March 3, 1967

To the Graduate Council:

I am submitting herewith a thesis written by William Francis Byrne entitled "Effects of Various Factors on Intake and Efficiency of Utilization of Energy for Milk Production." I recommend that it be accepted for nine quarter hours of credit in partial fulfillment of the requirements for the degree of Master of Science, with a major in Dairying.

Don D. Richardson
Major Professor

We have read this thesis and recommend its acceptance:

Eric W Swanson

M. J. Montgomery

J. F. Miles

Accepted for the Council:

Hilton A. Smith
Vice President for
Graduate Studies and Research

EFFECTS OF VARIOUS FACTORS ON INTAKE AND EFFICIENCY OF UTILIZATION OF ENERGY FOR MILK PRODUCTION

A Thesis

Presented to

The Graduate Council of

The University of Tennessee

In Partial Fulfillment

of the Requirements for the Degree

Master of Science

---

by

William Francis Byrne

March 1967

ACKNOWLEDGMENTS

Sincere appreciation is expressed to Dr. D. O. Richardson for patience, helpful suggestions, and capable guidance in the conducting of the analyses and preparation of the thesis. The author wishes to thank Drs. E. W. Swanson and J. T. Miles for their constructive criticisms and helpful suggestions in reviewing the thesis. Appreciation is due Dr. M. J. Montgomery for encouragement and helpful suggestions. The author is especially greatful to Mr. Lee Ruch for his assistance in programming the analyses.

711966

TABLE OF CONTENTS

CHAPTER		PAGE
I.	INTRODUCTION	1
II.	REVIEW OF LITERATURE	2
	Factors Affecting Feed Intake	2
	All Roughage Vs. Mixed Rations	2
	Maintenance Requirements	4
	Requirements for Milk Production	5
	Corrections for Body Energy Loss or Gain	8
	Genetic Control of Efficiency	9
	Summary	11
III.	EXPERIMENTAL PROCEDURE	12
	Selection of Sires and Mating Plan	12
	Rations	12
	Management of Experimental Animals	13
	Data Collection	15
	Statistical Analysis	15
IV.	RESULTS AND DISCUSSION	18
V.	SUMMARY AND CONCLUSIONS	36
REFERENCES		38

LIST OF TABLES

TABLE		PAGE
I.	Composition of Concentrate Mixtures	14
II.	Production and Intake Variables Used in the Statistical Analysis and their Abbreviations	16
III.	F and b Values for Discrete and Continuous Variables	19
IV.	R^2 Values and Increase in Efficiency of Model Due to Fitting S x R Interaction and Continuous Variables	20
V.	Least Squares Constants for Selected Variables	21
VI.	Sire Group Adjusted Means for Selected Variables	23
VII.	Ranks of Sires on Different Rations According to FCM Production and Efficiency	25
VIII.	Within Ration Correlation Coefficients of Selected Variables for Grain Ration	26
IX.	Within Ration Correlation Coefficients of Selected Variables for No Grain Ration	27
X.	Heritability Estimates for Selected Variables on Across and Within Ration Bases	34

CHAPTER I

INTRODUCTION

Selection on the basis of milk production alone yields little information about the efficiency of conversion of feed nutrients into milk. Increased production could be the result of several factors other than increased efficiency. With the increased economic pressures on the dairy industry to become more efficient, it has become necessary to critically examine the efficiency of milk production. Accomplishments of the swine and poultry industries in breeding and feeding for increased efficiency are well known. In the dairy field the contribution of the Danish sire testing stations toward increased efficiency have been of value and should be expanded.

Since efficiency of production is a cumulative expression of several processes of basically additive inheritance and varying heritability, it should be a genetically important trait of additive type inheritance.

The objectives of the present analysis were to determine the effects of sire, ration, and various other factors on feed intake and efficiency of utilization of energy for milk production; and to derive an estimate of the heritability of efficiency.

CHAPTER II

REVIEW OF LITERATURE

Factors affecting feed intake. Although feed intake is probably governed by physiological mechanisms (2), several factors other than metabolic processes may affect it. The needs of the cow have been shown to influence intake patterns (46,47); but in one large study (74) appetite was the greatest determinant of milk production. The physical limitations of the cow to ingest feed, especially on bulky rations, appeared to restrict intake (8,82); and forage quality and physical form of the ration also appeared to affect intake (12,14,24,74). Apart from effects on physical limitations, roughage quality appeared to influence intake. Intake was positively related to increasing concentration of available nutrients in the ration (2,6,7,13,36,40,50,61,78), which appeared to be influenced more by stage of maturity than by species (7, 73).

All roughage vs. mixed rations. The inability of most cows fed high or all roughage rations to produce as much milk as on conventional rations could be due to the effects of such rations on intake and digestibility or to a less efficient utilization of energy from roughages. In general, addition of concentrates to the ration (9,43,57,58,70), at a constant plane of nutrition increased digestibilities with the exception of crude fiber (CF) which declined. In addition, some respiration

calorimetry trials and statistical analyses indicated decreased efficiency on all forage rations (14,23,24,64,69). However, results of other trials (8,22,24) did not substantiate the theory of decreased efficiency on high roughage rations. The effects of roughage quality on efficiency have been demonstrated in trials where "low quality" roughages and high CF levels were used (44,50,55,68).

