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FACTORS AFFECTING EFFICIENCY TO WEANING IN ANGUS,
CHAROLAIS AND RECIPROCAL CROSS COWS

BY

DOUGLAS A. MARSHALL

A thesis submitted
in partial fulfillment of the requirements for the
degree Master of Science, Major in
Animal Science, South Dakota
State University

1975

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FACTORS AFFECTING EFFICIENCY TO WEANING IN ANGUS,
CHAROLAIS AND RECIPROCAL CROSS COWS

This thesis is approved as a creditable and independent investigation by a candidate for the degree, Master of Science, and is acceptable for meeting the thesis requirements for this degree. Acceptance of this thesis does not imply that the conclusions reached by the candidate are necessarily the conclusions of the major department.

Thesis Adviser

Date

Head, Animal Science Department

/ Date

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DAM

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PREFACE

A profitable future for the beef industry will depend on the efficient use of feed and fixed resources. If beef is to compete with new, less expensive, nutritionally adequate and consumer acceptable protein sources, efficiency of production must be greatly increased. Substantial improvement will be important not only in post-weaning conversion of resources to edible product but especially when considering the cow herd and production of calves to weaning.

Effect of cow size on efficiency of production has long been of interest to researchers and producers. Research has generally shown that maintenance feed requirements are proportional to body weight.⁷⁵ (Klosterman et al., 1968; Turner et al., 1974). This has promoted the belief that weaning efficiency is highly dependent on cow size. However, many studies have detected increases in calf weights with increasing cow weights.

The purpose of this study was to gain understanding of the variables affecting efficiency of cows and production of their calves to weaning. Specific effects of cow size, condition and milk production on efficiency were examined along with reproductive performance of the experimental females to determine net weaning efficiency. An attempt was also made to examine traits that could be used in practical situations to detect differences in cow efficiency.

Considerable research has been conducted to evaluate post-weaning efficiency of nutrient utilization, but due to expense and time requirements individual feeding of cows and their progeny has

been limited. Methods employed to individually feed cows in drylot have been feeding according to metabolic weight (Klosterman et al., 1974; Turner et al., 1974), feeding to maintain equal fatness by visual appraisal (Carpenter et al., 1972) and feeding low energy rations ad libitum (Kress et al., 1969; Onks et al., 1975). Various problems have been encountered with use of such methods. In the project reported here, an attempt was made to simulate pasture nutrition levels in the feeding of drylot cows.

The experiment began with production of straightbred Angus, straightbred Charolais and reciprocal cross females at the South Dakota State University Beef Breeding Unit from 1970 through 1972. Females were randomly allotted to a drylot or pasture management regime and data for this thesis came from the first three calf crops produced by drylot cows from 1972 through 1974.

Feeding of Females Until First Calving

Rations and amounts allotted to individually fed heifers from weaning to their first calving are presented in table 1. Pellet I fed initially to heifers born in 1970 contained 24.7% oats, 24.7% alfalfa hay, 7.4% corn, 9.1% soybean oil meal, 7.4% molasses and 1.2% Durabond. On May 6, 1971, the pellet formulation was changed to 24% corn cobs, 27% corn, 29% oats, 12% alfalfa, 7% molasses and 1% Durabond. During the period of June 7 to August 29, 1972, the 1971 heifers received either .9 or 1.8 kg of ground, shelled corn depending on the condition of the individual. On February 14, 1974, the ration was again changed

TABLE 1. FEEDING REGIME FROM WEANING TO FIRST CALVING

Period	Ingredient						
	Corn silage (kg)	Pellet I (kg)	Pellet II (kg)	Chopped alfalfa hay (kg)	Alfalfa pellets (kg)	Shelled corn (kg)	Ground ear corn (kg)
<u>1970 heifers</u>							
Weaning 72 to 5/5/71	2.27 ^a	<u>ad lib.</u>					
5/6/71 to 10/21/71			<u>ad lib.</u>	1.36			
10/22/71 to 11/9/71			(<u>3.86-7.04</u>) ^b	1.36			
11/9/71 to calving				1.36	(4.54-8.40)		
<u>1971 heifers</u>							
Weaning 71 to 1/29/72				1.36	<u>ad lib.</u>	1.36	
1/30/72 to 6/6/72				2.72	<u>ad lib.</u>	1.82	
6/7/72 to 8/29/72				2.72	<u>ad lib.</u>	(.91-1.82)	
8/30/72 to calving				2.72	(<u>4.09-6.58</u>)		
<u>1972 heifers</u>							
Weaning 72 to 7/3/73				1.36	<u>ad lib.</u>		
7/4/73 to 10/4/73				1.36	<u>ad lib.</u>	.91	
10/5/73 to 10/31/73				2.72	<u>ad lib.</u>		
11/1/73 to 2/13/74				2.72	(<u>5.45-7.26</u>)		
2/14/74 to calving				4.09			(3.18-4.31)

^a One numerical value indicates amount of ingredient fed to all heifers.

^b Values in parentheses indicate range of quantities fed.

when it became more economical to feed ground ear corn than alfalfa pellets to meet energy requirements.

Feeding Regime After First Calving

The feeding regime from initial parturition of the 1970 cows in 1972 through weaning of the 1974 calf crop is presented in table 2. Tabular TDN values of feeds on a 100% dry matter basis used in this study were chopped alfalfa hay, 58%; alfalfa pellets, 62%; cracked shelled corn, 91% and ground ear corn, 90%. During lactation, cows with calves received cracked shelled corn in 1972 and 1973 and increased levels of ground ear corn in 1974. Nonlactating cows also received grain supplementation during the breeding season but at reduced levels.

Calf Creep Rations

Creep feed formulations and estimated TDN level in each are presented in table 3. Two different rations were fed in 1972. Ration I was available from July 5 until September 4 and was changed at that time due to bloat problems. Ration II was fed from September 5 until weaning of that year.

Management Dates and Trait Measurement

Important management dates for the period of study are shown in table 4.

