Time trends, sex and age of dam correction factors, and genetic parameters for production traits in Angus and Hereford cattle

by Terry C Nelsen

A thesis submitted in partial fulfillment of the requirements for the degree of MASTER OF SCIENCE in Animal Science

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Abstract:

Field records of 6200 purebred calves from 6 Angus herds and 7700 purebred calves from 9 Hereford herds were analyzed by least squares analysis. Herd, year, year within herd, sire within year within herd, sex, age of dam and interactions among these factors along with partial regressions on day of birth and age at weaning were included in various combinations as independent variables in three basic least squares models. Response variables were birth weight, pre- and postweaning average daily gains, weaning and final test weights. The objectives of the study were to analyze time trends, to calculate and evaluate sex and age of dam correction factors, and to estimate genetic parameters. Time trend analyses showed that birth and weaning weights increased significantly in the time period (1959 to 1973) of the study. There was a nonsignificant increase in postweaning gain and no change in final test weight. Correction factor analyses showed that multiplicative factors were generally preferred over additive in the Angus data except for the age of dam corrections for preweaning gain and weaning weight, where no decision was reached. In the Hereford data, multiplicative factors were preferred in both birth weight adjustments and in weaning weight age of dam adjustments. Additive factors were preferred in both Hereford preweaning gain adjustments and in weaning weight age of dam adjustments. Decision criteria for additive vs. multiplicative correction factors were the factors' ability to affect major sources of variance, interactions, and individual sex and age of dam subclass variances. Estimates of heritability for birth weight, preweaning average daily gain, weaning weight, postweaning average daily gain and final test weight, respectively, were: .39, .29, .27, .20, and .25 for Angus combined sex analysis; .52, .32, .28, .23 and .16 for Angus bull analysis; .33, .15, .15, .27, and .16 for Angus heifer analysis; and .62, .32, .33, .16 and .40 for Hereford bull analysis. Estimates of heritability from Hereford weaning weight only analyses were .28 for males, .23 for females and .23 for the combined analysis of sexes.

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A thesis submitted in partial fulfillment of the requirements for the degree

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ABSTRACT

Field records of 6200 purebred calves from 6 Angus herds and 7700 purebred calves from 9 Hereford herds were analyzed by least squares analysis. Herd, year, year within herd, sire within year within herd, sex, age of dam and interactions among these factors along with partial regressions on day of birth and age at weaning were included in various combinations as independent variables in three basic least squares models. Response variables were birth weight, pre- and postweaning average daily gains, weaning and final test weights. The objectives of the study were to analyze time trends, to calculate and evaluate sex and age of dam correction factors, and to estimate genetic parameters. Time trend analyses showed that birth and weaning weights increased significantly in the time period (1959 to 1973) of the study. There was a nonsignificant increase in postweaning gain and no change in final test weight. Correction factor analyses showed that multiplicative factors were generally preferred over additive in the Angus data except for the age of dam corrections for preweaning gain and weaning weight, where no decision was reached. In the Hereford data, multiplicative factors were preferred in both birth weight adjustments and in weaning weight age of dam adjustments. Additive factors were preferred in both Hereford preweaning gain adjustments and in weaning weight age of dam adjustments. Decision criteria for additive vs. multiplicative correction factors were the factors' ability to affect major sources of variance, interactions, and individual sex and age of dam subclass variances. Estimates of heritability for birth weight, preweaning average daily gain, weaning weight, postweaning average daily gain and final test weight, respectively, were: .39, .29, .27, .20, and .25 for Angus combined sex analysis; .52, .32, .28, .23 and .16 for Angus bull analysis; .33, .15, .15, .27, and .16 for Angus heifer analysis; and .62, .32, .33, .16 and .40 for Hereford bull analysis. Estimates of heritability from Hereford weaning weight only analyses were .28 for males, .23 for females and .23 for the combined analysis of sexes.

INTRODUCTION

As the beef cattle industry strives towards more efficient cattle better suited to their environment, it becomes more and more important for the scientific community to provide the industry with more accurate methods of evaluating their cattle and choosing their breeding stock.

The objectives of this study were: to estimate the genetic parameters within production traits in Montana Angus and Hereford cattle by use of field records obtained from different herds throughout the state; to examine time trends as possible indicators of direct and indirect responses to selection in herds that had been practicing selection programs; and to calculate and then evaluate different adjustment factors to reduce the effects of sex and age of dam on the important production traits in these herds. The production traits included in this study were birth, weaning and final test weights and pre- and postweaning average daily gains. Genetic parameters are important because they are used to predict direct and correlated responses to selection. Past responses to selection can be estimated by analysis of time trends. Correction factors for the environmental effects allow a producer to evaluate the genetic value of his cattle more accurately. If the animals records can all be placed on an equal basis as far as environmental effects are concerned, then the differences among them can be considered mainly genetic, although some environmental effects and some random variation will remain.