Many feeding trials comparing all roughage and high roughage rations with roughage plus grain rations have been reported. Dawson, Kopland, and Graves (17) reported on a series of all roughage full lactation feeding trials using Holstein cows. Three different hays were used. Each cow's production on the hay ration was compared to her production on a roughage plus grain ration. The cows averaged 55.7, 51.0, and 47.0 percent as much milk on the hays as they did on conventional rations. In another study (32) the same workers used hay and silage made from the same field in a full lactation trial. Cows in the hay group produced 64.6 and 63.4 percent as much milk and fat, respectively, as they had on full feed. Cows in the silage group produced 61.2 percent as much milk and 61.5 percent as much fat as they had on grain supplemented rations. Graves et al. (33) noted Kansas, California, and Nevada work in addition to their own. California and Nevada work indicated that production on all alfalfa rations was greater than 80 percent of controls. In the Kansas study, where alfalfa hay was the only feed after 6 months of age, milk production was about 60 percent of controls. In their own study (33) Holstein cows were fed all

roughage rations for 2 to 3 lactations. The results were compared to performance on full feed. Twenty-four lactations by 15 cows averaged 57 percent as much milk and 60 percent as much fat as normal rations. Nine cows averaged 62.5 percent as much milk on 53.6 percent as much TDN as on full feed. Pounds of milk produced per pound of TDN above maintenance was 3.16 for the all alfalfa ration and 2.71 for the full feed ration. Cows grazed continuously, with supplemental roughage, produced 76 percent as much fat corrected milk (FCM) as cows on the same treatment with added grain (37). In a three year feeding trial (39) the average production of three all forage rations was 76 percent as much milk as normal and 72.5 percent as much fat. A cooperative study by 10 experiment stations and the USDA (48) indicated that cattle fed roughage alone produced 74 percent as much milk as a group fed roughage and grain. Montana work showed all roughage cows produced 81.5 percent as much as cows fed 1 pound of grain to 6 pounds of milk, and 76.5 percent as much as cows fed grain at the rate of 1 to 3. Other stations in the study reported 79 to 82 percent as much milk on all forage rations as on lower levels of grain feeding. Reid (71) estimated from several sources that all roughage rations support 70 to 87 percent of the milk production of roughage plus grain rations.

Maintenance requirements. The maintenance requirement of the cow for energy varies with some fractional power of body weight (4,5,10,11, 20,51,52,67,81). Maintenance appears to be the most efficient process in the body. Although some workers (24) reported lowered efficiency

with all roughage rations, it appeared that utilization of metabolizable energy (ME) when expressed on the same basis (4) did not differ much between rations (4,16,21,26,56). Percentage utilizations of ME corrected for energy required for methane formation ranged from 75 to 85 percent while uncorrected values averaged about 70 percent. Efficiency of utilization of digestible energy in a California study (31) was 50 percent.

Maintenance requirements reported in the literature varied from 6.7 pounds of TDN (27) to 17.8 pounds of digestible organic matter (72) per 1000 pounds of body weight. Hacker's original standard (34) recommended .7 pounds of digestible protein, 7.0 pounds of digestible carbohydrate, and .1 pound of fat per 1000 pounds of body weight. Morrison (66) recommends 7.9 pounds of TDN per 1000 pounds of weight which is equivalent to 6.3 therms of ENE. Maintenance was assumed to vary with the .87 power of body weight. NRC requirements (67) call for 11.0 pounds of TDN or about 9.1 therms of ME per 1000 pounds of weight. USDA (77) and Cornell (72) work indicated that the forage dry matter required to maintain body weight ranged from 11.5 to 13.0 pounds per 1000 pounds of body weight.

Values for ME requirements for maintenance ranged from 62 kcal. per kg. $BW^{.75}$ to as high as 146 kcal. per kg. $BW^{.75}$ (14,23,24,31,35) and averaged between 116-120 kcal. per kg. $BW^{.75}$.

Requirements for milk production. Milk production is the most important function of the dairy cow. Nearly all feeding standards

express requirements on a per unit basis. Fat content is considered because of its relation to energy content of the milk (30). Morrison (66) prescribes .32 pounds of TDN per pound of 4.0 percent milk. This is equal to about .30 therm of ENE per pound. The NRC recommendations (67) depending on level of production range from .33 to .42 kg. of TDN per kg. of 4 percent milk. ME requirements range from 1.2 to 1.5 therms per kg. Earlier standards (34) recommended .054 pounds of protein, .24 pounds of carbohydrates and .021 pounds digestible fat per pound of FCM.

Some New York studies (65,74) of milk production efficiency have assumed a true requirement at the mammary gland of .3 pounds of TDN per pound of FCM. In general TDN and DE requirements per pound of FCM decreased as concentrates replaced roughages if level of intake remained constant (9,19,38,43,70), indicating a more efficient utilization of TDN and DE. Work by Jarl (47) also indicated an increased efficiency on rations high in concentrates. If the level of intake increased, requirements of TDN and DE were increased to some extent (12,22,63,64,65,69,70, 74,79). Maine workers (49) and others (18,45,70,80) noted marked effects on TDN and DE utilization as lactation advanced. The overall requirement for DE per pound of FCM in the Maine study was .579 kcal. or about .29 pounds of TDN. USDA workers (54) found an average of 1.41 kg. of digestible DM per kg. of FCM with all roughage rations and 1.55 kg. with a normal ration. Kg. FCM per kcal. of energy consumed were .25 and .27. New Zealand work (80) indicated requirements for DM per pound of FCM of .53 to .58 and for TDN of about .35 pounds. Some English work

(13) used .3 pounds of digestible organic matter per pound of FCM. Several values for all alfalfa rations (17,32,33,39) indicated a range of pounds of milk per pound of available TDN from 2.49 to 3.16. Stone et al. (76) report an average efficiency on 12 rations of .567 pounds of TDN per pound of FCM including maintenance. Iowa work (82) with 3 rations of different energy concentrations found the ENE requirement per pound of FCM to be about .40 therm.