Milk production was estimated by the calf-weight-change method. Progeny were separated from their dams overnight, weighed at 7 am, allowed to nurse and reweighed. Calves remained separated during the

TABLE 2. FEEDING REGIME FROM CALVING IN 1972 TO WEANING IN 1974

Period	Ingredient			
	Chopped alfalfa hay (kg)	Alfalfa pellets (kg)	Cracked shelled corn (kg)	Ground ear corn (kg)
Calving 72 to 6/5/72	2.72 ^a		1.82	
6/6/72 to 7/3/72	2.72 ^b	(3.63-7.72) ^d	(1.82-3.63)	
	2.72 ^c	(2.72-4.54)	1.82	
7/4/72 to 8/2/72	2.72	(4.54-6.36)	(3.63-4.54)	
	2.72	4.54	3.63	
8/3/72 to weaning 72	2.72	(5.45-8.17)	(3.63-4.54)	
	2.72	(3.63-4.54)	3.63	
11/17/72 to 12/22/72	2.72	(2.72-4.54)		
12/23/72 to calving 73	2.72	(4.09-6.81)		
Calving 73 to 6/30/73	2.72	(4.09-6.36)	2.27	
	2.72	(4.31-5.90)		
7/1/73 to 8/29/73	2.72	(3.63-8.17)	(2.27-4.54)	
	2.72	(4.31-8.17)	1.36	
8/30/73 to weaning 73	2.72	(5.45-8.17)	(2.72-4.54)	
	2.72	(4.54-7.26)		
11/1/73 to 2/14/74	2.72	(4.54-8.17)		
2/15/74 to calving 74	4.09			(3.18-5.45)
Calving 74 to 8/1/74	4.09			(6.81-9.53)
	4.09			(1.36-2.27)
8/2/74 to weaning 74	4.09			(5.00-9.08)
	4.09			(.91-2.27)

^a One numerical value per period indicates quantity of ingredient fed to all cows.

^b Values on first line for period indicate quantity of ingredient fed to lactating cows.

^c Values on second line for period indicate quantity of ingredient fed to nonlactating cows.

^d Values in parentheses indicate range of quantities fed.

TABLE 3. CALF CREEP FEED FORMULATION

Ingredient	1972-I ^a	Percent of ration		1974
		1972-II	1973	
Cracked corn	50	65	65	70
Oats	25	10	10	15
Soybean oil meal	5	5	5	5
Alfalfa pellets	10	10	10	--
Chopped alfalfa	10	10	10	10
Vitamin A (IU/lb)	4000	--	--	--
Percent TDN (dry matter)	80.6	82.9	82.9	85.0
Percent TDN (as fed)	72.5	73.5	73.5	77.5

^a Ration I was fed initially in 1972 but was changed on September 4 due to incidence of bloat.

TABLE 4. IMPORTANT MANAGEMENT DATES

Item	1971	1972	1973	1974
First cow bred	June 21	June 20	June 6	
Last cow bred	Aug. 24	Aug. 21	Aug. 6	
First calf born		March 28	March 28	March 11
Last calf born		June 7	May 31	May 15
Creep feed started		July 5	June 8	May 14
Milk production measured		June 8	June 12	June 4
		July 7	July 10	July 2
		Aug. 31	Aug. 28	Aug. 27
		Sept. 28	Sept. 25	Sept. 24
Castration		Nov. 1	Oct. 19	Oct. 18
Calves weaned		Nov. 20	Nov. 2	Nov. 1

day and the same process was repeated at 4 pm. The sum of differences in pre- and postnursing weights was considered as 24-hour milk production. Six such measurements were collected in 1972 and 1974, but due to mechanical problems only four measures were taken in 1973. Additional estimates of milk levels recorded but not listed in table 4 or utilized in data analysis were collected August 3 and October 26 in 1972 and July 30 and October 22 in 1974.

Models Employed in Data Analyses

Four statistical models were employed for analysis of data by least squares procedures. Models I and II were used to analyze records of cows weaning calves for efficiency and related traits. Models III and IV were similar to models I and II, respectively, but were utilized for analysis of reproductive performance of all individually fed females. Model I was $Y_{ijklmnop} = \mu + B_i + D_j + S_k + R_l + bA_m + bP_n + bF_o + BD_{1j} + BS_{1k} + BR_{1l} + DS_{jk} + DR_{jl} + SR_{kl} + BDS_{1jk} + BDR_{1jl} + BSR_{1kl} + DSR_{jkl} + BDSR_{1jkl} + e_{ijklmnop}$ where

μ is the population mean

B_i is the effect common to all observations of the i th breed
of dam

D_j is the effect common to all observations of the j th age of
dam

S_k is the effect common to all observations of the k th sex of
calf

R_l is the effect common to all observations of the l th year

bA_m is the linear regression effect on the m th age of calf

bP_n is the linear regression effect on the n th previous parity

bF_0 is the linear regression effect on the 0th future parity

BD_{ij} refers to the interaction of the i th breed of dam and j th age of dam

BS_{ik} refers to the interaction of the i th breed of dam and k th sex of calf

BR_{il} refers to the interaction of the i th breed of dam and l th year

DS_{jk} refers to the interaction of the j th age of dam and k th sex of calf

DR_{jl} refers to the interaction of the j th age of dam and l th year

SR_{kl} refers to the interaction of the k th sex of calf and l th year

BDS_{ijk} refers to the interaction of the i th breed of dam, j th age of dam and k th sex of calf

BDR_{ijl} refers to the interaction of the i th breed of dam, j th age of dam and l th year

BSR_{ikl} refers to the interaction of the i th breed of dam, k th sex of calf and l th year

DSR_{jkl} refers to the interaction of the j th age of dam, k th sex of calf and l th year

$BDSR_{ijkl}$ refers to the interaction of the i th breed of dam, j th age of dam, k th sex of calf and l th year

$e_{ijklmnop}$ is the random effect particular to the i th breed of dam, j th age of dam, k th sex of calf, l th year, m th age of calf, n th previous parity and o th future parity that causes the p th observation to deviate from the expected mean.

Calf age, previous parity and future parity were coded as continuous variables resulting in estimation of partial regression coefficients associated with one degree of freedom. Second and third order interactions were not estimable directly with the computer program utilized for analyses. The third order interaction was assumed to be zero and $B \times D \times S$ and $B \times S \times R$ were estimated by difference for I and II, tested and found not significant ($P > .05$) by Bartlett's Test of Homogeneity (Snedecor, 1946). $B \times D \times R$ and $D \times S \times R$ were not estimable since all ages of dam were not present in all years. Analysis of variance for model I including main and first order interaction effects with expected mean squares is shown in table 5. Model II was identical to model I except that average cow weight, milk production and cow condition were also included as continuous independent variables.