LITERATURE REVIEW

General

The continuous variation in production traits of beef cattle is caused by both genetic and environmental factors. This review of literature deals with methods of estimating the relative magnitude of these two general factors and specific elements within them. Methods of standardization (correction factors) for age of dam and sex effects will be included. The majority of the studies cited deal specifically with Angus and Hereford cattle although studies with other beef breeds, dairy breeds, and even other mammals are included when pertinent.

Age of dam and sex effects can be adjusted for by either additive or multiplicative factors. Both methods will equalize means but they have different effects on variance. Additive factors do not alter the relative variances and thus are applicable when standard deviations of the classes are equal. Multiplicative factors will change the variation in proportion to the square of the ratio used. A ratio greater than one will increase the variation and a ratio of less than one will decrease it. Also, multiplicative factors can alter an interaction effect while additive factors cannot.

Birth Weight

The major environmental sources of variation in birth weight generally agreed upon in the literature are breed of calf, sex of calf, and age of dam. Other environmental sources considered are gestation length, season of birth, weight of dam, and herd effects.

Specific genetic sources of variation reported are sire effects and inbreeding.

It has been well established that there are breed differences in calf birth weights. Comparative studies involving Angus and Hereford have shown Angus calves to be consistently 3 to 5 kg lighter at birth. Studies by Sagebiel _et al_. (1967), Cobb _et al_. (1964), and Taylor _et al_. (1960) found differences of 3.7 (31.8 _vs_. 28.1), 3.6 (30.7 _vs_. 29.23), and 5.7 (67.6 _vs_. 61.9) kg, respectively, with Herefords the heavier. Burris and Blunn (1952) reported Herefords to be 1.5 (30.7 _vs_. 29.2) kg heavier than Angus (this smaller difference is due in part to their adjusting their data for a difference in gestation length).

Meiske _et al_. (1964), Meade _et al_. (1959), and Rife _et al_. (1943) also reported Angus to have birth weights significantly lighter than Herefords.

Studies of the effect of sex on birth weight have shown that bull calves weigh approximately 2.2 kg more at birth than heifers. Burris and Blunn (1952) found male Angus to be 2.4 kg (30.4 _vs_. 28.0) heavier than female Angus and male Herefords 2.0 kg (31.7 _vs_. 29.7) heavier than female Herefords. Taylor _et al_. (1960) reported a male advantage of 2.0 kg (29.1 _vs_. 27.1) in Angus and 2.3 kg (31.8 _vs_. 29.5) in Herefords. Marlowe (1962) studied 5067 Angus and 4778 Hereford calves and found a difference of 2.0 kg (28.0 _vs_. 26.0) and 1.8 kg (31.8 vs. 30.0), respectively, between sexes within breeds. Koch et al. (1959) found bulls outweighing heifers by a 2.4 kg (33.2 vs. 30.8) average in a study group composed of Hereford, Angus and Shorthorn calves. In studies of large numbers of Herefords, Brinks et al. (1961) with 4432 calves, found males heavier by 2.4 kg (36.0 vs. 33.6) and Koch et al. (1959) with 3462 calves, by 2.3 kg (36.0 vs. 33.7). Other beef cattle studies by Koch et al. (1973) and Dawson et al. (1947) and dairy cattle studies by Legault and Touchberry (1962), Fitch et al. (1924) and Eckles (1919) also found birth weight superiority in favor of males in the area of 2 to 3 kg. Smaller but significant (P<.01) differences in Herefords were found by Lasley et al. (1961) of 1.1 kg (32.6 avg.) and Rice et al. (1954) of 1.0 kg (331.1 vs. 32.1). A partial regression of birth weight on sex of calf was found to be significant for Angus but not for Shorthorns in a report by Foote et al. (1960).

Age of dam affects birth weight in that younger and older cows have smaller calves. A cow's first calf is generally her smallest after which the birth weights will increase until she attains mature weight and age and thereafter decrease. Beef cattle generally reach their "peak" at 5 to 10 years of age. Marlow (1962) reported that both Angus and Hereford birth weights increased approximately .75 kg for each year increase in age of dam, up to 6 or 7 years of age, and then decreased. Burris and Blunn (1952) found that Angus and

Herefords both "peaked" at 9 to 10 years. Hereford studies by Burfening and Kress (1973), Koonce and Dillard (1967), Lasley *et al.* (1961) and Knapp *et al.* (1942) reported peak production at 5, 8 to 11, 6 and 5 years, respectively.

Gestation length is generally accepted to be positively correlated with birth weight. Burris and Blunn (1952) regressed birth weight on gestation length in days and reported a coefficient of .171 kg/day. Knapp *et al.* (1941) found a correlation of .60 between gestation length and birth weight. Rice *et al.* (1954) and Long *et al.* (1948) also reported positive ($P<.01$) correlations.

