rate and milk production. Age at first calving, however, was later for the underfed heifers than for those fed more liberally.

Objectives of the present study were: (a) to evaluate the effects of sex, breed, season of birth, birth weight, and inbreeding on early weight gains of calves; (b) to determine the relationship of milk production to birth weight and body weight gains.

SOURCE AND CLASSIFICATION OF DATA

Data used in this study were collected from experiments in calf nutrition conducted at Iowa State University from 1945 to 1954. The rations varied, but other management practices remained relatively constant over the 9-yr period. Each animal was classified according to sex, breed (Ayrshire, Brown Swiss, Guern-

Received for publication March 22, 1962.

[1] Journal Paper No. J-4269 of the Iowa Agricultural and Home Economics Experiment Station, Ames, Iowa. Project No. 1324. Some of the data were collected on Project No. 1053, which is a contributing project to Regional Project NC-2.

[2] Present address: Dairy Department, Purdue University, Lafayette, Indiana.

[3] Present address: Dairy Department, Michigan State University, East Lansing, Michigan.

[4] Present address: C-E-I-R, Inc., 9171 Wilshire Blvd., Beverly Hills, California.

sey, Holstein, or Jersey), season of birth (winter, December to February; spring, March to May; summer, June to August; or fall, September to November), degree of inbreeding (0-5, 6-10%, ..., 26-30%, or over 30%), and ration. Rations involved in 16 experiments were classified into five broad types: (a) rations containing either chlortetracycline or oxytetracycline; (b) liberal milk plus hay and grain; (c) limited milk (less than 300 lb milk per 100 lb birth weight) plus hay and grain; (d) milk only; and (e) rations containing unhydrogenated vegetable oil. Since there were more than 40 individual rations, the classes described above are rather arbitrary groupings and represent a gradation from the best diets to the poorest, based on growth rate and wellbeing of the calves.

There were 659 calves included in this study, though all calves could not be included in all of the several analyses of the data. Most of the calves were weighed at weekly intervals up to 8 wk of age and some were weighed at 12 and 16 wk. Only Holstein calves were routinely weighed at six and 12 months of age. Since only a few of the calves were weighed at all the above ages, gain from birth to 8 wk, gain from birth to six months, and gain from birth to 1 yr were treated separately. Inbreeding occurred in the Holsteins but not in the other breeds. The measure of birth weight was taken at four days of age, when the calf was removed from the dam.

ANALYSIS OF DATA

The least-squares technique described by Kempthorne (16, chapter 6) was used to evaluate simultaneously the effects of sex, breed, season of birth, and ration on 8-wk gain and birth weight. This allowed the effects of the factors to be tested for significance, both before and after adjustment of gain values for birth weight variation. The analysis is presented in Table 1. Effects of sex and breed were reduced by adjusting to a common birth weight. However, the effects of sex and breed on adjusted gains were significant sources of variation. The method of analysis assumed no interaction between the main effects, but allowed a test of the significance of pooled interactions.

Since six-month weights were available only for Holsteins, no estimates of breed effect could be obtained from analysis of six-month gain data. Constants were fitted simultaneously for birth weight, 8-wk gain, and 6-month gain, Effects of sex, season of birth, and ration on the variation of six-month gain, six-month gain adjusted for birth weight, six-month gain adjusted for 8-wk gain (essentially a test of the effects of the various variables on gain from 8 wk to six months of age), and six-month gain adjusted for both birth weight and 8-wk gain are shown in Table 2.

Most male calves left the herd between six and 12 months of age, thus reducing further the number of calves available for an analysis of factors affecting 1-yr gain. Results of the analysis of 1-yr gain data followed closely the results of the previous analyses, except that season of birth effects were significant ($P \leqslant .05$).

Constants derived from the three analyses described above are shown in Table 3. These are deviations from the general mean. An estimate of the difference between any two breeds is the difference between the constants for the two breeds compared. Comparisons of any two rations, seasons, or sexes can be made in a similar manner. The differences in birth weight associated with rations were due to

TABLE 1

Analyses of variance and covariance of birth weight and 8-wk gain

Source of variance	d.f.	M. S. birth weight	M. S. 8-wk gain	M. S. 8-wk gain adjusted for birth weight
Season	3	103	281	245
Sex	1	7,992**	5,409**	2,607**
Ration	4	158	21,886**	21,803**
Breed	4	12,570**	2,410**	814**
Interactions	122	139	288	303
Within cells	458[a]	140	249	243