The complete model III for analysis of reproductive performance was $Y_{ijklm} = \mu + B_i + D_j + R_k + bP_l + BD_{ij} + BR_{ik} + DR_{jk} + BDR_{ijk} + e_{ijklm}$ where

μ is the population mean

B_i is the effect common to all observations of the i th breed of dam

TABLE 5. ANALYSIS OF VARIANCE WITH EXPECTED MEAN SQUARES FOR MODEL I

Source of variation	Degrees of freedom	Expected mean square
Breed of dam (B)	(B-1)	$\sigma_e^2 + k_{13}\sigma_b^2$
Age of dam (D)	(D-1)	$\sigma_e^2 + k_{12}\sigma_d^2$
Sex of calf (S)	(S-1)	$\sigma_e^2 + k_{11}\sigma_s^2$
Year (Y)	(Y-1)	$\sigma_e^2 + k_{10}\sigma_y^2$
B x D	(B-1)(D-1)	$\sigma_e^2 + k_9\sigma_{bd}^2$
B x S	(B-1)(S-1)	$\sigma_e^2 + k_8\sigma_{bs}^2$
B x Y	(B-1)(Y-1)	$\sigma_e^2 + k_7\sigma_{by}^2$
D x S	(D-1)(S-1)	$\sigma_e^2 + k_6\sigma_{ds}^2$
D x Y	(D-1)(Y-1)-3	$\sigma_e^2 + k_5\sigma_{dy}^2$
S x Y	(S-1)(Y-1)	$\sigma_e^2 + k_4\sigma_{sy}^2$
Age of calf (linear bA)	1	$\sigma_e^2 + k_3\sigma_a^2$
Previous parity (linear bP)	1	$\sigma_e^2 + k_2\sigma_p^2$
Future parity (linear bF)	1	$\sigma_e^2 + k_1\sigma_f^2$
Remainder		σ_e^2

D_j is the effect common to all observations of the j th age of dam

R_k is the effect common to all observations of the k th year

bP_l is the linear regression effect on the l th previous parity

BD_{ij} refers to the interaction of the i th breed of dam and j th age of dam

BR_{1k} refers to the interaction of the i th breed of dam and k th year

DR_{jk} refers to the interaction of the j th age of dam and k th year

BDR_{1jk} refers to the interaction of the i th breed of dam, j th age of dam and k th year

e_{ikjlm} is the random effect particular to the i th breed of dam, j th age of dam, k th year and l th previous parity that causes the m th observation to deviate from the expected mean.

Analysis of variance is shown in table 6. Model IV was the same as III except that cow weight was included as a continuous independent variable.

Coefficients for breed group comparisons of reproductive traits are shown in table 7. Five comparisons were made with three available degrees of freedom and therefore all comparisons are not independent. Decreased confidence in probability levels due to nonorthogonal comparisons was counterbalanced by the use of more conservative

TABLE 6. ANALYSIS OF VARIANCE WITH EXPECTED MEAN SQUARES FOR MODEL III

Source of variation	Degrees of freedom	Expected mean square
Breed of dam (B)	(B-1)	$\sigma_e^2 + k_7 \sigma_b^2$
Age of dam (D)	(D-1)	$\sigma_e^2 + k_6 \sigma_d^2$
Year (Y)	(Y-1)	$\sigma_e^2 + k_5 \sigma_y^2$
B x D	(B-1)(D-1)	$\sigma_e^2 + k_4 \sigma_{bd}^2$
B x Y	(B-1)(Y-1)	$\sigma_e^2 + k_3 \sigma_{by}^2$
D x Y	(D-1)(Y-1)-3	$\sigma_e^2 + k_2 \sigma_{dy}^2$
Previous parity (linear bP)	1	$\sigma_e^2 + k_1 \sigma_p^2$
Remainder		σ_e^2

TABLE 7. COEFFICIENTS FOR BREED GROUP COMPARISONS

Comparison	Breed group			
	AA	CC	AC	CA
Straightbred vs crossbred	-1	-1	+1	+1
Angus vs Charolais	+1	-1	0	0
Angus-Char. vs Char.-Angus	0	0	-1	+1
Angus vs crossbred	+2	0	-1	-1
Charolais vs crossbred	0	-2	+1	+1

two-tailed Student's t-tests when one-tailed values would be appropriate for tests of heterosis as indicated by Cundiff et al. (1974).

INTRODUCTION

A profitable future for the beef industry depends on its ability to become more efficient. There has been interest in recent years in the relationship between cow size and efficiency of production. Maintenance requirements are generally regarded to be dependent on cow weight (Klosterman et al., 1968; Turner et al., 1974; N.R.C., 1970), and this fact has propagated the belief that efficiency is highly dependent on cow size. However, research has indicated positive association between dam weight and progeny weights (Bennyshek and Marlowe, 1973; Trail et al., 1971; Christian et al., 1965; Jeffery and Berg, 1972; Brinks et al., 1962; Miguel et al., 1972; Vaccaro and Dillard, 1966; Urick et al., 1971).

This report deals with an analysis of data collected in the first three years of an experiment designed to detect differences in cow efficiency. The purpose of this study was to examine the sources of variation affecting cow-calf efficiency to weaning with special emphasis placed on effects due to breed group, cow weight, condition and milk production. Reproductive traits were also analyzed to characterize net weaning efficiency of the experimental females.

MATERIALS AND METHODS

Source of Data

Straightbred Angus, straightbred Charolais and reciprocal crosses of these breeds were produced from 1970 through 1972. They were the objective of an earlier crossbreeding project in which straightbred Angus and 75% or higher Charolais cows were bred at random to one Angus and one Charolais sire. Thus, straightbred Angus and Angus-Charolais crosses were paternal half-sibs, as also were straightbred Charolais and Charolais-Angus crosses.

Heifers were randomly allotted to either a drylot or pasture management regime. All 1970 heifers were individually fed in drylot until a year of age at which time half were placed on pasture. The 1971 and 1972 heifers were assigned to one of the two systems at weaning. The pasture group was grazed on improved pasture in the summer and wintered in drylot under traditional management conditions. Drylot cows were individually fed weighed amounts of feed throughout the year.

Data for this study were collected from drylot cows and their first three calf crops produced from 1972 through 1974. The breed-year-age of dam distribution of drylot cows is presented in table 8. All cows were artificially inseminated to calve first as two-year-olds. Breeding seasons were 65, 63 and 62 days. Cows were removed from the project if they failed to wean a calf in two consecutive years. One Polled Hereford bull sired the 1972 and 1974 calf crops and a second

TABLE 8. SUBCLASS FREQUENCIES OF EXPERIMENTAL FEMALES

Year	Age	Breed group ^a				Total
		AA	CC	AC	CA	
1972	2	12	6	11	8	37
1973	2	6	6	5	6	23
	3	6	6	7	6	25
1974	2	5	6	6	6	23
	3	6	6	4	6	22
	4	7	6	8	6	27
Total		42	36	41	38	157

^a AA = Angus x Angus, CC = Charolais x Charolais, AC = Angus x Charolais and CA = Charolais x Angus.

sire of the same breed produced the 1973 progeny. Thus, sire and year differences were confounded.