It has been established that while breed and sex affect birth weight directly, there is also strong evidence that breed, and to a lesser extent sex, also affect gestation length and thus exert an indirect influence on birth weight. The Angus breed is reported to have a shorter gestation period than the Hereford and within the breeds the bull calves are carried longer. Burris and Blunn (1952) reported a difference in gestation length of 2.2 days (282.9 *vs.* 280.7) and 1.4 days (286.8 *vs.* 285.4) within Angus and Hereford, respectively, between sexes with males having the longer gestation period. The overall breed difference was 4.4 days (286.1 *vs.* 281.7) with Herefords the longer. All the differences were significant ($P<.01$). Livesay and Bee (1945) found overall that Angus gestation lengths were shorter by 2.5 days (285.2 *vs.* 282.5, ($P<.01$) and within the breeds males were longer by .5 days (292.7 vs. 282.2) in Angus and .2 days (285.2 vs. 285.0) in Herefords. Thorton and Wiltbank (1959), Wheat and Riggs (1958) and Rife et al. (1943) also reported breed differences of 7.7 (287.2 vs. 279.5), 5.4 (284.9 vs. 279.5) and 16.2 (289.0 vs. 272.8) days, respectively, with Angus again having the shorter gestation length. The difference of 16.2 days is by far the largest found in the literature and may be due to a relatively smaller number of animals in the study, 36 Angus and 36 Herefords. A study of Herefords by Rice et al. (1954) found that bull calves were carried .8 days (287.3 vs. 286.5) longer than heifers but the difference was not significant.

In studies where the calving season extended over several months, the season or month of birth was reported to have an effect on birth weight. Lasley et al. (1961) and Loganathan et al. (1965) found this effect ($P<.01$) in Hereford calves.

Knapp et al. (1942) reported that the year of a calf's birth had an effect on its birth weight, especially in years following extreme range conditions. Similar results ($P<.01$) were reported in Hereford cattle by Burfening and Kress (1973), Koonce and Dillard (1967) and Loganathan et al. (1965). Burris and Blunn (1952) reported that year effects, when analyzed within breed and sex, were not significant. They reasoned that similarities in management practices from year to year nullified any year effects. Burfening and Kress (1973) and Flower et al. (1963) also reported that Hereford calves' specific birth dates were a major (P<.01) source of variation on their birth weights.

The weight of the dam was reported as a major (P<.01) effect on the birth weight of Herefords by Gregory et al. (1950) and of Shorthorns by Dawson et al. (1947). Meiske et al. (1964) found a significant effect in Angus and Herefords, but the relationship lost its significance when the variation due to age of dam was removed. Eckles (1919) reported a weight of dam effect on the birth weight of dairy calves while Foote et al. (1959) found a similar effect (P<.05) in Holstein calves.

Barlowe et al. (1974) and Koonce and Dillard (1967), analyzing Angus and Hereford calves, respectively, found major (P<.01) herd effects on birth weight in their results. The majority of the studies in the literature deal with one herd or are analyzed on a within herd basis.

The analysis of sire effects on birth weight is complicated by the fact that sires are not chosen at random. Normally, a sire selection program tends to group like sires, thus reducing variation. Dairy studies by Eckles (1919) found that sire effects were not significant within a breed but were significant on crossbred calves. Fitch et al. (1924) reported a nonsignificant trend in dairy cattle but noted that the ability to sire large calves is an individual characteristic, to a limited degree. In a later study Foote et al. (1959) reported significant sire effects in Holsteins. In beef cattle, sire effects ($P<.01$) were reported by Lasley et al. (1961) and Rice et al. (1954) with Herefords, and Brown and Galvez (1969) with Hereford and Angus. Gregory et al. (1950) reported important ($P<.05$) sire effects with Herefords. Lasley's group also reported a sire effect on gestation length in Herefords. Thorton and Wiltbank (1959) reported sire effects on gestation length in Angus ($P<.01$) but not in Herefords ($P<.05$).

Burfening and Kress (1973) and Flower et al. (1963) reported that among linebred Herefords the specific line has an important ($P<.01$) effect on birth weight.

