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PARAMETERS OF GROWTH OF HOLSTEIN-FRIESIAN BULLS

L. L. Calo
East-West Food Institute, Hono!ulu, Hawaii

R. E. McDowell
Cornell University

L. Dale Van Vleck
University of Nebraska-Lincoln, dvan-vleck1@unl.edu

P. D. Miller
American Breeders Services, Inc., DeForest, Wisconsin

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Abstract: Growth records of 504 pedigree selected Holstein-Friesian bulls by 120 sires collected for progeny testing at the American Breeders Service, Inc., DeForest, Wisconsin from 1964 to 1971, were studied to determine the shape of the growth curve, relationships among body weights and growth rates at various ages and to estimate heritability of growth. Body weight and average/daily gain were consistently higher than the previous growth standards for Holstein-Friesian bulls. Bulls weighed about 480 kg at 15 months, which was 46% of average mature weight. Average daily gain ranged from 1.3 to 0.8 kg between 6 and 18 months of age. A sustained high rate of gain was observed even beyond recommended slaughter age which clearly shows that Holstein-Friesian bulls with potentially high milk production levels also have a good capacity to produce beef. Body weights, expressed as deviations from contemporary group averages, at successive ages were positively correlated but the relationships declined as intervals between ages increased, indicating that using earlier weights to predict later weights would be effective only at shorter age intervals. There were no definite relationships between growth rates at subsequent ages, implying that growth rates obtained for a certain age range should be applied only for that particular age range. Correlations between body weight and growth rates were largely negative, suggesting that heavier animals at certain ages tended to gain less in subsequent periods. Within group heritabilities for body weight increased with age from 6 to 30 months of age but gradually declined thereafter. The trends for average daily gain (ADG) and daily gain per 100 kg body weight (DG/100) were almost the opposite for body weight. The overall average heritability estimates for body weight, ADG and DG/100 were 0.83, 0.44 and 0.46, respectively. Since the majority of the Holstein-Friesians being born are progeny of AI sires, the values for growth rate will serve as a standard for Holstein-Friesian males.

PARAMETERS OF GROWTH OF HOLSTEIN-FRIESIAN BULLS [1]

L. L. Calo,[2] *R. E. McDowell,*[3] *L. D. VanVleck*[3] *and P. D. Miller*[4]
Cornell University,[3] Ithaca, New York 14850

Summary

GROWTH records of 504 pedigree selected Holstein-Friesian bulls by 120 sires collected for progeny testing at the American Breeders Service, Inc., DeForest, Wisconsin from 1964 to 1971, were studied to determine the shape of the growth curve, relationships among body weights and growth rates at various ages and to estimate heritability of growth.

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Within group heritabilities for body weight increased with age from 6 to 30 months of age but gradually declined thereafter. The trends for average daily gain (ADG) and daily gain per 100 kg body weight (DG/100) were almost the opposite for body weight. The overall average heritability estimates for body weight, ADG and DG/100 were 0.83, 0.44 and 0.46, respectively.

Since the majority of the Holstein-Friesians being born are progeny of AI sires, the values for growth rate will serve as a standard for Holstein-Friesian males.

Introduction

The increasing importance of the Holstein-Friesian breed as a source of beef in addition to milk calls for information on parameters of growth, particularly among bulls with relatively high genetic superiority in milk production. Previous growth standards (Matthews and Fohrman, 1954; Ragsdale, 1934) were based on sons of a few sires from single herds. Current opinion is that continuous selection for superiority in milk production by extensive use of AI led to a correlated change in the growth parameters for Holstein-Friesian males. The objective of this study was to establish an expected growth curve, determine relationships among body weight and growth rates at different ages, and to derive estimates for heritability for growth rate.

Materials and Methods

The data included 8,412 growth records of 504 Holstein-Friesian bulls pedigree selected (DPT) for sampling on superiority to transmit high milk yield by the American Breeders Service, Inc., (ABS) DeForest, Wisconsin from 1964 to 1971. The DPT bulls were progeny of special matings of 120 AI proven sires (SPT) with predicted difference$>$454 kg milk and dams with mature equivalent milk production records exceeding 8,409 kilograms.