Mason et al. (59) and Mather (60) showed that efficiency and production are highly related. It follows that higher producing cows should be more efficient. Early work (18) indicated efficiencies of 38 percent or lower. These values were based on feed energy inputs and included all losses. Later work at Pennsylvania (29) showed that the utilization of ME for milk production varied from 60.1 to 75.8 percent. If methane production losses were taken into account the values rose as high as 91.5 percent. On the average (27) 69.3 percent of ME available was used for milk production. Moe (65) accepted this value. Blaxter (4) showed that the efficiency of utilization of ME for common rations should be maximal at 70 percent. According to Brody (10), as production increased "gross" efficiency, which was as high as 47 percent, approached "net" efficiency, which averaged about 60 percent, at an ever decreasing rate. One Iowa study (82) showed "gross" efficiencies of about 60 percent while another (43) showed "net" efficiencies of as high as 115 percent. A study (49) essentially duplicating Brody's methods found an overall "net" efficiency of 60.2 percent but with a standard deviation of 5 percent. This range is sufficient to cover the values found by

USDA workers (14,24) in a series of respiration trials. Efficiencies of ME for milk production were 54 percent for an all roughage ration and 61 and 65 percent for rations containing concentrates. Body energy correction factors affected efficiency estimates markedly. The average efficiency for balance trials in the literature was 75.5 percent. The 70 percent efficiency assumed in some Cornell work (65) appeared to be substantiated by Japanese investigators (35) who found production efficiency of a high concentrate ration to be 70.4 percent. However, protein content of the ration was a complicating factor. The Japan trials found production efficiency of a high roughage ration to be 83.3 percent. Armstrong and Blaxter (1) fed goats a basal ration with 10 percent of the energy intake supplied as acetic; propionic; or a steam volatile acid mixture. There were no significant differences between treatments in efficiency of milk secretion. The average efficiency was 69.1 percent.

Corrections for body energy loss or gain. Changes in body energy equilibrium appeared to have considerable effects on efficiency estimates (14,22,23,25) and failure to account for them could result in considerable error. Brody (10) recommended an energy correction factor of 2.1 pounds of TDN (4200 kcal.) for each pound of body tissue lost or gained by mature lactating cows. Recent California work (3) indicated that 2,266 kcal. per pound of live weight loss was a reliable estimate for lactating heifers.

Energy loss is utilized more efficiently than energy gain is made. Values used to correct for energy loss ranged from 1.43 to 1.61 times the energy (14,20,22,23) which appeared as milk or heat while values used to correct for energy gain ranged from 1.63 to 2.00 times the energy gain (14,20,22,23,24). The values grew less accurate as the magnitude of the loss or gain increased (20,22). High producing cattle appeared to be able to lose large amounts of energy in early lactation and store large amounts in late lactation (22).

Genetic control of efficiency. New York investigators (74) have concluded that there is little difference between cows in digestion or utilization of absorbed energy for milk production. However, Iowa studies (8,43) using varying levels of feeding and hay to grain ratios over considerable time periods indicated that treatments could not mask the ability of the cow to produce milk. A Cornell study (76) using 12 forages showed highly significant differences between cows in their efficiency of feed utilization. Early work in both England (18) and America (28) showed appreciable between cow differences in efficiency. Jumah et al. (49) using high producing cattle in a continuous efficiency study found significant inter-cow variation in regression of "net" efficiency on FCM production. Calorimeter studies by Pennsylvania workers (29) on three cows at different periods throughout lactation gave efficiencies of utilization of ME for milk production of 61 to 75.8 percent. Some of the variation could have been due to animal differences.

Mather (60) has concluded that efficiency is highly heritable. English workers (59) studied heritabilities of milk yield and "gross" efficiency in daughters of 152 bulls used in Danish progeny testing station herds. Heritability of "gross" feed efficiency was .48. On a between bull basis, which should approximate a genetic correlation, the correlation of yield and efficiency was .95. Huston (45) stated that under standard conditions heredity accounted for 39 percent of the variation in "gross" feed efficiency. Using repeatability of efficiency in successive lactations as the upper limit of heredity gave a maximum of 51 percent for several reports (45). Heredity appeared to account for only 23 percent of the variation in one measure of "net" efficiency (45). A USDA study (42) provided indirect evidence of genetic control by showing a significant correlation, .21, between growth efficiency and production efficiency. Comparison of 136 lactations of 42 daughters of 7 sires (75) found "gross" efficiencies for sire groups ranging from 27.2 to 31.7 percent. Sire effects on daughter-dam differences ranged from an increase of 4.17 percent to a decrease of 5.21 percent. FCM yield was highly correlated with efficiency, .54. Beltsville work (41) using 104 daughters of 6 sires in a full first lactation feeding trial showed significant differences between sire groups in "gross" feed efficiency even when milk production was held constant. Second lactation repeatabilities of feed efficiency were about two-thirds as high as for FCM production. Later work (54) using 200 daughters of 14 sires on an all roughage or roughage plus grain ration indicated highly significant

sire and ration differences in "gross" efficiency and a nonsignificant sire by ration interaction.