Many studies have been done on the effects of inbreeding on birth weight in beef cattle. The reader is referred to Brinks and Knapp (1975) for a review of literature for both beef and dairy breeds. Studies of the effect of inbreeding of calf on birth weight have provided the following regression coefficients (kg per 1% inbreeding): -.0424 in males and -.0300 in females, Brinks and Knapp (1975); -.001, Nelms and Stratton (1967); -.06 for males and -.18 for females, Brinks et al. (1965); -.09, Swiger et al. (1961a). A nonsignificant ($P<.05$) regression was reported by Bovard et al. (1963) in Angus calves. Alexander and Bogart (1961) also reported nonsignificant effects of inbreeding in Angus and Herefords, but they attributed this result to a low replacement rate in their herds which resulted in more than the usual percentage of mature cows in their study. They suggested that calves of younger dams may be affected more by inbreeding than those of mature dams. The inbreeding of the dam appears to have a lesser effect on the birth weight of her calf than does the calf's inbreeding. Regressions on inbreeding of dam include: -.077 in male calves and .0007 in females, Brinks and Knapp (1975); -.03, Swiger *et al.* (1962) and .01 and .06 in two herds, Swiger *et al.* (1961). Results of 0 and negligible were reported, respectively, by Nelms and Stratton (1967) and Bovard *et al.* (1963).

The results of heritability studies for birth weight of Angus and Hereford calves are shown in table 1. The method used most often to estimate heritability in cattle involves the correlation among paternal half-sibs (for a review of methods of estimating heritability, see Falconer, 1960). Exceptions to the paternal half-sib method in table 1 are: Brown and Galvez (1969) used an average of several methods including regressing offspring on sire, paternal half-sib and paternal half-sib corrected for inbreeding; Koch and Clark (1955b) regressed progeny average on sire (h^2=.35) and offspring on dam (h^2=.44); and Knapp and Nordskog (1946) regressed offspring on sire (h^2=.34). In published summaries of birth weight heritabilities, Preston and Willis (1974) gave a preferred value of .38 using all breeds and Petty and Cartwright (1966) reported a weighted average of .44 in beef breeds alone.

Repeatability is defined by Falconer (1960) as "a correlation

TABLE 1. HERITABILITY OF BIRTH WEIGHT ESTIMATES

h^2	Breed[a]	Sex[b]	No. calves	Reference
.00	H	M,F	214	Thorton *et al.* (1960)
.13	A	M,F	175	Thorton *et al.* (1960)
.14	H	F	350	Pahnish *et al.* (1964)
.15	H	M,F	580	Miguel and Cartwright (1963)
.17	A	M,F	932	Brown and Galvez (1969)
.22	H,A,S	M,F	502	Burris and Blunn (1952)
.22	H	M,F	793	Swiger (1961)
.23	H	M	177	Knapp and Nordskog (1946)
.32	H	M	370	Pahnish *et al.* (1964)
.34	H	M	177	Knapp and Nordskog (1946)
.35	H	M,F	85	Koch and Clark (1955b)
.35	H	MF	4553	Koch and Clark (1955a)
.36	H	M,F	789	Brown and Galvez (1969)
.38	H	F	5192	Brinks *et al.* (1964)
.42	H	M	177	Knapp and Nordskog (1946)
.44	H	M,F	4234	Koch and Clark (1955b)
.53	H	M	177	Knapp and Nordskog (1946)
.59	H	M	542	Shelby *et al.* (1957)
.67	H	M,F	351	Lasley *et al.* (1961)
.72	H	M	635	Shelby *et al.* (1955)
.88	H	M,F	469	Loganathan *et al.* (1965)

[a] H = Hereford, A = Angus, S = Shorthorn.
[b] M = male, F = female.

between repeated measurements of the same individual" and "therefore expresses the proportion of the variance of single measurements that is due to permanent, or non-localized, differences between individuals, both genetic and environmental." Values for repeatability of birth weight as a trait of the dam are shown in table 2. Petty and Cartwright (1966) calculated a weighed average of .25 in their summary.

TABLE 2. REPEATABILITY OF BIRTH WEIGHT ESTIMATES

r_e-	Breed[a]	No. dams	No. offspring	Reference
.10	A	325	932	Brown and Galvez (1969)
.11	PH	100	493	McCormick *et al.*(1956)
.18	H,A,Sh	103	458	Taylor *et al.* (1960)
.18	H	-	620	Botkin and Whatley (1953)
.19	H	245	789	Brown and Galvez (1953)
.20	Mixed	370	892	Petty (1966)
.26	H	1166	4849	Koch and Clark (1955b)
.27	H	648	3342	Kress and Burfening (1972)
.28	H	-	-	Meade *et al.* (1959)
.30	H,A,Sh	364	1038	Taylor *et al.* (1960)
.35	A	-	-	Meade *et al.* (1959)

[a] A = Angus, H = Hereford, PH = Polled Hereford, Sh = Shorthorn.

Preweaning Average Daily Gain

The preweaning growth rate of a calf is a reflection of its dam's maternal ability, its environment and its own genes. Its dam's maternal ability is determined by her age, environment, and genotype. Its environment is made up of natural effects, such as weather and pasture condition, and management effects, such as birth date, creep-feeding, nutrition level, age at weaning, etc. Its genes are determined by its parents and variations in their relationship caused by inbreeding, crossbreeeding or linebreeding.