Cows were assigned at random to individual feeding pens and were allowed weighed amounts of feed twice daily. During the first two years of the study, cows received constant amounts (2.7 kg daily) of chopped alfalfa hay, variable quantities of alfalfa pellets throughout the period and variable levels of cracked shelled corn during lactation. In 1974, 4.1 kg of chopped alfalfa hay were fed daily to all cows and variable amounts of ground ear corn provided the major energy requirement. The quantities of pellets and/or corn allocated to each cow was dependent on her individual weight change over each 28-day period and the weight change of her contemporary age-breed-parity group in the previously described pasture management regime. If an individually

fed drylot cow was not gaining or losing weight at the same rate as her pasture contemporaries, her diet was adjusted accordingly. Thus, an attempt was made to simulate pasture weight change patterns in the drylot population. Figure 1 depicts least squares means of weights taken at calving and weaning for drylot and pasture groups over the period of study. These means were calculated for cows weaning calves and were adjusted for breed, age, year and unequal subclass numbers. Figure 2 shows a plot of similarly calculated means for weight-wither height ratios taken at calving and weaning.

Progeny were allowed to nurse twice daily while cows were exposed to individual feeders. Weighed amounts of creep feed were available ad libitum at night and calves ran together in drylot during the day. Creep feed TDN estimates ranged from 72.5 to 77.5% over the three-year period.

Trait Measurement

All cows were weighed at 28-day intervals. Weights and wither-height measurements were taken following parturition and at weaning. Nonlactating cows were also weighed and measured during the calving season and at weaning.

Weaning efficiency was calculated as the ratio of total TDN intake of the cow and calf to weaning weight of the calf. Cow TDN was the total intake from weaning time of the previous year until weaning of the calf and calf TDN was that amount received from creep feed only. Weaning weight used in the denominator of the efficiency ratio was the actual unadjusted measure.

Figure 1. Least squares means of cow weights taken at calving and weaning and plotted for the period of study.

Figure 2. Least squares means of cow weight-height ratios taken at calving and weaning and plotted for the period of study.

Milk production data were collected by the calf-weight-change method (Neville, 1962). Measures were taken at 28-day intervals beginning when progeny averaged 40 to 50 days of age and could consume all milk produced by their dams in one nursing. Although six monthly milk production measures were taken in two years of study, only four were available in one year. Totusek et al. (1973) found a correlation of .91 ($P < .01$) between four calf-weight-change measures and actual 210-day lactation totals. Based on those results, the sum of four measurements taken on similar dates in all three years was used as an estimate of annual milk yield.

Cow weight was calculated as the average of 14 weights taken over the same thirteen 28-day periods as cow TDN intake. The ratio of weight to wither height taken at weaning served as a measure of cow condition in this analysis. Weight-height ratios have been used by several workers as an indicator of fatness (Klosterman et al., 1968, 1974; Kress et al., 1969; Lindsey et al., 1970; Jeffery and Berg, 1972; Hohenboken et al., 1973). This measure was not available for dry cows in the first year of the study.

Reproductive traits were coded as 0 or 1 with the exception of previous parity. Codes for this trait were 1 = heifer, 2 = calf weaned, 3 = calf born but not weaned and 4 = nonparturating. Future parity indicated pregnancy status for the last portion of the year of record. Calves born was used as an indicator of fertility and a 1 was recorded at parturition regardless of the condition of the calf.

Calves weaned was an indicator of livability. Results for fertility and livability are presented as percentages.

Analyses of Data

Least squares procedures (Harvey, 1960) were utilized for initial analysis of the data. Four statistical models were employed, two for the study of weaning efficiency which included only data of cows weaning calves (table 9) and two for the analysis of reproductive traits of all individually fed females.

In model I, cow TDN, calf TDN, total TDN, actual weaning weight of the calf, weaning efficiency, milk production, cow weight and cow condition were dependent variables. Effects due to breed of dam, age of dam, calf sex, year and all first order interactions were included along with calf age, previous parity and future parity as continuous independent variables. Model II was similar to model I, except that milk production, cow weight and cow condition were included as continuous independent variables rather than as dependent variables. The purpose of this analysis was to study the influence of milk, weight and condition on efficiency and related traits and to observe any reduction in breed of dam effects when these variables were included.

Model III for analysis of fertility and livability included breed, age and year as discrete classes, first order interactions between them and previous parity as a continuous variable. In model IV, cow weight was also included as a continuous variable along with those sources listed for model III. Because height measures were not

TABLE 9. SUBCLASS FREQUENCIES OF COW-CALF WEANING RECORDS

Breed of dam ^a	Year						Total
	1972		1973		1974		
	M ^b	F	M	F	M	F	
AA	6	4	7	4	7	7	35
CC	2	2	4	3	7	5	23
AC	5	4	2	5	5	9	30
CA	4	4	3	8	10	5	34
Total	17	14	16	20	29	26	122

^a AA = Angus x Angus, CC = Charolais x Charolais, AC = Angus x Charolais and CA = Charolais x Angus.

^b M = male, F = female.

available for six dry cows in the first year, cow condition was not incorporated in the model. The effect of condition was estimated in an analysis excluding the six missing observations.

Linear functions of least squares constants were utilized to make breed group comparisons for reproductive traits. Comparisons are not all orthogonal since more are made than there are independent degrees of freedom. Thus, the error rate may be slightly different from probability levels noted. However, Student's two-tailed t-test was used to evaluate all comparisons when more lenient one-tailed values would be appropriate (Cundiff et al., 1974).

Where possible, the importance of second order interactions was estimated. Breed of dam x year x age of dam and sex x year x age of dam effects were not estimable due to missing subclasses in year-age of dam categories. Breed of dam x sex x age of dam and breed of

dam x sex x year were found not to be significant by Bartlett's Test of Homogeneity (Snedecor, 1946). The third order interaction for models I and II was assumed to be zero.

A step-down procedure was used to delete those independent variables in all models which were not important sources of variation. Variables were deleted if analysis resulted in F values less than the .25 probability level. Each dependent variable was analyzed separately. Breed of dam was included in all models even though it did not always attain significance of .25.

Multiple regression analysis was undertaken to examine biological differences and practical indicators of cow-calf efficiency. Partial regressions of cow weight, condition and milk production on efficiency were calculated from the residual correlation matrix of the final step-down efficiency analysis of model I. Proportion of variation in efficiency accounted for by these three variables was then determined by utilizing the standard partial regressions to calculate the appropriate reductions. Stepwise multiple regression analysis was utilized to estimate the importance of practical and available traits in accounting for variation in efficiency. Initially actual weaning weight, calf age and sex, cow weight, condition and milk levels were included as independent variables. In a second analysis, age, sex and age of dam adjusted weaning weight (B.I.F., 1974) was also studied.

RESULTS AND DISCUSSION

Means and standard deviations of traits describing the drylot population are shown in table 10. Cow TDN intake was higher than values reported by Carpenter et al. (1972), Klosterman et al. (1974) and Turner et al. (1974) utilizing mature cows on higher roughage diets. Intake and resulting efficiency differences may reflect cow age and ration energy content differences among these studies.