Summary. Feed intake was affected by a number of factors and was probably one of the major reasons that cows on all forage rations did not produce as well as cows on conventional rations. Efficiency of utilization of energy of all roughage and conventional rations was also felt to be important, in this respect.

Although results in the literature indicated that efficiency was a heritable trait, more work appeared to be needed in this area to determine the heritability of efficiency and to clarify the genetic relationship of efficiency and feed intake to each other and to other traits.

CHAPTER III

EXPERIMENTAL PROCEDURE

The data used in this analysis were taken from data routinely collected in the Dairy Experiment Station herd for a genetic-environmental interaction study conducted jointly by the University of Tennessee and the USDA. Data on 228 first lactation records on two rations over a seven-year period were utilized.

Selection of sires and mating plan. Thirteen sires, selected on the basis of their daughters' milk production, were used in the project. The bulls were either selected from the DES herd or from artificial breeding organizations. Two of the bulls, both from New Zealand, were proven on all forage rations.

Effort was made to have 20 daughters, 10 on each ration, of each bull complete an experimental lactation. Although the experiment covered a seven-year period, individual sire groups were usually completed in three years.

Rations. Two experimental rations were used. Ration two consisted of alfalfa-grass silage and alfalfa-grass hay ad libitum with concentrates fed at the rate of one kg. of concentrates to three kg. of milk. Ration two was an all roughage ration of alfalfa-grass silage and hay fed ad libitum.

The grain mix, which was custom ground and obtained in bulk from a local mill, was changed once during the experiment. The compositions of the mixes fed are shown in Table I. Each year the better quality hay produced at the station was utilized for the project. Silage was cut at as close to the bud to early bloom stage as possible, wilted, and ensiled without preservatives in conventional upright concrete stave silos.

Management of experimental animals. The heifers used were raised according to generally accepted management practices with the exception that after eight months of age no supplemental concentrates were fed regardless of roughage or pasture quality. Heifers were bred to calve at as close to the age of 24 months as possible. The first daughter of a bull calving was assigned at random to one of the rations. Successive daughters were assigned alternately to the rations. They were brought to the experimental barn one to four days after calving, placed in tie stalls, and started on their respective rations. Silage was fed in the morning; and hay was fed in the evening. Sufficient silage and hay were fed to insure small weighbacks which were taken in the morning and evening for hay and silage, respectively. The heifers were allowed exercise twice daily, at milking time, in a concrete holding lot. Water was available at all times; and minerals were provided free choice in the holding area. Concentrates, for those heifers receiving them, were fed in the milking parlor. The experimental animals were bred as soon after 60 days post-calving as possible.

TABLE I

COMPOSITION OF CONCENTRATE MIXTURES

PRIOR TO 30 JUNE 1959			AFTER 1 JULY 1959		
Ingredient	%	kg.	Ingredient	%	kg.
Shelled Corn	40.0	363.6	Shelled Corn	45.0	409.1
Barley	20.0	181.8	Barley	17.5	159.1
Oats	15.0	136.4	Molasses	5.0	45.6
Wheat Bran	10.0	90.9	Wheat Bran	20.0	181.8
SBOM	15.0	136.4	SBOM	12.5	113.6

Data collection. The experimental lactation was divided into 23 periods. All periods except the first and last were of 14 days length. The first and last periods were varied to standardize beginning and ending points. There were 21 successive 14 day periods. Total hay, silage and grain consumption were recorded for each period. Samples of hay and silage were taken bi-weekly and analyzed by routine methods for proximate analysis constituents; and grain samples were analyzed whenever the mix changed. Monthly body weights were taken on all cows.

Daily milk weights were taken with Milk-o-meters and semi-monthly samples were analyzed for percentage of butterfat.

Statistical analysis. Statistical analyses of the data were made with the aid of an IBM 7040 data processing system. Least squares analysis was used to fit constants for the effects of year-season of freshening, sire, ration, and sire x ration interaction on 28 intake and production variables. Age, days open, and body weight were included as continuous variables. Within ration correlation analyses were also performed on the variables. The variables used in these analyses and their abbreviations are shown in Table II.

TDN and ENE variables used were computed from laboratory analyses according to the formulae of the Tennessee Forage Testing Laboratory (62). The formulae were as follows:

$$\text{Silage and Hay TDN} = 65.14 + (0.45 \times CP) - (0.38 \times CF)$$

$$\text{Grain TDN (EE} < 6.5 \text{ percent)} = 80.49 - (1.17 \times CF)$$

$$\text{Grain TDN (EE} > 6.5 \text{ percent)} = 74.04 - (1.06 \times CF) + (0.82 \times EE)$$

TABLE II

PRODUCTION AND INTAKE VARIABLES USED IN THE STATISTICAL ANALYSIS AND THEIR ABBREVIATIONS

Variable	Abbreviation
Milk	Milk
Fat Corrected Milk	FCM
Fat	Fat
Butter Fat %	BF%
Total Hay	Hay
Total Silage	Silage
Total Grain	Grain
Total Intake	Intake
Hay Dry Matter	HDM
Silage Dry Matter	SDM
Roughage Dry Matter	RDM
Grain Dry Matter	GDM
Total Dry Matter	TDM
Hay ENE	HENE
Silage ENE	SENE
Roughage ENE	RENE
Grain ENE	GENE
Total ENE	TENE
Hay TDN	HTDN
Silage TDN	STDN
Roughage TDN	RTDN
Grain TDN	GTDN
Total TDN	TTDN
Age	Age
Days Open	DO
Persistency	Perst.
Body Weight	BW
Efficiency	Eff.