The age of dam effect was called "the most important source of variation" for preweaning growth rates in an Angus, Hereford and Shorthorn study by Marlowe and Gaines (1958). Major (P<.01) age of dam effects on preweaning gain of Angus and Hereford calves were reported by Schaeffer and Wilton (1974a), Kress and Webb (1972), Cunningham and Henderson (1965a), and Marlowe _et al_. (1965). Brinks _et al_. (1972) with Herefords and Brinks _et al_. (1962) with Hereford bulls also found an age of dam effect (P<.01) on preweaning average daily gain. Humes _et al_. (1973) found an age of dam effect on preweaning average daily gain to be highly significant (P<.01) in Hereford bull calves and significant (P<.05) in heifer calves. Other studies by Tanner _et al_. (1970), with Angus, and Nelms and Bogart (1956) with Angus and Hereford, found that the age of dam effect on preweaning average daily gain only approached significance. Nelms and Bogart noted that there was a large difference in gains of calves with two-year-old dams as compared to gains of calves with older dams. Schaeffer and Wilton (1974b) found an additive correction factor to be preferable to multiplicative when correcting preweaning gain of age of dam effects.

Age of dam by sex interaction effects on preweaning growth rates were reported in Angus calves ($P<.05$) by Barlow et al. (1974) and in Angus and Herefords ($P<.01$) by Schaeffer and Wilton (1974a). However, the same effect was found to be not significant in Angus and Hereford studies by Kress and Webb (1972) and Cunningham and Henderson (1965a). Schaeffer and Wilton (1974a) also reported on other effects on preweaning gain caused by interactions involving age of dam. Their results included: Age of dam by feeding system (creep), not significant; age of dam by level of herd performance, significant ($P<.01$); age of dam by sex by level of herd performance, not significant; and age of dam by sex by feeding system (creep), significant ($P<.05$) in Herefords but not significant ($P>.05$) in Angus.

The year of a calf's birth was found to have an effect ($P<.01$) on its preweaning gain in both Angus and Hereford in studies by Kress and Webb (1972), Cunningham and Henderson (1965a), Marlowe et al. (1965) and Alexander and Bogart (1961). Angus studies by Barlow et al. (1974) and Tanner et al. (1970) also found major ($P<.05$ and $P<.01$, respectively) year effects on preweaning gain. Brinks et al. (1972) and Mahmud and Cobb (1963) reported similar results ($P<.01$) in Hereford calves.

Humes et al. (1973) found a year effect ($P<.05$) on preweaning average daily gain in Hereford males but not ($P>.05$) in females.

Barlow et al. (1974) reported that year by herd, year by sex and year by age of dam interaction effects on preweaning average daily gain were all significant ($P<.05$) in Angus calves. Tanner et al. (1970) also found year by sex interaction effects ($P<.01$) on preweaning average daily gain in Angus calves.

Mahmud and Cobb (1963) reported with Herefords that the specific ranch on which a calf is raised has a major effect ($P<.01$) on its preweaning gain. Barlow et al. (1974) reported similar results ($P<.05$) in Angus calves.

Creep-feeding was reported to be a major ($P<.01$) effect on the preweaning growth rates of Angus and Hereford calves in a study by Schaeffer and Wilton (1974). Marlowe et al. (1967) reported that creep-fed Angus and Hereford calves grew .04 (.78 vs. .73) and .07 (.80 vs. .73) kg per day faster than their non-creep-fed contemporaries. Marlowe and Gaines (1958) reported that analysis of a group of Angus, Hereford and Shorthorn calves showed that creep-fed calves gained .05 (.80 vs. .75) kg per day faster than non-creep-fed.

A sex by feeding level (creep) interaction effect on preweaning gain was reported in Angus ($P<.05$) and in Herefords ($P<.01$) by Schaeffer and Wilton (1974a).

Mahmud and Cobb (1963) reported that the specific age of a Hereford calf within the preweaning period has substantial ($P<.01$) effect on its rate of gain. Brinks et al. (1962), however, reported that the age effect on preweaning growth rate was nonsignificant in Hereford bull calves. Marlowe and Gaines (1958) reported that the age effect on preweaning growth rate was greater for creep-fed Angus, Hereford and Shorthorn calves than for non-creep-fed calves. Marlowe et al. (1965), however, found age was a major effect ($P<.01$) on the preweaning growth rate of both creep and non-creep-fed Angus calves and in non-creep-fed Herefords but not in creep-fed Hereford calves. Kress and Webb (1972) found that the age at weaning had an effect ($P<.01$) on preweaning growth rate in Angus calves but did not significantly affect the same period of growth in Herefords.