Model I Analysis

Least squares means and partial regression coefficients are shown in table 11 for sources remaining in the model after final step-down elimination. Correlations presented in table 12 are from the residual matrix of dependent variables of the initial model I analysis.

Although significant breed of dam differences in milk production did not exist, Angus cows had the highest estimates, crossbreeds were intermediate and Charolais cows produced the lowest levels (table 11). Calf age and year effects were significant ($P < .01$) for this trait as was the breed of dam x sex interaction ($P < .05$). Milk estimates decreased as calf age increased, indicating a decline in milk production as lactation progressed. Calf sex had no important effect ($P > .25$) on milk production, but cows nursing bull calves tended to produce higher levels. Milk production was moderately associated with efficiency ($r = -.52$) and weaning weight ($r = .44$). High positive correlations for milk yield and weaning weight have been reported by

TABLE 10. MEANS AND STANDARD DEVIATIONS OF
DRYLOT DAM AND PROGENY TRAITS

Item	Mean	Standard deviation
Average cow weight (kg)	431.5	43.3
Cow weight/height at weaning (kg/cm)	3.92	.27
Milk production (kg) ^a	19.9	5.5
Actual weaning weight (kg)	218	30
Adjusted weaning weight (kg) ^b	255	26
Calf age at weaning (days)	201	20
Cow TDN intake (kg)	2234	160
Calf TDN intake (kg)	235	75
Total TDN intake (kg)	2469	205
Total TDN/actual weaning weight (kg/kg)	11.47	1.21

^a Total of four measurements.

^b Age, sex and age of dam adjusted.

TABLE 11. LEAST SQUARES MEANS, PARTIAL REGRESSION COEFFICIENTS AND STANDARD ERRORS FROM FINAL MODEL I ANALYSES

Item	Milk production (kg)	Cow weight (kg)	Cow condition (kg/cm)	Cow TDN (kg)	Calf TDN (kg)	Total TDN (kg)	Wearing weight (kg)	Efficiency (kg/kg)
Breed of dam ^a		**	**	**		**		
AA	20.7 ± .9	415 ± 5	3.90 ± .05	2187 ± 14	253 ± 10	2446 ± 19	218 ± 4	11.32 ± .17
CC	17.9 ± 1.1	459 ± 7	4.02 ± .06	2290 ± 17	285 ± 13	2584 ± 24	226 ± 5	11.41 ± .23
AC	19.9 ± 1.0	426 ± 6	3.84 ± .05	2288 ± 15	259 ± 9	2553 ± 20	223 ± 4	11.46 ± .19
CA	19.8 ± 1.0	444 ± 6	4.02 ± .05	2255 ± 14	273 ± 10	2530 ± 19	220 ± 4	11.63 ± .18
Age of dam		**		**	**	**		
2	19.2 ± .6	424 ± 5	3.90 ± .04	2230 ± 10	205 ± 9	2426 ± 17	217 ± 3	--
3	18.2 ± .9	430 ± 7	3.90 ± .06	2214 ± 14	280 ± 13	2507 ± 24	218 ± 4	--
4	21.3 ± 1.2	454 ± 9	4.03 ± .07	2321 ± 20	318 ± 16	2651 ± 30	231 ± 6	--
Sex of calf	b	b	b				**	**
M	20.0 ± .7	436 ± 4	3.94 ± .04	--	276 ± 8	--	231 ± 3	11.00 ± .14
F	19.1 ± .7	436 ± 5	3.95 ± .04	--	260 ± 9	--	212 ± 3	11.91 ± .14
Year	**			**	**	**		**
1972	18.8 ± 1.1	431 ± 7	4.02 ± .06	2371 ± 13	321 ± 13	2700 ± 24	228 ± 5	11.90 ± .21
1973	17.4 ± 1.0	432 ± 6	3.87 ± .05	2115 ± 16	265 ± 12	2384 ± 22	222 ± 5	10.79 ± .21
1974	22.6 ± .6	446 ± 4	3.95 ± .04	2279 ± 10	216 ± 8	2499 ± 15	215 ± 3	11.67 ± .14
Calf age (linear b)	** -.09 ± .3	--	--	** 1.82 ± .41	** 1.90 ± .29	** 3.75 ± .55	** .88 ± .12	** -.03 ± .01
Previous parity (linear b)	--	** 17.07 ± 5.82	* .10 ± .05	--	** -31.19 ± 10.04	** -45.00 ± 18.93	--	--
Future parity (linear b)	--	--	--	24.64 ± 17.34	--	--	--	--

^a AA = Angus x Angus, CC = Charolais x Charolais, AC = Angus x Charolais and CA = Charolais x Angus.

^b Sex remained in model due to significant (P < .25) first order interactions.

* P < .05.

** P < .01.

TABLE 12. SIMPLE CORRELATION COEFFICIENTS OF DEPENDENT VARIABLES FROM MODEL I ANALYSIS

	Cow TDN	Calf TDN	Total TDN	Weaning weight	Weaning effi- ciency	Milk produc- tion	Cow weight
Cow TDN							
Calf TDN	.23 ^a						
Total TDN	.87	.69					
Weaning weight	.33	.47	.48				
Weaning efficiency	.08	-.17	-.03	-.87			
Milk production	.08	-.11	.00	.44	-.52		
Cow weight	.65	.35	.66	.32	-.04	.04	
Cow condition	.55	.25	.54	.14	.08	-.06	.83

^a Correlations > |.17| significant at $P < .05$.

Totusek et al., 1973 ($r = .88$); Neville, 1962 ($r = .81$) and Melton et al., 1967 ($r = .72$). Similarly, Rutledge et al. (1971) found 60% of the variation in weaning weight accounted for by milk production. Association of these traits appears to be lower when calves are allowed ad libitum access to creep feed in drylot as indicated by the correlation in the present study and those reported by Hohenboken et al., 1973 ($r = .33$) and Carpenter et al., 1972 ($r = .35$).

Significant ($P < .01$) breed, cow age, previous parity and age x year effects existed for cow weight and only breed and previous parity accounted for significant ($P < .01$) condition differences (table 11). A relatively high correlation existed in these data between weight and condition ($r = .83$), and there was moderate relation of these traits with cow TDN and total TDN but little association with efficiency or milk production (table 12).

Cow TDN intake was significantly ($P < .01$) influenced by breed and age of dam, year and calf age effects. The largest breed of dam differences appeared between straightbred Angus and the other three groups, but these were not practically important (68 to 103 kg). Four-year-old dams had highest intake levels and the range of values for age of dam effects was similar to that for breed groups. The regression of cow intake on calf age at weaning was positive and probably due to the feeding regime, since grain levels were increased at parturition to support lactation. Thus, earlier calving cows received more TDN because of longer lactations. The correlation of cow TDN and weaning efficiency was .08 (table 12), indicating a small undesirable association. Kress

et al. (1969) reported phenotypic correlations of first, second and third lactation TDN consumption and cow lifetime weaning efficiency in Hereford twins to be $-.25$, $-.30$ ($P < .05$) and $-.01$, respectively, when cow salvage weight was not included in the efficiency measure. They used an inverse of the efficiency ratio utilized in the present study, thus accounting for opposite signs of the correlations. Carpenter et al. (1972) found a correlation of $-.43$ between cow 205-day lactation feed consumption and weaning weight produced per unit of feed intake. The lower association of intake and efficiency in this analysis may result from TDN intake being a yearly rather than lactation total.