Hay ENE = (0.945 x TDN) - 10.56.

Silage ENE = (0.753 x TDN) + 3.07.

Grain ENE = (1.040 x TDN) - 4.59.

Dry matter, TDN, and ENE values were expressed on an as-fed basis.

CHAPTER IV

RESULTS AND DISCUSSION

Results of the analysis are presented in Tables III, IV, V, VI, VII, VIII, and IX. Since TDN and ENE were highly correlated for both rations and efficiency was computed as the ratio of milk energy output to feed energy input (ENE); only the ENE values are reported. In order to facilitate testing for significance, sires were considered fixed effects in all parts of the analysis except in calculating heritability estimates.

The significant effects of year-season on most variables (Table III) are most probably due to increased management ability during the course of the trial. Also, variations in feed quality from year to year could help explain these effects. The relative magnitude of each of these factors and the contributions of herd and farm management to the total increase attributable to management cannot be ascertained from this analysis.

Significant sire effects on production variables were not unexpected; and least squares constants (Table V) showed considerable variation. These results agree with USDA work (41,54) reported in the literature. The significant effects of sire on roughage intake variables may be due to the effects of milk production on feed intake or to some intrinsic or inherited difference in appetites for roughage. Then too, these effects could be partially related to the effects of

TABLE III

F AND b VALUES FOR DISCRETE AND CONTINUOUS VARIABLES

	F. Values				Regression Coefficients		
	Year-Season	Sire	Ration	SXR	Age	DO	BW
Milk	4.87**	2.71**	106.5**	1.70	111.3[a]	1.65	2.45
FCM	4.80**	2.50**	175.5**	1.66	129.4[a]	2.59	3.50[a]
Fat	4.35**	2.42**	198.1**	1.53	5.65[a]	0.13	0.17[a]
Hay	15.29**	2.39**	42.1**	1.26	-5.02	-0.21	0.93[b]
Silage	8.00**	1.83*	46.4**	1.52	-18.17	1.80	5.24[b]
Grain	4.12**	1.47	14018.0**	8.03**	12.43	0.19	0.12
Intake	3.99**	1.73	163.1**	1.64	-10.77	1.79	6.30[a]
HDM	14.99**	2.41**	42.8**	1.28	-4.25	-0.18	0.79[b]
SDM	8.74**	1.71	54.7**	1.40	-9.59	0.70	1.41[a]
RDM	1.81*	1.14	90.8**	0.69	-13.97	0.52	2.21[a]
GDM	4.14**	1.47	14161.0**	8.03**	10.66	0.16	0.10
TDM	1.89*	1.89*	1215.0**	2.41**	-3.17	0.68	2.32[a]
HENE	17.17**	2.30**	43.0**	1.23	-2.03	-0.07	0.35[b]
SENE	11.16**	1.85*	51.2**	1.38	-4.67	0.36	0.68[a]
RENE	4.09**	1.20	87.6**	0.71	-6.90	0.29	1.04[a]
GENE	8.37**	0.93	7195.0**	12.18**	21.01[b]	0.40	0.19
TENE	3.34**	1.78	3639.0**	9.12**	14.16	0.69	1.23[a]
Age	1.75	1.51	0.34	1.81			
DO	1.11	2.08*	0.17	2.50**			
Perst.	1.79	2.12*	23.9**	1.09	0.72[a]	0.01	-0.00
BW	2.38**	3.38**	18.1**	0.56			
Eff.	7.24**	0.59	390.6**	4.89**	0.03	0.00	-0.00
df	13	12	1	12	1	1	1
error df	189	189	189	189	186	186	186

[a] F value significant at $P \leq .01$.

[b] F value significant at $P \leq .05$.

*($P \leq .05$) **($P \leq .01$)

TABLE IV

R^2 VALUES AND INCREASE IN EFFICIENCY OF MODEL DUE TO FITTING S x R INTERACTION AND CONTINUOUS VARIABLES

Model	1	2	S x R Inc.	3	Cont. Var. Inc.	4 Grain	4 No Grain
Milk	61.9	65.7	3.8	67.7	2.0	59.0	60.2
FCM	66.1	69.3	3.2	72.4	3.1	57.9	62.2
Fat	66.2	69.2	3.0	72.8	3.6	54.1	62.3
Hay	66.2	68.8	2.6	69.9	1.1	70.2	65.2
Silage	52.1	56.3	4.2	60.7	4.4	60.4	54.6
Grain	98.2	98.8	0.6	98.8	0.0	67.2	0.00
Intake	58.2	62.1	3.9	66.8	4.7	49.6	44.5
HDM	65.7	68.3	2.6	69.4	1.1	69.8	64.4
SDM	55.6	59.2	3.6	62.6	3.4	62.4	55.9
RDM	45.9	48.2	2.3	53.3	5.1	34.1	32.1
GDM	98.2	98.8	0.6	98.8	0.0	67.3	0.00
TDM	86.3	88.1	1.8	89.3	1.2	54.1	32.1
HENE	67.2	69.6	2.4	70.6	1.0	70.8	66.1
SENE	61.0	64.1	3.1	67.2	3.1	68.4	61.1
RENE	49.7	51.9	2.2	56.8	4.9	38.9	41.0
GENE	96.0	97.8	1.8	97.8	0.0	86.2	00.0
TENE	93.1	95.7	2.6	96.0	0.3	78.3	41.0
Age	14.7	23.5	8.8			27.8	31.6
DO	17.0	28.4	11.4			34.5	27.4
Perst.	38.7	42.7	3.8	42.5	0.2	33.0	48.3
BW	42.7	44.7	2.0			41.8	53.9
Eff.	72.1	78.7	7.1	79.2	0.5	78.0	62.7