The majority of the DPT bulls arrived at the ABS testing center under 6 months of age, with a few more added prior to 10 months of age. They were housed, eight bulls to a pen, in one barn until they were ready for semen collection. Size of pen mates was maintained

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[2] Present address: East-West Food Institute, Honolulu, Hawaii 96822

[3] Department of Animal Science.

[4] Present address: American Breeders Services, Inc., DeForest, Wisconsin 53532.

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as uniform as possible since quantity of feed offered was based on the average body weight for each pen.

The ration consisted of alfalfa haylage and a concentrate mix of 70% shelled corn, 20% corn cob or oats by-products and 10% oats. Rations were formulated based on the N.R.C. nutrient requirements for dairy animals. Haylage was offered free choice with concentrate feeding at a fixed level twice a day. Mineral supplement and water were available at all times. Body weights were recorded at 28-day intervals until semen collection was completed (about 24 months of age).

After 500 ampules of semen had been collected, the bulls were transferred to another barn until their progeny test was completed. The feeding was the same except for the inclusion of corn silage in the ration. During this period weights were recorded at 56-day intervals (2.0 to 4.5 years).

Those retained for further service, following their initial proof, were transferred to individual stalls in a third barn. Feeding was essentially the same as that in the rearing barn except that amounts offered were based on body weights of individuals. Weighings were at 28-day intervals as long as the bulls remained in the stud. Efforts were made to treat all bulls as uniformly as possible as they moved from one barn to another at different stages.

The average monthly body weights and standard deviations from 6 months to 9 years of age were computed based on records of individual bulls within age ±15 days. Three other growth measures were computed from actual records:

(a) Average daily gain (ADG)= $(X_{t_2}-X_{t_1})/t_2-t_1)$

(b) Daily gain per 100 kg body weight (DG/100)=(ADG x 100)/X_{t_1}

(c) Degree of maturity (DM)=X/A

Where: X=body weight

t=time (age in days) and

A=average mature weight (1,044 kg, derived by averaging all weights accumulated in the testing center between 4.5 and 6.5 years of age).

Age groupings for body weight were based on age ±15 days, while average daily gains and daily gain per 100 kg body weight were derived from differences in weights at 3-month intervals.

Relationships between growth measures at different age intervals were estimated. The DPT bulls were classified into 19 contemporary groups. Each contemporary group comprised animals which came into the testing center within a 3-month period. Growth records for DPT bulls were expressed as deviations from the contemporary group average to minimize environmental effects and the deviations used in the computations for correlations between growth measures at various ages.

Components of variance attributable to sire groups, contemporary groups and error for body weight, ADG, and DG/100 at different ages were determined by method 1 described by Henderson (1953). Heritabilities within contemporary group for each trait were estimated as:

$$h^2=\frac{4\sigma^2_s}{\sigma^2_s+\sigma^2_e}$$

where σ^2_s and σ^2_e were estimates of the sire and error components of variance.

Results and Discussion

Post Weaning Growth Performance. The means and standard deviations for body weight, ADG, DG/100 and degree of maturity from 6 months to 8 years of age are in table 1. Body weights were higher at all ages than reported by Matthews and Fohrman (1954) and Ragsdale (1934), figure 1. On the assumption that the weights used in the three studies were collected in at least the decade preceding publication, the potential for growth rate of Holstein-Friesian males appears to have increased. This may not be entirely a genetic trend as level of nutrition and scope of sample may have been important. The earlier reports were based on bulls from single herds, whereas, more than 100 herds were represented in the present study. In any case it is apparent that updating of growth standards is desirable (table 1).

The bulls grew rapidly from 6 to 24 months of age (figure 2). Growth rate began to level off at about 36 months, but body weight continued to show some increase until 8 years, 11 months. Changes in weight were irregular after 60 months of age since feeding was regulated to keep the bulls in good condition for service and not maximum weight gains. As indicated by the standard deviations (table 1) variability in body weight declined with age. The coefficient of variation for body weight ranged from 13.5 to 1.7% between 6 months and 9 years of age.