Age of dam, year, calf age and previous parity status caused significant ($P < .01$) variation in calf TDN consumption. Creep intake was lowly correlated ($-.17$) with efficiency indicating that, as creep consumption increased, efficiency tended to improve. Carpenter et al. (1972) found a similar relationship of $.25$. Kress et al. (1969), analyzing cow lifetime efficiency within lactation period, reported positive association with creep consumption in second and third lactations but negative correlations in first calving cows.

With the exception of significant ($P < .05$) effects due to previous parity, total TDN intake was influenced by the same factors as cow TDN (table 11). This is reasonable since a high correlation of $.87$ existed between these traits, and cow TDN accounted for the greatest portion of total TDN. Total intake had essentially zero relationship to efficiency.

Calf sex and age were the only variables accounting for significant ($P < .01$) variation in weaning weight in these data. Efficiency was highly correlated with weaning weight ($r = -.87$). Carpenter et al. (1972) also reported a high association of .71, but Kress et al. (1969) found correlations of .21 to .50 when cow salvage weight was not included in the efficiency estimate.

Model I analysis indicated that sex, year and calf age accounted for most of the variance in efficiency (table 12). Onks et al. (1975) similarly reported calf age and sex to have important effects on Angus cow-calf efficiency and Carpenter et al. (1972) found year and sex effects significantly affected 205-day production efficiency. In the present study, cows weaning male calves were 8% more efficient than those with female progeny.

Model II Analysis

Linear regression coefficients are shown in table 13 for cow weight, milk production and condition effects remaining after final elimination for each dependent variable in model II analyses.

Milk production had significant ($P < .01$) effects on weaning weight and efficiency and accounted for significant ($P < .25$) variation in creep feed intake. Cows producing more milk had heavier calves at weaning and were more efficient. Linear regression coefficients for weaning weight and efficiency on milk production were 1.528 and $-.095$, respectively. This trend for greater efficiency in higher milking cows agrees with results of Kress et al. (1969) and Carpenter et al. (1972). However, Holloway et al. (1975) using dam breeds of widely varying

TABLE 13. LINEAR REGRESSION COEFFICIENTS AND STANDARD ERRORS FOR EFFICIENCY
AND RELATED TRAITS ON MILK PRODUCTION, COW WEIGHT
AND CONDITION FROM FINAL MODEL II ANALYSES

Item	Cow TDN (kg)	Calf TDN (kg)	Total TDN (kg)	Weaning weight (kg)	Efficiency (kg/kg)
				**	**
Milk production (kg)	--	-1.832 $\pm$.973	--	1.528 $\pm$.369	-.095 $\pm$.018
	**	**	**	**	
Cow weight (kg)	1.616 $\pm$.192	.686 $\pm$.151	2.259 $\pm$.244	.367 $\pm$.108	-.006 $\pm$.005
Cow condition (kg/cm)	--	--	--	-21.973 $\pm$ 13.190	.868 $\pm$.532

** P < .01.

milking ability (Hereford, Holstein and Hereford x Holstein) reported no significant ($P > .05$) breed group variation in weaning efficiency. In the present study, calves receiving more milk tended to consume less creep TDN.

Although cow weight significantly ($P < .01$) affected all measures of TDN consumption and weaning weight, the regression of efficiency on cow weight was small and nonsignificant ($b = -.006$). Heavier cows and their calves required more feed but also produced more weaning weight, thus one trait appeared to counterbalance the other when combined in the efficiency ratio. Onks et al. (1975) reported a similar effect of initial weight of individually fed Angus cows. Kress et al. (1969), Carpenter et al. (1972) and Klosterman et al. (1974) indicated a trend for lighter cows to be more efficient, but only Kress and co-workers found a significant relationship. The sign of the regression coefficient calculated by model II analysis indicates cow weight effects on efficiency in these data are contrary to those reports. The regression of progeny weight on dam weight in this study ($b = .367$) is larger than values reported in the literature ranging from .011 to .127 (Christian et al., 1965; Tanner et al., 1965; Urick et al., 1971; Trail et al., 1971; Jeffery and Berg, 1972; Bennyshek and Marlowe, 1973; Edwards and Bailey, 1975). This coefficient, however, was calculated holding milk production and condition constant and was an average dam weight for the year of record rather than one weight taken at parturition, weaning or in the previous fall as in the aforementioned studies.

Increases in cow condition negatively affected weaning weight and efficiency, and condition effects were eliminated from TDN intake models. More highly conditioned cows tended to produce lighter calves at weaning and to be less efficient when weight and milk production were constant (table 13). Kress et al. (1969) also found cows with higher weight-wither height ratios to be less efficient.

Least squares breed group means for efficiency and related traits after inclusion of cow weight, condition and milk production as sources of variation are shown in table 14. Means and analysis of variance indicated breed group variation was reduced for all traits. Largest mean square reductions occurred for TDN intake measures and weaning weight, but breed group differences did remain significant ($P < .01$) for cow TDN and total TDN. Compared to model I analyses, breed group variance in calf TDN decreased by 95%, but reduction in the mean square for efficiency was only 14% when milk, weight and condition were included. Thus, these variables described most breed differences in progeny feed consumption but little breed group variation in efficiency. The small decrease in efficiency could result from opposing effects of milk, weight and condition between breed of dam groups.

Regression Analysis

Standard partial regression coefficients presented in table 15 were calculated from the residual correlation matrix of cow weight, condition, milk production and efficiency from an analysis including breed of dam, calf age and sex, year, breed of dam x year and sex x

TABLE 14. LEAST SQUARES MEANS AND STANDARD ERRORS FOR BREED OF DAM CLASSES FROM ANALYSES INCLUDING MILK PRODUCTION, COW WEIGHT AND CONDITION

Item	Cow TDN (kg)	Calf TDN (kg)	Total TDN (kg)	Weaning weight (kg)	Efficiency (kg/kg)
Breed of dam ^a	**		**		
AA	2217 ± 12	266 ± 9	2483 ± 15	223 ± 4	11.31 ± .18
CC	2247 ± 15	259 ± 13	2516 ± 19	225 ± 5	11.19 ± .22
AC	2297 ± 12	259 ± 10	2557 ± 15	225 ± 4	11.43 ± .18
CA	2237 ± 12	264 ± 9	2504 ± 15	220 ± 4	11.52 ± .16

^a AA = Angus x Angus, CC = Charolais x Charolais, AC = Angus x Charolais and CA = Charolais x Angus.