** F significant at the 1% level of probability.
[a] 457 for adjusted 8-wk gain mean square.

TABLE 2

Analyses of variance and covariance of birth weight, 8-wk gain, and six-month gain (Holsteins only)

Source of variance	d.f.	M. S. six-month gain	M. S. six-month gain adjusted for birth weight	M. S. six-month gain adjusted for 8-wk gain	M. S. six-month gain adjusted for 8-wk gain and birth weight
Sex	1	63,601**	42,448**	27,519**	20,963**
Season	3	2,664	2,476	1,451	1,662
Ration	4	23,771**	19,402**	1,672	1,398
Interactions	27	1,209	1,166	971	879
Within cells	260[a]	1,393	1,304	871	845

** F significant at the 1% level of probability.

[a] 259 degrees of freedom for six-month gain mean square adjusted for either birth weight or 8-wk gain; 258 degrees of freedom for six-month gain mean square adjusted for 8-wk gain and birth weight.

the allotment procedures, since the calves did not receive the rations until after birth.

Data from two nutrition experiments were used in a preliminary study of the linear regression of body weight gain to 12 wk of age on inbreeding. One experiment was analyzed as a randomized complete block experiment with 12-wk gain of the calf as the dependent variable. Inbreeding and birth weight of the calf and inbreeding, birth weight, and 8-wk gain of the dam were used as independent variables in a covariance analysis. The portion of total variance due to regression on all five variables was .273, whereas the portion of total variance due to regression on inbreeding of calf alone was .203 ($r = -.450$). Inclusion of variables other than inbreeding of the calf added little accuracy to the prediction of 12-wk gain in this small sample. Correlation of inbreeding with 12-wk gain in the second experiment was $-.275$ as compared to $-.450$ in the first experiment. The regression coefficients for the first and second experiments, respectively, were $-.98$ and $-.78$ lb 12-wk gain per 1% inbreeding. All calves used in these two experiments were 5% or more inbred.

TABLE 3

Constants derived from least squares analysis of birth weight and gain data

Effect	Birth weight [a]	8-wk gain	Six-month gain	1-yr gain
T_1 (Male)	3.61	3.08	15.15	29.85
T_2 (Female)	−3.61	−3.08	−15.15	−29.85
B_1 (Ayrshire)	4.88	5.30		
B_2 (Brown Swiss)	12.39	4.61		
B_3 (Guernsey)	−8.24	−8.64		
B_4 (Holstein)	10.05	4.29		
B_5 (Jersey)	−18.89	−5.55		
S_1 (Winter)	.82	−.44	1.30	−10.63
S_2 (Spring)	.71	2.00	1.40	21.87
S_3 (Summer)	−.88	−.46	−9.35	−6.35
S_4 (Fall)	−.65	−1.10	6.64	−4.89
R_1 (Antibiotics)	−.78	19.27	25.59	46.49
R_2 (Lib. milk)	1.31	11.33	18.76	12.78
R_3 (Lim. milk)	.28	1.07	3.44	4.05
R_4 (Milk only)	1.26	−11.86	−7.30	.22
R_5 (Unhyd. veg. oil)	−2.06	−19.81	−44.49	−63.11

[a] All weights and gains are in pounds.

Following the above preliminary analyses, this study was expanded to include all available data. To remove more completely the ration and time trend effects, as well as sex effects, a two-way classification of the data was effected. One classification was the inbreeding classes described earlier and the second was a sex, experiment, ration class. Use of the inbreeding classes allowed an estimation of the curvilinear effects of inbreeding on weight gain.

Constants derived in the more complete analysis are plotted in Figure 1. The trend

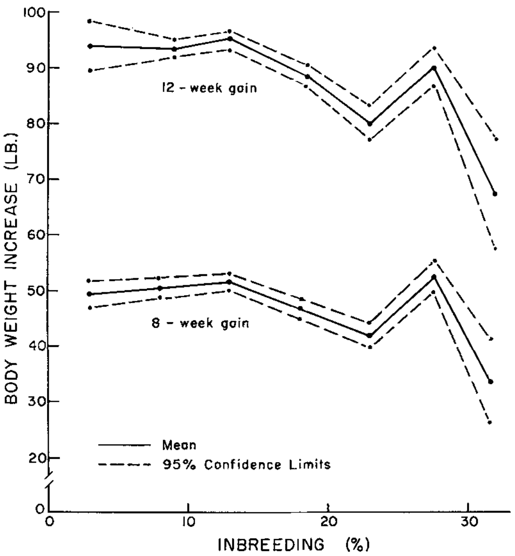

FIG. 1. Relationship between 8- and 12-wk body weight gains and coefficient of inbreeding.

shown indicates little influence of inbreeding when the coefficient is less than 15%. Beyond 15% inbreeding there was, with exception of the 26-30% class, a negative association between inbreeding and weight gain. The high value found for the 26-30% class could be due to sampling errors, since there were only six calves in that class.