TABLE 1. MEANS AND STANDARD DEVIATIONS FOR BODY WEIGHT, GROWTH RATES AND DEGREE OF MATURITY OF HOLSTEIN-FRIESIAN BULLS FROM 6 MONTHS TO 8 YEARS OF AGE

Age		No. of animals	Body weight[a]		ADG[b]		DG/100 kg[c]		Degree maturity[a]	
Year	Month		Mean	S.D.	Mean	S.D.	Mean	S.D.	Mean	S.D.
			kg						%	
0	6	18	218	28.8	1.31	0.08	0.73	0.06	20.9	2.76
0	9	211	297	32.3	1.36	2.46	0.50	0.78	28.4	3.09
1	0	381	389	40.1	1.14	0.48	0.32	0.14	37.2	3.84
1	3	318	479	43.7	1.02	0.46	0.23	0.11	45.9	4.19
1	6	212	559	50.3	0.83	0.50	0.16	0.10	53.6	4.82
1	9	153	638	60.1	0.85	0.47	0.14	0.08	61.2	5.76
2	0	114	711	73.8	0.85	0.49	0.13	0.08	68.1	7.07
2	3	128	771	80.0	0.78	0.45	0.11	0.07	73.8	7.66
2	6	107	817	87.5	0.64	0.38	0.09	0.06	78.3	8.38
2	9	116	868	88.8	0.69	0.52	0.09	0.09	83.1	8.51
3	0	98	905	96.9	0.60	0.53	0.07	0.06	86.7	9.29
3	3	103	930	101.3	0.49	0.58	0.06	0.07	89.1	9.71
3	6	100	946	93.5	0.34	0.63	0.04	0.07	90.7	8.96
3	9	96	977	96.6	0.41	0.64	0.04	0.07	93.6	9.26
4	0	85	996	91.8	0.31	0.69	0.04	0.07	95.4	8.79
4	3	95	1010	94.4	0.27	0.65	0.03	0.07	96.8	9.04
4	6	79	1021	96.5	0.19	0.74	0.02	0.08	97.8	9.24
4	9	70	1027	102.3	0.24	0.65	0.03	0.07	98.3	9.80
5	0	65	1014	103.4	0.06	0.56	0.01	0.06	97.2	9.90
5	3	48	1034	102.8	0.18	0.60	0.02	0.06	99.1	9.85
5	6	48	1058	91.3	0.05	0.71	0.01	0.07	101.3	8.74
6	0	28	1051	105.0	0.03	0.83	0.01	0.08	Fully mature	
6	6	20	1071	58.3	0.24	0.45	0.02	0.04	....	....
7	0	18	1059	81.3	0.08	0.94	0.01	0.09	....	....
7	6	11	1069	47.2	0.18	0.65	0.02	0.06	....	....
8	0	7	1099	58.5	—.01	0.55	—.01	0.05	Fully mature	

[a] Average body weights of individuals within age ±15 days.
[b] Average daily gain in weight between later and previous weighings.
[c] Average daily gain in weight between later and previous weighing times 100 divided by previous weight.
[d] Degree of maturity=(Body weight x 100)/mature weight. Mature weight=1,044 kilograms.

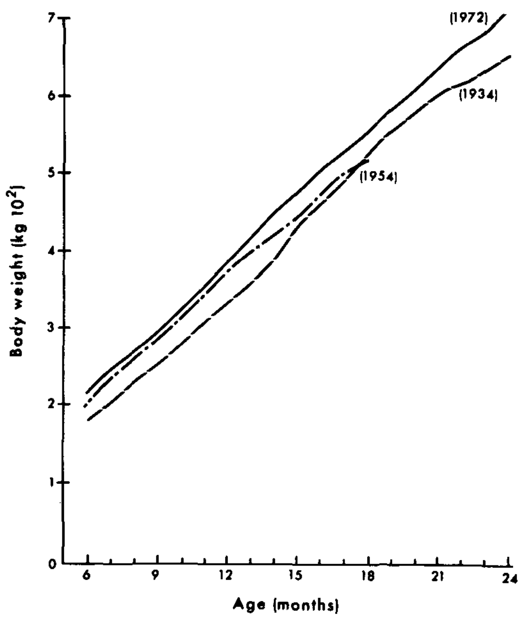

Figure 1. Growth rate of Holstein-Friesian bulls in four eras of time (Ragsdale, 1934; Matthews and Fohrman, 1954; and present, 1972).