TABLE V

LEAST SQUARES CONSTANTS FOR SELECTED VARIABLES

Sire	No..	Milk Kg.	FCM Kg.	Fat Kg.	Hay Kg.	Silage Kg.	Grain Kg.	Intake Kg.	HDM Kg.	SDM Kg.	RDM Kg.
Y-87	1	-61.56	46.09	4.70	49.2	-250.24	8.38	-192.66	42.67	-76.99	-34.17
X21	2	-31.30	-28.33	-1.08	36.59	-189.08	-9.74	-162.23	31.57	-65.64	-33.89
2WO	3	-354.50	-291.16	-9.96	-82.17	-130.39	-52.05	-264.77	-69.45	-39.55	-108.98
L152	4	36.30	129.26	7.67	68.94	-109.22	26.72	-14.73	58.99	-24.18	34.68
L175	5	-239.74	-202.25	-7.10	11.67	38.30	-27.48	22.48	11.09	-.11	11.29
WB	6	213.07	159.39	4.95	-34.40	102.85	15.37	83.82	-27.64	35.95	7.97
NZ257	7	-66.26	15.00	2.81	-1.54	-221.45	-3.36	-226.35	-2.26	-36.66	-39.37
NZ235	8	101.77	68.91	1.89	-103.61	141.79	-4.20	33.98	-91.48	59.81	-31.70
Bishop	11	-9.39	-209.44	-13.73	39.04	-49.54	6.29	-4.22	33.09	-44.29	-10.84
CAP	12	0.73	-52.94	-3.56	-47.48	205.11	-9.30	148.34	-40.75	64.77	24.11
Jeweler	13	2.81	-17.95	-1.32	-12.90	242.25	-9.61	219.74	-10.62	73.14	62.04
Diamond	14	-4.83	-3.67	-.07	56.47	-13.71	19.41	62.16	47.81	-3.91	44.00
S-74	15	412.73	387.08	14.77	28.81	234.50	39.73	339.89	16.70	62.20	74.87
Grain		328.74	424.38	19.52	-57.37	-197.27	+651.7	397.06	-49.09	-66.57	-115.62
No Grain		-328.74	-424.38	-19.52	57.37	197.27	-651.7	-397.06	49.09	66.57	+115.62
S_1 x R		-71.82	-28.52	.019	-70.33	216.76	-109.76	36.66	-60.86	71.25	10.20
S_2 x R		-76.66	-35.11	-.31	-36.07	-137.69	-50.68	-224.44	-30.41	-32.17	-62.86
S_3 x R		-41.76	-47.76	-2.06	-35.33	-67.88	-80.28	-183.49	-30.54	-7.02	-37.51
S_4 x R		25.85	-7.95	-1.22	-16.18	107.24	-9.55	81.51	-13.64	26.43	13.08
S_5 x R		-24.69	-0.93	.59	3.65	-177.42	-9.25	-183.01	3.17	-48.53	-45.68
S_6 x R		-77.39	-53.06	-1.50	9.53	76.83	42.98	129.34	7.66	12.84	20.44
S_7 x R		-75.48	-92.49	-4.14	-2.55	-12.03	33.86	19.29	-2.06	2.93	0.71
S_8 x R		-265.25	-300.81	-12.96	41.03	8.98	22.18	72.18	35.64	-31.18	4.75
S_{11} x R		154.69	57.26	-.31	29.26	-59.24	26.41	-3.58	24.39	-16.14	8.76
S_{12} x R		-65.81	-40.04	-.88	43.38	214.85	1.65	-169.83	37.57	-63.22	-25.68
S_{13} x R		228.14	215.80	8.25	47.80	167.42	25.91	241.14	40.95	49.22	90.25
S_{14} x R		294.32	322.47	13.67	-8.02	84.31	54.70	131.08	-6.32	32.85	26.53
S_{15} x R		-4.14	11.14	.86	-6.26	7.55	51.84	53.15	-5.88	2.74	-2.99

TABLE V (continued)