Kress and Webb (1972) regressed preweaning gain on birth date and found a significant ($P<.05$) effect in Herefords and a highly significant ($P<.01$) effect in Angus. Marlowe et al. (1965) and Nelms and Bogart (1956) found month of birth to be a major ($P<.01$ and $P<.05$, respectively) effect on preweaning gain in both Angus and Herefords. Humes et al. (1973) found no significant effect of birth date on the preweaning gain of Hereford male calves, but did find an effect ($P<.05$) on the gain of Hereford females. Marlowe and Gaines (1958) reported in Angus, Hereford and Shorthorns that season of birth had a "significant" effect on the preweaning gains of non-creep-fed calves but was of "little practical importance" in the gains of creep-fed calves.

The actual birth weight of a calf was reported to have a major effect ($P<.05$) on preweaning gain in an Angus and Hereford study by Nelms and Bogart (1956). Birth weight was reported by Christian et al. (1965) to have an effect ($P<.05$) on the growth rate of Hereford calves during their first 60 days of age.

Alexander and Bogart (1961) and Nelms and Bogart (1956) both reported that line of calf effects were an important ($P<.01$ and $P<.05$, respectively) source of variation for the preweaning growth rates of Angus and Hereford calves. Humes et al. (1973) reported that line of sire was an influence ($P<.05$) on the preweaning gains of female Hereford calves, but not on the gains of male Herefords. Line of dam had an opposite effect on preweaning gain in their study; there was no significance for female calves but definite significance ($P<.05$) for male calves. Brinks et al. (1972) concurred to a large degree with Humes and coworkers' line of dam results, but Brinks and coworkers found nonsignificance for both sexes for the effects of line of sire on preweaning growth rates of the calves in their study. Brinks and Humes and their respective coworkers both reported line of dam by line of sire interaction effects on preweaning gain to be non-significant for Hereford male calves. Brinks found a highly significant ($P<.01$) effect for female Hereford calves while Humes reported nonsignificance. Brinks and coworkers also found no significant effects on preweaning gain due to interactions between line of sire and years and line of dam and years. Kress et al. (1973) found that line of sire and line of dam were both important ($P<.01$) sources of variation for the preweaning gain of Hereford cattle. The interaction between line of sire and line of dam was also significant ($P<.05$). They noted in their study that "there tended to be an inverse relationship between rankings of line of sire and line of dam." Mahmud and Cobb (1973) and Thrift et al. (1970) reported sire effects on preweaning gains to be important ($P<.01$ and $P<.05$, respectively) in Hereford calves. Tanner et al. (1970) analyzed sire within year and found it to be a major ($P<.01$) effect on the preweaning gains of Angus calves. Kress and Webb (1972) used the same type of analysis and found highly significant sire effects ($P<.01$) in Angus calves and significant sire effects ($P<.05$) in Herefords. Gregory et al. (1950) found no important sire effects on preweaning gains in two Hereford herds, but they suggested that their results may have been influenced by the small number of cattle involved in the study.

Tanner et al. (1970) and Thrift et al. (1970) both reported no significant effects on preweaning gain of a sire by sex interaction. However, Kress and Webb (1972) found a sex by sire within year interaction effect on preweaning gains in both Angus ($P<.01$) and Herefords ($P<.05$).

Sex has been reported to be a major ($P<.01$) effect on preweaning gains in Angus and Hereford calves in studies by Schaeffer and Wilton

(1974a), Kress and Webb (1972), Marlowe et al. (1965) and others. Brinks and Knapp (1975), Brinks et al. (1972), Tanner et al. (1970), Mahmud and Cobb (1963), and Koch et al. (1959) all working with Angus and/or Herefords, reported that male calves gained .04 to .06 kg per day more than females from birth to weaning. Bovard et al. (1963) obtained higher estimates of male advantage for preweaning gain of .10 kg per day for Angus and .09 kg per day for Herefords. Nelms and Bogart (1956), however, found sex effects on preweaning gains of Angus and Hereford calves to be nonsignificant when corrections were made for birth weight. They suggested the male and female calves having the same birth weights would gain alike up to weaning.

To adjust preweaning average daily gain for sex effects, both Brinks et al. (1961) and Koch et al. (1959) used a multiplicative adjustment factor since variance among bull calves was larger than among heifer calves. Schaeffer and Wilton (1974b), however, preferred additive factors.

The preweaning gain of a calf can also be affected by its dam's or its own level of inbreeding. Brinks and Knapp (1975) in their extensive study on inbreeding found that the inbreeding of the calf caused a -.0012 kg per day change in the preweaning average daily gain per one percent increase in inbreeding of male calves and a -.0014 change in female calves. Inbreeding of the dam had a larger effect; -.0022 kg per day in males and -.0011 kg per day in females. it is of interest to note that the inbreeding of the dam had twice as much effect on male calves as on female calves. Brinks and Knapp theorized that "males have more potential and are handicapped more by decreased milk production." Their findings were supported by Humes et al. (1973) who found that the inbreeding of the dam decreased preweaning gain of Hereford bull calves by .006 kg per day and of female calves by .003 kg per day per one percent increase in inbreeding. Swiger et al. (1961a) found that a one percent increase in inbreeding of the calf decreased preweaning gain of all calves by .005 kg per day in one Hereford herd but had no effect in another herd. Also, they found that a one percent increase in the inbreeding of the dam caused a -.0006 kg per day change in the preweaning gains of the calves in one herd and -.0005 kg per day change in the other.