The relationship between age and degree of maturity is presented in figure 3 and table 1. The bulls attained 21% of mature weight at 6 months, 37% at 12 months, 46% at 15 months and 86% at 36 months based on an average mature weight of 1,044 kilograms. On

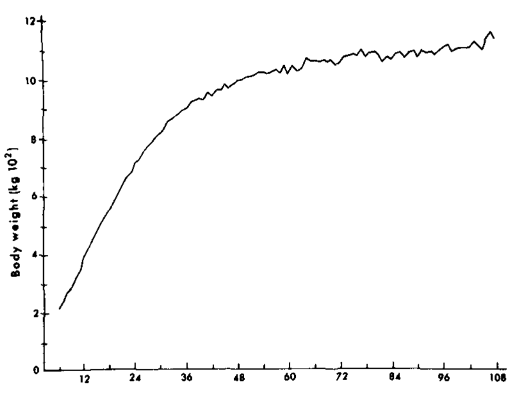

Figure 2. Growth curve of Holstein-Friesian bulls pedigree selected for milk.

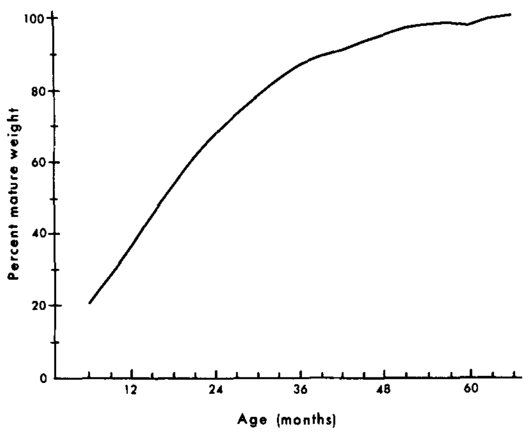

Figure 3. Relationship between age and degree of maturity for Holstein-Friesian bulls.

the average, the bulls reached 454 kg at 14 months of age but this represented only 43.5% of mature weight. Hallman (1971) reported that Holstein-Friesian male calves artificially raised from 3 days of age to 14 weeks, followed by fattening in a feedlot reached 454 kg at 12.5 months. Nichols *et al.* (1964) showed that Holstein-Friesian bulls reached 454 kg in 13 months. In Israel, where selection for beef among dairy bulls has been considered, records of 4,663 Israeli Holstein bulls averaged 454 kg at 13.6 months of age with ADG of 1.013 kg from birth (Israel-Friesian Herdbook, September, 1971). The slightly higher weights in these reports could be attributed to feedlot fattening conditions while those in this study received a ration with a higher proportion of roughage. Irrespective of condition, all studies reveal the ability of the Holstein-Friesians to reach an acceptable slaughter weight at a young age which fits trends in demand for more efficient meat production and preference for lean meat among consumers. At about 454 kg Holstein-Friesian males would likely have less fat and more lean in carcass than most standard beef breeds, (Cole *et al.*, 1964; Callow, 1961). Because of their relative leanness Holstein-Friesian males would be expected to be relatively efficient feed converters.

Although feeding was not at maximum intake, the average ADG between 6 and 15 months exceeded 1 kg per day (table 1) and ADG was still 0.5 kg per day even after 36 months. A sustained high rate of gain from 18 months to 36 months, which is beyond the recommended slaughter age for most beef breeds, would offer added flexibility to feed-

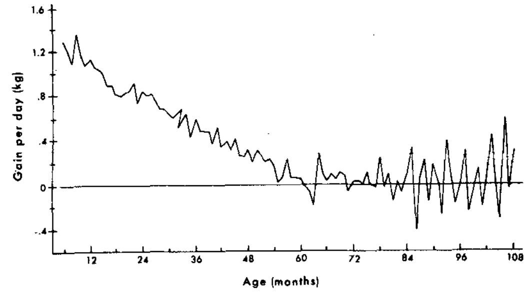

Figure 4. Average daily gain of Holstein-Friesian bulls pedigree selected for milk.

ing operations for beef. For example, under conditions when feeders are scarce and feed supply abundant, Holstein-Friesian males could be kept profitably on feed longer than for other breeds.