Sire	No.	GDM Kg.	TDM Kg.	HENE Therm	SENE Therm	RENE Therm	GENE Therm	TENE Therm	Perst. %	Eff.	BW Kg.
Y-87	1	7.43	-26.75	42.45	-82.43	-40.28	22.18	-18.50	-4.29	-.06	-4.83
X21	2	-8.26	-42.18	30.27	-71.74	-42.48	-44.19	-86.57	0.43	-.13	3.91
2WO	3	-45.23	-154.37	-69.24	-38.41	-109.04	-100.38	-210.25	-1.77	-.08	1.14
L152	4	23.38	57.82	58.64	-23.38	34.88	65.35	101.18	-1.78	.01	1.17
L175	5	-23.69	-12.65	10.26	-6.34	3.96	-69.59	-66.38	-1.48	.01	5.41
WB	6	13.06	21.52	-29.38	36.30	7.51	44.19	52.25	2.51	.14	1.42
NZ257	7	-3.11	-42.39	2.68	-37.01	-33.65	9.26	-25.23	2.07	.15	1.37
NZ235	8	-4.00	-35.75	-84.45	55.11	-28.91	4.71	-22.86	4.87	.20	6.97
Bishop	11	5.36	-5.50	24.75	-51.91	-23.32	8.80	-13.76	-2.21	-.03	-27.53
CAP	12	-7.49	16.06	-40.31	74.43	-34.49	-41.72	-8.43	-4.08	-.06	-12.45
Jeweler	13	-8.32	53.89	-11.79	90.76	79.88	-27.29	52.48	0.81	-.11	13.67
Diamond	14	16.42	61.03	-45.45	-8.40	37.96	46.04	83.91	1.52	-.06	-9.19
S-74	15	2.05	155.64	111.57	43.02	89.27	82.64	162.16	3.30	-.02	18.59
Grain		566.58	451.40	-48.97	-67.54	-116.49	1287.64	1172.45	2.06	-.51	7.30
No Grain		-566.58	-451.40	+48.97	67.54	116.49	-1287.64	-1172.45	-2.06	.51	-7.30
S_1 x R		-95.11	-85.31	-60.75	72.28	11.63	-400.12	-391.11	0.32	.31	3.68
S_2 x R		-43.80	-106.83	-29.33	-33.93	-64.04	-205.99	-270.59	0.81	.23	-5.41
S_3 x R		-69.55	-107.47	-30.15	-14.01	-43.79	-170.95	-215.66	-.063	.20	1.50
S_4 x R		-8.04	4.61	-12.86	30.40	17.11	-59.92	-42.31	2.09	.02	.42
S_5 x R		-7.79	-53.71	3.94	-51.88	-48.32	-48.92	-98.18	0.76	.01	-2.76
S_6 x R		36.86	58.07	7.08	14.80	21.42	170.49	193.37	-.29	-.26	.35
S_7 x R		29.00	30.16	-.27	.90	1.70	152.10	154.20	-1.30	-.27	-.12
S_8 x R		18.78	23.67	30.05	-28.03	2.04	127.64	131.53	-3.01	-.34	.75
S_{11} x R		22.96	31.61	23.89	-17.68	6.92	71.75	79.40	.18	.00	-7.53
S_{12} x R		2.16	-24.21	40.72	-63.33	-72.48	-33.72	-57.96	2.98	.11	-5.52
S_{13} x R		22.38	113.09	38.33	53.64	91.26	103.08	194.70	-2.93	.07	4.18
S_{14} x R		47.03	74.40	-6.12	33.88	28.25	196.87	226.70	- .09	-.06	4.40
S_{15} x R		44.76	41.92	-4.69	3.86	-1.70	97.69	95.91	1.11	-.02	6.06

TABLE VI

SIRE GROUP ADJUSTED MEANS FOR SELECTED VARIABLES

Sire	BW Kg.	FCM Kg.	Hay Kg.	Silage Kg.	Grain Kg.	Intake Kg.	HDM Kg.	SDM Kg.	RDM Kg.	GDM Kg.
					GRAIN RATION					
S-74	371.1	4929.5	1341.4	4338.6	1365.5	7100.5	1141.4	1320.0	2457.3	1166.4
Diamond	341.7	4850.0	1367.3	4171.4	1361.8	6895.5	1145.0	1284.1	2455.9	1183.2
Jeweler	364.3	4729.1	1353.6	4510.5	1304.1	7168.2	1160.9	1377.3	2537.7	1133.7
L152	348.1	4652.7	1371.4	4097.7	1305.0	6774.1	1175.9	1257.3	2433.2	1135.0
WB	348.2	4637.7	1293.6	4278.2	1229.5	6920.5	1110.5	1303.6	2414.1	1169.6
Y-87	345.3	4549.1	1297.3	4067.3	1186.4	6551.4	1112.3	1253.6	2361.4	1032.3
X21	345.0	4469.6	1319.1	3774.1	1227.3	6320.5	1132.3	1157.3	2288.6	1067.3
NZ257	348.7	4454.1	1314.6	3851.8	1318.2	6500.0	1125.9	1221.4	2346.8	1145.5
CAP	330.8	4438.6	1314.6	4091.4	1280.0	6685.9	1125.9	1256.4	2383.6	1114.1
Bishop	311.4	4379.1	1386.8	3992.3	1320.5	6699.5	1187.7	1194.6	2383.2	1147.7
L175	349.1	4328.2	1334.1	3957.3	1250.9	6546.8	1144.6	1206.4	2350.9	1088.2
NZ235	338.7	4299.6	1233.2	3950.0	1305.9	6813.6	1074.6	1283.6	2358.6	1134.6
2WO	349.1	4192.3	1200.9	3902.7	1155.0	6259.1	1030.5	1208.6	2239.1	1004.5
					NO GRAIN					
S-74	344.4	4058.6	1467.7	4738.6		6200.5	1255.9	1446.8	2694.6	
NZ235	338.1	4052.3	1288.7	4628.2		5875.5	1105.9	1478.6	2580.5	
WB	333.0	3895.0	1477.3	4565.0		5868.2	1268.6	1410.9	2600.0	
NZ257	333.4	3836.0	1434.6	4285.9		5668.2	1232.7	1348.2	2576.8	
L152	332.6	3820.0	1518.6	4277.7		5817.3	1305.9	1337.3	2638.2	
Y-87	323.4	3757.2	1552.7	4030.9		5684.1	1336.8	1239.5	2572.3	
X21	341.2	3689.5	1505.9	4444.1		5975.9	1295.0	1354.1	2645.9	
CAP	325.0	3670.0	1342.3	4915.6		6240.9	1159.5	1515.9	2670.9	
L175	340.1	3481.4	1441.4	4711.8		6119.1	1240.9	1436.4	2673.6	
Jeweler	314.0	3444.5	1372.3	4570.5		5892.3	1181.8	1411.8	2588.6	
2WO	331.5	3439.1	1386.4	4414.5		5832.3	1194.1	1355.0	2544.6	
Bishop	311.9	3415.9	1443.2	4505.0		5913.2	1241.8	1364.1	2551.8	
Diamond	318.3	3356.4	1497.7	4397.3		5844.6	1287.3	1350.9	2635.9	