The heritability of preweaning gain is generally estimated to be .30. A preferred value of .27 was reported by Preston and Willis (1974). Petty and Cartwright (1966) reviewed 31 estimates by various methods up to 1966. Their overall unweighted average was .26, which rose to .31 when weighted by number of records per method. Koch et al. (1973) used paternal half-sib methods to estimate heritability of preweaning gain in 3462 Herefords and arrived at estimates of .13 for bulls and .21 for heifers.

Weaning Weight

Weaning weight is influenced by much the same factors as pre-weaning gain. However, the importance of weaning weight is such that it is treated separately in the literature and thus will be accorded a separate section in this review.

Sex is generally considered a main effect on weaning weight. Bulls are heavier than steers which are in turn heavier than heifers. When comparing bulls to steers however, it is important to remember that the effects of castration can be confounded with the effects of selection plus there may be stress effects on the steers from the actual castration.

Differences between steers and heifers in Hereford studies ranged from 7.5 to 14.5 kg at 180 to 240 days in reports by Tanner et al. (1970), Linton et al. (1968), Sewall et al. (1963), Brinks et al. (1961), Urick (1958), Evans et al. (1955), Koch and Clark (1955a) and Koger and Knox (1945). More extreme differences in Herefords of .9 and 17.7 kg were reported by Burgess et al. (1954) and Bradley et al. (1966), respectively. An Angus study by Tanner et al. (1970) reported a difference in weaning weight between steers and heifers of 12.1 kg., with steers the heavier. A combined Angus-Hereford study by Cundiff et al. (1966a) found steers 5.1 kg heavier than heifers at weaning. Differences between Hereford bulls and heifers were reported in the area of 10 to 15 kg by Linton et al. (1968), Harwin et al. (1966), Manyard and Dinkel (1965a) and Evans et al. (1955). Brinks et al. (1961) and Brown (1958) found differences of 24.1 and 48.6 kg, respectively, between bulls and heifers at weaning. In a study of two different Angus herds, O'Mary and Ament (1961) found weaning weight differences between bulls and heifers of 22.8 and 30.5 kg. Cundiff et al. (1966a) reported a difference in weaning weight of 25.3 kg with bulls the heavier in a combined Angus-Hereford study. Brown (1960) and Brown (1958) combined bulls and steers together in two Hereford and three Angus herds, and compared the combined average weaning weights to those of the heifers. He reported Hereford results of 11.4 and 25.9 kg in favor of the males and Angus results as 10.0, 10.5 and 15.0 kg advantage for males. All of the above differences were reported as highly significant (P<.01). A significant (P<.05) difference between sexes was reported by Bradley et al. (1966) and Evans et al. (1955) with the males were again being larger. Sawyer et al. (1948) found heifers heavier at weaning, but the difference was not significant. Gregory et al. (1950) found a nonsignificant sex effect but they attributed this result to a very large standard deviation.

Age of dam by sex of calf interaction effects on weaning weight were reported as nonsignificant in combined Angus-Hereford studies by Cardellino and Frahm (1971), Cundiff et al. (1966a), Minyard and Dinkel (1965a) and Kress and Webb (1972). Their results were supported in Hereford studies by Linton et al. (1968), Cooper et al. (1965), and Swiger (1961). An interactive effect (P<.05) of age of dam by sex of calf was reported in Herefords by Harwin et al. (1966).

Sex by year interactive effects on weaning weight have been reported as highly significant (P<.01) by Cooper et al. (1965), Blackmore et al. (1960), Pahnish et al. (1961) and Linton et al. (1968). Linton postulated that the reason for the interaction is that bull calves are more sensitive to the environment. Tanner et al. (1970) also found a sex by year interactive effect on weaning weight, although their level of significance was less (P<.05). Studies by Cardellino and Frahm (1971), Harwin et al. (1966) and Swiger (1961) all reported nonsignificant sex by year interactive effects on weaning weight, although Harwin and his co-workers did report a trend. Sex by ranch and mating system interactive effects (P<.05) on weaning weight were reported by Pahnish et al. (1961) and Harwin et al. (1966), respectively. Sex by season of birth interaction was reported by Cooper et al. (1965) to have a major (P<.01) effect on weaning weight. However, Cundiff et al. (1966a) called the same effect "small" and Sellers et al. (1969) called it "unimportant". In studies analyzing the effect of sex by sire interactions on weaning weight of purebred calves, Tanner et al. (1970) with Angus and Pahnish et al. (1961) and Koger and Knox (1945) with Herefords all reported nonsignificance. Kress and Webb (1972) found a sex by sire within year effect in Herefords (P<.05) but not in Angus (P>.05). Wilson et al. (1967) reported a sex by sire interactive effect ($P<.05$) on weaning weight in Angus-Holstein x Polled Hereford calves. Interaction effects of pasture unit and management by sex on weaning weight were both reported to be nonsignificant in a combined Angus-Hereford study by Cundiff et al. (1966a). An interaction that was found to be significant ($P<.01$) for weaning weight was the age of calf (in days) at weaning by sex interaction, which was reported by Swiger (1961). He reported that bull calves grew at a faster rate than heifer calves. Cardellino and Frahm (1971) reported that sex by breed interactive effects on weaning weight were nonsignificant in their study of Angus and Herefords.