The highest average ADG was observed at 9 months of age (figure 4) while the highest DG/100 was observed at 6 months of age (figure 5).

Relationships Between Growth Measures at Different and Successive Age Intervals. The correlations between body weights, expressed as deviations from their contemporary group average, at different and successive ages for bulls with complete weight records are in table 2. All the correlation coefficients were positive indicating that animals heavy at an early age tended to be heavy at later ages. However, as the interval between ages increased the correlation declined which corroborates the findings of Taylor and Craig (1965).

Average daily gain from 6 to 9 months was negatively correlated with ADG 9 to 12 months, but became positively correlated at later ages (table 3). A similar trend was observed in the relationship between DG/100 expressed as deviation from contemporary group average at 6 to 9 months and those of later stages. There seems to be no definite

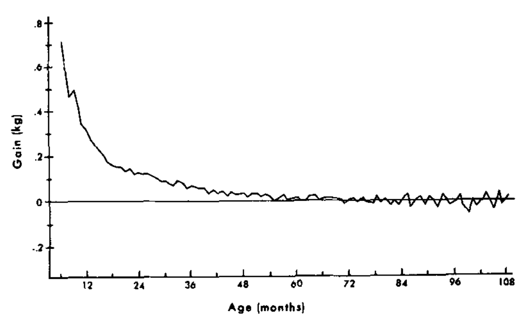

Figure 5. Daily gain per 100 kg body weight for Holstein-Friesian bulls.

TABLE 2. CORRELATIONS BETWEEN BODY WEIGHT EXPRESSED AS DEVIATION FROM CONTEMPORARY GROUP AVERAGE AT SUCCESSIVE AGES

Age (month)	12	15	18	24	36	60
9	0.84	0.73	0.56	0.43	0.19	0.24
12	....	0.88	0.75	0.59	0.36	0.33
15	....	....	0.85	0.71	0.42	0.46
18	....	....	....	0.78	0.53	0.34
24	....	....	....	....	0.65	0.43
36	....	....	....	....	....	0.64

Correlation coefficients >.15 significant at P<.01 (Steel and Torrie, 1960).

relationship between growth rates at subsequent ages. Animals with high rates of gain during a certain period were not necessarily those with high rates of gain in subsequent periods. It should be appreciated however, that if errors occurred in these data, such as, unusual fill and weighing device errors, correlations between growth rates between consecutive intervals would become automatically biased negatively. For example, a high weight at 12 months due to unusual fill simultaneously caused growth from 9 to 12 months to be overestimated and growth from 12 to 15 months to be underestimated, thus the observed covariance includes both the true covariance in growth rate and the negative covariance from weighing errors.

The correlations between body weight and growth rate at successive age intervals shown in table 4 were largely negative. The relationship between body weight and DG/100 had higher negative values than with ADG. This implies that heavier animals at a certain age

TABLE 3. CORRELATIONS BETWEEN GROWTH RATES EXPRESSED AS DEVIATION FROM CONTEMPORARY GROUP AVERAGE AT DIFFERENT AGE INTERVALS

Age Interval	9–12	12–15	15–18	18–24	24–30
6–9	−.22[a]	0.10	0.26	0.17	0.03
	−.10[b]	0.18	0.34	0.24	0.09
9–12	....	0.14	−.05	−.04	0.01
	....	0.15	−.04	−.02	−.03
12–15	....	....	−.15	0.11	−.06
	....	....	−.13	0.10	−.10
15–18	....	....	....	−.06	−.12
	....	....	....	−.05	−.07
18–24	....	....	....	....	0.02
	....	....	....	....	0.05

[a] Between ADG at successive age intervals.
[b] Between daily gain per 100 kg body weights at successive age intervals.
Correlation coefficients >.15 significant at P<.01 (Steel and Torrie, 1960).