In each of the analyses concerned with the effects of season of birth, sex, breed, and ration, correlations of weight gain with birth weight were computed. It is desirable to know whether weight gain in the early periods has a higher or lower correlation with birth weight than gain in the periods considered earlier in this study. Correlations of birth weight with weight gain to various ages would tend to shed some light on the differences in growth patterns of large and small calves. All correlations computed in all analyses are listed in Table 4. Very early weight gain is negatively correlated with birth weight and the value of birth weight as a predictor of weight gain increases at least to 12 wk of age. Beyond that point, the correlation tends to stabilize and sometimes even decreases.

Of the animals included in this study, 113 Holstein females had all of the following information available: birth weight, 8-wk gain, six-month gain, 1-yr gain, age at first calving, and first-lactation milk production. Correlations among these traits were computed and are shown in Table 5. Production records were 305-day, 2×, M.E., 3.5% F.C.M.; therefore, the expected correlation between calving age and production was zero. Correlations among the various measures of weight gain were part-whole relationships and were expected to be large.

DISCUSSION

As observed previously by other workers (7, 8, 12, 22, 27), sex and breed were found

TABLE 4

Correlations between birth weight and gain from birth to various ages [a]

Data analysis [b]	d.f.	Dependent variable; gain to age in wk							
		2	4	6	8	12	16	26	52
8-wk gain	457 [c]				.161**				
Six-month gain	259				.195**			.260**	
1-yr gain	181								.319**
All gains to 8 wk	349	−.100	.057	.133*	.164**				
All gains to 16 wk	149	−.051	.131	.244**	.297**	.382**	.272**		
All gains except 12 and 16 wk	161	−.159*	.001	.107	.188*			.316**	.327**

* Significant at the 5% level of probability.
** Significant at the 1% level of probability.
[a] Correlations within breed × sex × season × ration classification.
[b] Sets of data are not entirely independent, since some calves were included in two or more data analyses.
[c] All breeds represented; other analyses include Holsteins only.

TABLE 5

Correlations among birth weight, 8-wk gain, six-month gain, 1-yr gain, age at first calving, and production based on 95 degrees of freedom within ration and season (Holsteins only)

	8-wk gain	Six-month gain	1-yr gain	Age at calving	Production
Birth weight	.166	.356**	.291**	−.205*	.276**
8-wk gain		.578**	.337**	−.104	.088
Six-month gain			.559**	−.058	.300**
1-yr gain				−.067	.301**
Age at calving					.044

* Significant at the 5% level of probability.

** Significant at the 1% level of probability.

to influence birth weight of the calf. In the present study, primary attention was directed toward the relationship between weight gain and birth weight.

Relatively large differences in weight gain were found among the breeds and between the sexes. Variation due to sex and breed was reduced by adjustment for birth weight, but these effects were still important sources of variation. This would indicate that calves should be assigned to treatments in such a way as to allow treatment effects to be independent of sex and breed. A randomized block design, wherein all animals in a block are of the same sex and breed, would probably best fit this situation. If, however, the research worker is willing to accept a less accurate estimate of treatment effects, a design unbalanced with respect to sex and breed could be used and a part of the variation attributable to breed and sex removed by adjusting gains to a common birth weight by covariance. Season-of-birth effects were not a major source of variation in any of the analyses, but this does not imply that extreme heat or cold as well as other environmental factors do not affect weight gain over a short period of time. It does, however, imply that the average conditions in the four seasons in the present study were essentially equally conducive to weight increase of the young calf. Season effects were significant in the analysis of 1-yr weight gains and probably should be accounted for in experiments extending beyond six months of age. If further subdivision is possible, after all of the more important sources of variation are blocked out, season of birth should be accounted for by dividing the calves into groups as nearly contemporary as possible. The reasons for the significant season effects at 1 yr of age are not entirely clear, but the differences may be associated with seasonal variations in feeding and management practices between six months and 1 yr of age.