** P < .01.

TABLE 15. STANDARD PARTIAL REGRESSION COEFFICIENTS AND COEFFICIENTS OF DETERMINATION FOR EFFICIENCY CALCULATED FROM RESIDUALS OF FINAL-STEP, MODEL I EFFICIENCY ANALYSIS

Equation no.	Milk production	Cow weight	Cow condition	R ²
1	-.46	-.21	.22	.24
2	-.47	-.02	--	.23
3	-.47	--	.04	.23
4	--	-.35	.36	.04
5	-.43	--	--	.23
6	--	-.21	--	.003
7	--	--	.19	.003

year as sources of variation. From a biological standpoint, regressions indicate that milk production levels are accountable for much more variation in weaning efficiency than either cow weight or condition or both traits in combination. The R^2 value was as high for milk production alone ($R^2 = .23$) as it was in combination with either weight or condition. Weight or condition individually accounted for less than 1% of the variation (table 15), indicating that over the range studied these traits had little effect on weaning efficiency.

Results of stepwise multiple regression analysis (table 16) indicate the relative importance of practical measures which may be used to predict efficiency. Dam age was not included initially as an independent variable since it accounted for such a small portion of variance in efficiency by least squares analyses. Actual weaning weight accounted for 62% of the variation and all six variables included accounted for 74%. The high R^2 value for weaning weight alone suggests this trait accounts for considerable variation in efficiency due to age, sex and milk production effects shown to be important by least squares analyses. Sex, milk and cow weight generally accounted for little variation (table 16). Calf age increases had detrimental effects on efficiency in regression analysis. The beneficial effect of calf age on efficiency in the least squares results (table 11) was due to associated weight increases with increased age. The opposite effect of age by regression analysis (table 16) resulted from inclusion of weaning weight as an independent variable and indicates greater efficiency in heavier weaning calves at young ages. Effects of increased cow condition on

TABLE 16. STANDARD PARTIAL REGRESSION COEFFICIENTS AND COEFFICIENTS OF DETERMINATION FOR VARIOUS EFFICIENCY PREDICTION EQUATIONS

Equation no.	Adjusted ^a weaning weight	Weaning weight	Calf age	Calf sex	Milk production	Cow weight	Cow condition	R ²
1	--	-.99	.32	.03	-.08	.00	.24	.74
2	--	-1.02	.34	.03	--	-.17	.25	.74
3	--	-1.00	.34	.03	-.09	.20	--	.72
4	--	-1.01	.35	--	-.09	.21	--	.71
5	--	-1.03	.35	--	--	--	.24	.74**
6	--	-.98	.31	--	--	.19	--	.71**
7	--	-1.04	.38	--	--	--	--	.68**
8	--	-.79	--	--	--	--	--	.62**
9	-.69	--	--	--	-.12	-.14	.30	.53
10	-.68	--	--	--	-.14	--	.19	.52*
11	-.70	--	--	--	--	--	.18	.50**
12	-.69	--	--	--	--	--	--	.47**

^a Beef Improvement Federation suggested adjustments for age, sex and age of dam.

* $P < .05$.

** $P < .01$.

efficiency were always undesirable and significant ($P < .01$). Regressions were of similar magnitude to those for calf age. Cow weight had no effect on efficiency when all variables were included, nonsignificant beneficial effects (equations 2 and 9) when condition was also present but significant ($P < .01$) detrimental effects (equations 3, 4 and 6) when condition was not included in the prediction equation. This variable effect is probably due to a high correlation (.83) between weight and condition in these data. Kress et al. (1969) suggested a similar explanation for negative regression effects of cow weight in Hereford twin efficiency data.

Results of initial analyses (equations 1 through 8) suggested adjusted weaning weight might be an accurate predictor of efficiency. Further analysis indicated, however, that age, sex and age of dam adjusted weight accounted for only 47% of the variation, and accuracy of equations including this trait (9 through 12) was considerably reduced. Correction for dam age likely reduced R^2 values since this factor was unrelated to efficiency by least squares analyses. Adjustment to 205 days may have also accounted for reduction.

Of those examined, efficiency prediction equations presented in table 17 appear to be most effective from an accuracy and simplicity standpoint. Equation 5 including actual weaning weight, calf age and cow weight-height ratio was most accurate and would necessitate cow condition measurements. For breeders obtaining cow weights, equation 6 would be most reliable. From a practical viewpoint, however, equation 7

TABLE 17. SUGGESTED REGRESSION EQUATIONS FOR
PREDICTION OF WEANING EFFICIENCY

No.	Equation	Standard error of the estimate	R ²
5	$Y = 11.9708 - .0416 (\text{actual weaning weight, kg})$ $+ .0211 (\text{age at weaning, days}) + 1.1008$ (cow weight-height at weaning, kg/cm)	$\pm .634$	.74
6	$Y = 13.7083 - .0419 (\text{actual weaning weight, kg})$ $+ .0226 (\text{age at weaning, days}) + .0054$ (cow weight, kg)	$\pm .661$	.71
7	$Y = 16.3468 - .0394 (\text{actual weaning weight, kg})$ $+ .0185 (\text{age at weaning, days})$	$\pm .693$	.68

including actual weaning weight and calf age would allow ample effectiveness with minimum additional record collection.

Reproductive Trait Analysis

Least squares model III breed group comparisons of reproductive traits are shown in table 18. Year and previous parity effects remained in the model for fertility. Age of dam, year and age of dam x year were included in the final analysis of livability. Straightbred Charolais cows were significantly ($P < .05$) less fertile and weaned significantly ($P < .05$) fewer calves than straightbred Angus or crossbred dams, but important differences did not exist between Angus and crosses for these traits. Fertility and calf crop weaned heterosis estimates of 8 and 10%, respectively, are similar to values reported by Cundiff et al., 1974 (7.5, 8.5%) for Angus, Hereford, Shorthorn and reciprocal crosses and

TABLE 18. LEAST SQUARES MEANS, DIFFERENCES AND STANDARD ERRORS
OF BREED GROUP COMPARISONS FOR REPRODUCTIVE TRAITS

Item	No.	Calves born (%)	Calves weaned (%)
AC and CA ^a	79	90.4	81.0
AA and CC	78	83.7	73.6
Difference		6.7	7.4
Standard error		11.1	13.2
AC and CA	79	90.4	81.0
AA	42	91.6	83.0
Difference		-1.2	-2.0
Standard error		14.1	16.8
AC and CA	79	90.4	81.0
CC	36	75.8	64.2
Difference		14.6*	16.8*
Standard error		14.9	17.8
AA	42	91.6	83.0
CC	36	75.8	64.2
Difference		15.8*	18.8*
Standard error		7.9	9.4
CA	38	94.1	89.5
AC	41	86.6	72.4
Difference		7.5	17.1
Standard error		9.4	11.3

^a AA = Angus x Angus, CC = Charolais x Charolais, AC = Angus x Charolais and CA = Charolais x Angus.