TABLE 4. CORRELATIONS BETWEEN BODY WEIGHT AND MEASURES OF GROWTH RATES EXPRESSED AS DEVIATION FROM CONTEMPORARY GROUP AVERAGE FOR SUCCESSIVE AGE INTERVALS

Age (months)	9–12	12–15	15–18	18–24	24–30
9	0.02[a]	0.01	−.08	−.17	0.14
	−.44[b]	−.32	−.24	−.26	0.03
12	....	0.13	−.02	−.09	0.07
	....	−.30	−.24	−.28	−.05
15	....	....	0.07	0.03	−.02
	....	....	−.20	−.22	−.19
18	....	....	....	0.13	−.03
	....	....	....	0.18	−.20
24	....	....	....	....	0.03
	....	....	....	....	−.18

[a] Between body weight and ADG.
[b] Between body weight and daily gain per 100 kg body weight.
Correlation coefficients >.15 significant at P<.01 (Steel and Torrie, 1960).

tended to gain less per day in subsequent age intervals.

Estimates of Heritability Within Contemporary Group. Paternal half sib estimates of heritability within contemporary groups for body weight, ADG and DG/100 are given in table 5. The unusually high heritability values for body weight at ages 18 to 36 months may be due to some confounding that increased the component of variance attributed to sires or to sampling variance. Since the sire variance component was multiplied by four to estimate additive genetic variance, any discrepancy present would be quadrupled resulting in unusually high heritability values. The overall average heritability was for ADG 0.44; for DG/100, 0.46 and for body weight, 0.83.

Heritability estimates for growth rate of Holsteins, in terms of ADG and DG/100 from 9 to 12 months of age were 0.89 and 0.82, respectively, which are higher than those reported by Langlet, Gravert and Rosenhahn

TABLE 5. HERITABILITY ESTIMATES WITHIN CONTEMPORARY GROUP FOR GROWTH MEASURES AMONG HOLSTEIN-FRIESIAN BULLS PEDIGREE SELECTED FOR MILK PRODUCTION

Age (month)	ADG	DG/100 kg	Age (month)	Body weight
6–9	0.70	0.89	9	0.00
9–12	0.89	0.82	12	0.66
12–15	0.00	0.00	15	0.65
15–18	0.07	0.32	18	0.98
18–24	0.56	0.36	24	1.22
24–30	0.39	0.34	30	1.42
Mean	0.44	0.46	36	1.06
	....	....	60	0.67
			Mean	0.83

(1967) (0.45) and Bar-Anan *et al.* (1965) (0.33). The very wide differences between estimates in this study and those reported could be attributed to the different conditions under which measurements were made. Langlet *et al.* (1967) obtained their values in open feedlots with no protection against weather changes. Bar-Anan *et al.* (1965) made their observations on 50 farms, while at the ABS center the bulls were kept in well ventilated barns with few exchanges between pens.

Heritability estimates for the measures of growth changed with age (table 5) and heritability for ADG increased with age from 0.69 at 6 to 9 months to 0.89 at 9 to 12 months of age. This trend is in partial agreement with the claim of Taylor and Craig (1967) and Dinkel (1958). After 12 months heritability for ADG decreased to zero and gradually increased up to 0.56 at 18 to 24 months. The pattern of heritability changes with age for DG/100 was slightly different from that of ADG. Heritability for DG/100 started high, 0.89 at 6 to 9 months, declined to zero at 12 to 15 months of age and then gradually increased to 0.36 at 18 to 24 months. The explanation for the abrupt change in heritability for growth rate at ages between 12 and 18 was not discernible, but is in line with the results of Brinks *et al.* (1964) for Herefords.

A more distinct pattern of change in heritability with advancing age occurred for body weight, increasing from 6 to 30 months of age, and then declining. The tendency to increase with age is in line with the report of Averdunk (1968). The age for highest heritabilities (24 to 30 months) agrees with reports by Blackmore, McGilliard and Lush (1958) and Tyler *et al.* (1948), who found maximum heritability for body weight among Holstein-Friesian heifers at around 2 years of age.

The different pattern of heritability change with age for body weight and growth rate may be explained by the fact that body weight is cumulative; therefore, differences in weight among progeny of sires gradually widen during the early growth phase, increasing heritability. Assuming early growth and later growth may be somewhat independent, it is conceivable that a group of sires might transmit delayed development, such as results from inbreeding; hence, many of the initial differences may be diminished and heritability of growth drops, then increases as the sire differences for later growth become cumulatively large.

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