Inbreeding appeared to have little effect on weight change of young calves until the coefficient of inbreeding exceeded 15%. However, above 15%, inbreeding apparently depressed growth rate. This suggests that when the herd furnishing experimental animals is inbred extensively, and the range of inbreeding coefficients is great, calves should be grouped into inbreeding classes, or an analysis of covariance should be used to remove part of the variation due to inbreeding.

Correlations of birth weight with weight gains were consistently small, and less than 15% of the variation in gain could be removed by adjusting to a common birth weight. Analysis of covariance, with birth weight as the independent variable, can be justified only when there is a question regarding significance of treatment effects and a modest increase in precision will help clarify the situation, or when the research worker is unable to balance breeds and sexes in the design. The association between age and the correlation of birth weight with gain in weight indicate that large calves are slow starters, whereas small calves adjust more rapidly to extra-uterine environment.

Ration was found to affect weight gains from birth to all ages considered in this study. Analysis of covariance and correlation studies indicate that, though ration effects persist to 1 yr of age, weight gain beyond the treatment period (first 8 to 12 wk) was not affected by gain during the treatment period. The nature of the ration classifications virtually forced ration effects to be significant at 8 wk.

Reid (24), Hansson et al. (14), and Eckles and Swett (10) all reached the conclusion that growth rate and consequent age of maturity could be influenced by feeding. They did not, however, find any great influence of early rate of growth on first-lactation milk production. The study reported herein is not in complete agreement with these findings, inasmuch as six-month and 1-yr gain were correlated ($r = .30$) with milk production. Since no correction for inbreeding was made, and inbreeding could affect both gain and milk production, this correlation could have been the result of correlated effects of inbreeding. Also, six-month and 1-yr gains represent a substantial portion of mature weight and it is possible that the observed correlation is simply that between body weight and milk production. Blackmore et al. (4) and Holtz et al. (15) concluded that the factors creating rapid early growth are independent of those causing high production. In the present study, 8-wk gain had little or no effect on later gains, age at calving, or subsequent milk production. It would seem that the calf-raising program has little effect on traits independent of and expressed after the experimental period.

If weight gain is not to be used as an index of the sufficiency of a calf ration, a health or condition index is a possible substitute. However, it has the major disadvantage of being subject to human judgment and, therefore, easily biased. Changes in skeletal measurements would identify only the most inadequate rations. The present study was not designed to test the adequacy of the two indexes suggested above, but it does clearly raise a question concerning the use of weight gain as an index of calf ration sufficiency. The unit cost of weight gains prior to the development of rumen function is considerably greater than that of gains made later. Therefore, it would seem advisable to keep calves healthy and thrifty during the early weeks of their life without great regard for weight gains. If weight gains are used as the criterion of adequacy, it should be borne in mind that the variable is a growth response which has little relationship to the ultimate lactational response of the animal.

Growth standards have been tabulated by several workers in the past. A comparison of the values reported for Holstein heifers with average growth of Holstein heifers included in this study is shown in Table 6. There was variation within the Iowa State University herd, as indicated by ration differences. The differences between standards indicate differences from one sample or herd to another. If a standard other than one for the herd in question is used, the research worker is comparing herds as well as management regimes. Obviously, a control ration should be incorporated into the design of each calf nutrition experiment designed to evaluate growth response, and standard growth curves should be used only as an additional criterion.

REFERENCES

(1) Arizona Agricultural Experiment Station. Heavy Calves Make Rapid Gains. Arizona Agr. Expt. Sta., Ann. Rept., 48: 35. 1937.

(2) Bailey, G. L., and Broster, W. H. The Influence of Live Weight on Milk Production During the First Lactation. J. Dairy Research, 21: 5. 1954.

(3) Baker, G. A., Mead, S. W., and Regan, W. M. Effect of Inbreeding on the Growth Curves of Height at Withers and Weight and Heart Girth of Holstein Females. J. Dairy Sci., 28: 607. 1945.

(4) Blackmore, D. W., McGilliard, L. D., and Lush, J. L. Relationships Between Body Measurements, Meat Conformation, and Milk Production. J. Dairy Sci., 41: 1050. 1958.

(5) Campbell, I. L., and Flux, D. S. Body Weights of Some New Zealand Jersey and Friesian Cattle. J. Agr. Sci., 42: 150. 1952.

(6) Dawson, W. M., Phillips, R. W., and Black, W. H. Birth Weight as a Criterion of Selection in Beef Cattle. J. Animal Sci., 6: 247. 1947.

(7) Eckles, C. H. A Study of the Birth Weight of Calves. Missouri Agr. Expt. Sta., Research Bull. 35. 1919.