Cundiff et al. (1966a) found that variances of the three sexes were significantly different in both creep and non-creep-fed Angus and Hereford calves. They reported that multiplicative factors removed the sex by management type (creep feeding) interaction effects and thus were preferable. The ratios (.89 for bulls, 1.00 for steers and 1.02 for heifers) were the same for both types of management. Sellers et al. (1970) also found a heterogeneity of variance between the sexes and so used multiplicative correction factors. These factors were: .97, 1.00 and 1.07 for Angus bulls, steers and heifers, respectively, and .93, 1.00 and 1.08 for Herefords. Minyard and Dinkel (1965a) used a multiplicative factor of 1.082 to adjust the weaning weight of Hereford heifers to that of bulls. They tried both multiplicative and additive adjustment factors and found that the multiplicative factors reduced the sex effects more than did the additive factors. Linton et al. (1968) reported that a multiplicative factors of 1.071 to adjust Hereford heifers' weaning weights to those of Hereford bulls was better at equalizing the standard deviations than was an additive factor. The Beef Improvement Federation recommends general multiplicative factors of .95, 1.00 and 1.05 for bulls, steers and heifers, respectively (B.I.F., 1972).

The age of dam effect on weaning weight is considered an important effect throughout the literature. Hereford studies by Linton et al. (1968), Swiger et al. (1962), Brinks et al. (1962) and others all found major ($P<.01$) age of dam effects on weaning weight. Angus studies by Tanner et al. (1970) and Hohenboken and Brinks (1969) found significant ($P\leq.05$ and $P\leq.01$, respectively) effects, also. Studies involving both Angus and Hereford calves by Cardellino and Frahm (1971), Cundiff et al. (1966a) and Cunningham and Henderson (1965a) reported major ($P<.01$) age of dam effects on weaning weight. Warren et al. (1965) found age of dam effects ($P<.01$) on weaning weight in a study of 25,000 Angus, Hereford and Santa Gertrudis. Brown (1960) found age of dam effects on weaning weight at 60, 120, 180 and 240 days to be highly significant ($P<.01$) in a herd of Herefords and one of Angus. In a second herd of Angus, he found the age of dam effects highly significant ($P<.01$) at 60 and 120 days, significant ($P<.05$) at 180 days and nonsignificant ($P>.05$) at 240 days.

All of the above studies found that a cow reaches her most productive age when she is 6 to 8 years old.

Cardellino and Frahm (1971) found an age of dam by breed effect ($P < .01$) on weaning weight in their Angus-Hereford study. They obtained within breed multiplicative age of dam correction factors of: 1.15, 1.08, 1.02 and 1.00 for 2-, 3-, 4- and 5- to 9-year-old Angus dams, respectively; and 1.23, 1.09, 1.01 and 1.00 for Hereford dams of the same respective ages. They then compared their factors with the general beef cattle age of dam correction factors for weaning weight (1.15, 1.10, 1.05 and 1.00) as recommended by the Beef Improvement Federation (B.I.F., 1972). They reported that within herd factors were preferable, if possible, but the general factors were adequate except for the calves of two-year-old Hereford heifers, which would be under-corrected. Sellers et al. (1970) also reported age of dam by breed interactive effects on weaning weight, but the effects were not of sufficient magnitude to consider separate correction factors for Angus and Hereford. Their multiplicative correction factors were 1.12, 1.07, 1.03, 1.00 and 1.05 for bull calves of cows aged < 34 mos., 34 to 45 mos., 4 to 5 yrs., 6 to 12 yrs., and 12 yrs., respectively. Steer and heifer correction factors for the same respective ages of cows were 1.11, 1.06, 1.02, 1.00 and 1.02 and 1.09, 1.06, 1.02, 1.00 and 1.04, respectively. Cundiff et al. (1966b) divided ages of dam into < 28 mos., 28 to 30 mos., 31 to 33 mos., 34 to 39 mos., 40 to 45