* $P < .05$.

Peacock et al., 1971 (9.4, 11.5%) for Shorthorn, Brahman and crossbred cows. Gaines et al. (1971) reported lower and Turner et al. (1968) reported higher heterosis levels than the present study. Although not significant ($P > .05$), the difference between reciprocal cross means was large (table 18). This variation, however, may be a result of the single sire mating scheme employed to produce the experimental females. Cundiff et al. (1974) found differences between Hereford and Angus reciprocal crosses of 7.7% for full-term calves born and 11.1% ($P < .05$) for calves weaned. Conversely, Turner et al. (1968) reported no significant variation between reciprocal crosses of the Hereford, Angus, Brahman and Brangus breeds.

Partial regressions of reproductive traits on cow weight were positive and approached significance ($P > .05$) for the overall analysis, but effects were substantially reduced when cow condition was included in the model. The effect of milk production levels on rebreeding performance was also estimated for cows weaning calves and results were small positive regressions accounting for little variation in fertility in these data. This trend indicates higher milk production levels were supported by the feeding regime and stress situations interfering with fertility probably did not exist in these drylot data.

General Conclusions

Breed group evaluations in these analyses were probably influenced by the one-sire mating scheme used to produce the experimental females. Results suggest, however, that small breed variation

in efficiency exists for cows weaning calves and raised and managed in the same environment. Differences in the gross efficiency measure are minor when compared to reproductive efficiency differences. Thus, it appears that heterosis for reproductive performance is the major advantage of the crossbred cow.

Results indicate that cow size and condition have little effect on efficiency of cows weaning calves, whereas higher milk production levels measured directly or indirectly as weaning weight are beneficial. Larger cows apparently produced enough more calf weight to balance greater nutrient requirements. It would seem desirable to study similar efficiency information over a wider range of cow weights. The significant ($P < .01$) biological effect of milk production on efficiency and the importance of reproductive performance on net weaning efficiency suggest further study of milk secretion and its relationship to fertility in range and pasture management regimes.

SUMMARY

Records of individually fed two-, three- and four-year-old Angus, Charolais and reciprocal cross cows weaning calves were analyzed to determine factors affecting weaning efficiency measured as the ratio of units of cow-calf TDN input per unit of weaning weight produced. Reproductive traits of all cows were also studied.

Calf age and sex, milk production and year had significant ($P < .01$) effects on efficiency. Breed of dam effects were small and nonsignificant both before and after inclusion of cow weight, condition and milk production in the least squares model. Cow size measured as the average weight for the year of record significantly ($P < .01$) affected all measures of cow and calf TDN intake and weaning weight but accounted for less than 1% of the variation in efficiency. Cow condition effects were of similar magnitude. Milk production differences explained 23% of the variance in efficiency.

Multiple regression analysis indicated that actual weaning weight accounted for 62% of the variation in efficiency. The importance of this trait resulted from an accumulation of effects due to milk production, calf age and sex which had significant effects on efficiency in least squares analysis. Efficiency prediction equations which were most accurate included weaning weight, calf age and cow condition or cow weight, but simplest and nearly as reliable was an equation including only actual weaning weight and calf age.

Angus and crossbred cows were not different ($P > .05$) for reproductive traits, but these groups were more fertile ($P < .05$) and weaned more calves ($P < .05$) than Charolais cows. When pooled across breed groups, cow weight, condition and milk production had small effects on reproductive performance under the drylot management regime of this experiment.

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APPENDIX

TABLE 1. MEAN SQUARES OF FINAL-STEP MODEL I ANALYSES

Source of variation	df	Cow TDN	df	Calf TDN	df	Total TDN	df	Weaning weight	df	Weaning effic.	df	Milk prod.	df	Cow wt	df	Cow cond.
Breed of dam (B)	3	** 73385	3	** 5576	3	** 103422	3	334	3	.56	3	28.2	3	** 10030	3	** .24
Age of dam (D)	2	** 63004	2	** 39799	2	** 180851	2	1108			2	46.4	2	* 3699	2	.09
Sex of calf (S)			1	6787			1	** 10286	1	** 23.40	1	^a 22.5	1	^a 1	1	^a .00
Year (Y)	2	** 358336	2	** 75408	2	** 531754	2	1073	2	** 8.15	2	** 214.7	2	2198	2	.16
B x D											6	24.2				
B x S											3	* 58.2	3	1667	3	.10
B x Y							6	715	6	1.56						
D x S																
D x Y			1	5357									1	** 7847		
S x Y																
Calf age (linear b)	1	** 107513	1	** 116167	1	** 455452	1	** 24412	1	** 27.75	1	** 228.0				
Previous parity (linear b)			1	** 26212	1	* 55836							1	** 7127	1	* .22
Future parity (linear b)	1	11209														
Remainder	112	5548	110	2713	112	9885	106	426	108	1.03	103	20.3	108	827	109	.06

^a Variable remained in model due to significant ($P < .25$) interaction.* $P < .05$.** $P < .01$.

TABLE 2. MEAN SQUARES OF FINAL-STEP MODEL II ANALYSES

Source of variation	df	Cow TDN	df	Calf TDN	df	Total TDN	df	Weaning weight	df	Effic.
Breed of dam (B)	3	** 35426	3	** 287	3	** 29603	3	120	3	.48
Age of dam (D)	2	** 23968	2	** 23890	2	** 74519	2	411		
Sex of calf (S)			1	** 10405			1	** 9066	1	** 19.53
Year (Y)	2	** 327619	2	** 68097	2	** 531659	2	** 4078	2	** 14.10
B x D										
B x S										
B x Y							6	560	6	1.20
D x S										
D x Y	1	** 13900			1	9866	1	483		
S x Y							2	* 1183	2	2.02
Calf age (linear b)	1	** 146828	1	** 103154	1	** 559897	1	** 31153	1	** 40.21
Previous parity (linear b)	1	** 32556	1	** 38405	1	** 158977	1	** 2191		
Future parity (linear b)	1	7128			1	11914				
Milk production (linear b)			1	8133			1	** 5388	1	** 21.65
Cow weight (linear b)	1	** 242173	1	** 47526	1	** 473389	1	** 3598	1	1.33
Cow condition (linear b)							1	871	1	1.49
Remainder	109	3424	109	2294	109	5511	99	314	103	.79

* P < .05.

** P < .01.