TABLE 6

Growth standard values for Holstein heifers at birth, two months, six months, and 1 yr of age

Standard	Birth	Two months	Six months	1 yr
Campbell and Flux (5)	....	160	390	575
Eckles (9)	90	157	349	558
Espe et al. (11)	89	132	358	662
Morrison (18)	91	150	365	653
Ragsdale (21)	90	148	355	632
USDA (17)	96	161	396	714
Present study [a]	**86**	**125**	**307**	**579**

[a] All values based on 170 or more animals.

(8) ECKLES, C. H. A Study of the Birth Weight of Calves. J. Dairy Sci., 2: 159. 1919.

(9) ECKLES, C. H. The Normal Growth of Dairy Cattle. Missouri Agr. Expt. Sta., Research Bull. 36. 1920.

(10) ECKLES, C. H., AND SWETT, W. W. Some Factors Influencing the Rate of Growth and the Size of Dairy Heifers at Maturity. Missouri Agr. Expt. Sta., Research Bull. 31. 1918.

(11) ESPE, D. L., CANNON, C. Y., AND HANSEN, E. N. Normal Growth in Dairy Cattle. Iowa Agr. Expt. Sta., Research Bull. 154: 297. 1932.

(12) FITCH, J. B., MCGILLIARD, P. C., AND DRUMM, G. M. A Study of the Birth Weight and Gestation of Dairy Animals. J. Dairy Sci., 7: 222. 1924.

(13) FORSHAW, R. P., MADDOCK, H. M., HOMEYER, P. G., AND CATRON, D. V. The Growth of Duroc Suckling Pigs Raised in Drylot. J. Animal Sci., 12: 263. 1953.

(14) HANSSON, A., AND BONNIER, G. Studies on Monozygous Cattle Twins. XII. Influence of Nutrition on the Rate of Body Development. Acta Agr. Scand., 1: 98. 1950.

(15) HOLTZ, E. W., ERB, R. E., AND HODGSON, A. S. Relationships Between Rate of Gain from Birth to Six Months of Age and Subsequent Yields of Dairy Cows. J. Dairy Sci., 44: 672. 1961.

(16) KEMPTHORNE, O. The Design and Analysis of Experiments. John Wiley and Sons, Inc., New York. 1952.

(17) MATTHEWS, C. A., AND FOHRMAN, M. H. Beltsville Growth Standards for Holstein Cattle. USDA Tech. Bull. 1099. 1954.

(18) MORRISON, F. B. Feeds and Feeding. 22nd ed. Morrison Publishing Co., Ithaca, N. Y. 1956.

(19) NELSON, R. H., AND LUSH, J. L. Effects of Mild Inbreeding on a Herd of Holstein-Friesian Cattle. J. Dairy Sci., 33: 186. 1950.

(20) PLUM, M., SINGH, B. N., AND SCHULTZE, A. B. Relationship Between Early Rate of Growth and Butterfat Production in Dairy Cattle. J. Dairy Sci., 35: 957. 1952.

(21) RAGSDALE, A. C. Growth Standards for Dairy Cattle. Missouri Agr. Expt. Sta., Bull. 336. 1934.

(22) RATHORE, A. Hereditary and Environmental Factors Which Influence Birth Weight in Holstein-Friesian Calves. Thesis, Iowa State University of Science and Technology, Ames, Iowa. 1947.

(23) RATHORE, A. Differences in Growth of Sindhi and Crosses of Sindhi with Jersey, Brown Swiss, Holstein-Friesian and Guernsey Cattle. Thesis, Iowa State University of Science and Technology, Ames, Iowa. 1949.

(24) REID, J. T. Effects of Several Levels of Nutrition upon Growth, Reproduction, and Lactation in Cattle. Proc. 1953 Cornell Nutr. Conf. Feed Mfrs., 88. 1953.

(25) ROLLINS, W. C., AND GUILBERT, H. R. Factors Affecting the Growth of Beef Calves During the Suckling Period. J. Animal Sci., 13: 517. 1954.

(26) STRAUS, F. S. Birthweights of the Calves as a Means of Evaluating the Productive Ability of Dairy Sires. Thesis, Iowa State University of Science and Technology, Ames, Iowa. 1940.

(27) TYLER, W. J., CHAPMAN, A. B., AND DICKERSON, G. E. Sources of Variation in the Birth Weight of Holstein-Friesian Calves. J. Dairy Sci., 30: 483. 1947.