TABLE VI (continued)

Sire	TDM Kg.	HENE Therm	SENE Therm	RENE Therm	GENE Therm	TENE Therm	MAINT Therm	GROSS Eff.	NET Eff.
					GRAIN RATION				
S-74	3703.6	1221	1373	2528	2721	4978	2245	0.87	1.80
Diamond	3641.4	1062	1354	2506	2784	5005	2114	0.84	1.68
Jeweler	3672.7	1141	1470	2611	2617	4965	2212	0.87	1.72
L152	3568.2	1160	1333	2492	2546	4787	2144	0.91	1.76
WB	3585.5	1083	1377	2469	2757	4954	2144	0.84	1.65
Y-87	3393.6	1095	1316	2411	2163	4366	2129	1.01	2.03
X21	3354.6	1115	1220	2333	2291	4415	2129	0.94	1.96
NZ257	3493.6	1116	1290	2408	2702	4853	2147	0.84	1.65
CAP	3497.7	1114	1315	2452	2466	4653	2062	0.91	1.71
Bishop	3538.1	1065	1256	2424	2622	4763	1970	0.88	1.57
L175	3439.6	1128	1268	2396	2423	4589	2147	0.90	1.77
NZ235	3493.6	1060	1365	2413	2673	4824	2098	0.83	1.58
2WO	3230.5	1005	1274	2287	2270	4358	2147	0.95	1.90
					NO GRAIN RATION				
S-74	2716.8	1328	1422	2754		2706	2123	1.36	6.96
NZ235	2543.6	1097	1544	2632		2486	2095	1.60	10.36
WB	2566.8	1175	1483	2649		2499	2071	1.54	9.10
NZ257	2530.5	1215	1423	2628		2461	2074	1.55	9.91
L152	2656.4	1284	1407	2681		2784	2071	1.35	5.36
Y-87	2661.4	1315	1306	2612		3013	2028	1.19	3.81
X21	2667.7	1272	1423	2685		2824	2111	1.19	5.18
CAP	2643.6	1131	1599	2720		2690	2034	1.28	5.60
L175	2689.6	1218	1507	2715		2672	2105	1.36	6.14
Jeweler	2544.1	1162	1498	2652		2498	1983	1.27	6.69
2WO	2556.3	1173	1473	2598		2645	2065	1.23	5.93
Bishop	2565.9	1213	1417	2633		2547	1973	1.34	5.95
Diamond	2590.0	1173	1419	2679		2497	2004	1.36	6.81

TABLE VII

RANKS OF SIRES ON DIFFERENT RATIONS ACCORDING TO FCM PRODUCTION AND EFFICIENCY

Grain Ration			No Grain Ration		
FCM	Gross Eff.	Net Eff.	FCM	Gross Eff.	Net Eff.
S-74	Y-87	Y-87	S-74	NZ235	NZ235
Diamond	2WO	X21	NZ235	NZ257	NZ257
Jeweler	X21	2WO	WB	WB	WB
L152	CAP	S-74	NZ257	L175	S-74
WB	L152	L175	L152	Diamond	Jeweler
Y-87	L175	L152	Y-87	S-74	Diamond
X21	Bishop	CAP	X21	L152	L175
NZ257	Jeweler	Jeweler	CAP	Bishop	2WO
CAP	S-74	Diamond	L175	CAP	Bishop
Bishop	WB	WB	Jeweler	Jeweler	CAP
L175	NZ257	NZ257	2WO	2WO	L152
NZ235	Diamond	NZ235	Bishop	X21	X21
2WO	NZ235	Bishop	Diamond	Y-87	Y-87

TABLE VIII

WITHIN RATION CORRELATION COEFFICIENTS[a,b] OF SELECTED VARIABLES FOR GRAIN RATION

	Milk	FCM	FAT	Hay	Silage	Grain	Intake	HDM	SDM	RDM	GDM	TDM	HENE	SENE	RENE	GENE	TENE	Age	DO	Perst.	BW	Eff.
Milk	1.000	.947	.858	.167	.057	.937	.388	.158	.139	.281	.936	.727	.116	-.026	.076	.883	.895	.124	.130	.485	.267	.335
FCM		1.000	.978	.154	.086	.890	.400	.145	.194	.322	.888	.730	.109	.023	.122	.851	.880	.132	.221	.447	.358	.347
Fat			1.000	.136	.100	.808	.384	.129	.220	.330	.807	.690	.099	.054	.145	.781	.820	.130	.268	.397	.391	.335
Hay				1.000	-.338	.189	.067	.999	-.442	.520	.190	.478	.991	-.474	.384	.047	.182	-.064	-.013	-.025	.060	.106
Silage					1.000	-.052	.877	-.336	.893	.530	-.052	.348	-.376	.907	.611	-.003	.215	.196	.059	.009	.186	.174
Grain						1.000	.304	.180	.050	.218	1.000	.718	.149	-.118	.010	.925	.913	.031	.139	.529	.256	.406
Intake							1.000	.066	.762	.784	.305	.730	.014	.716	.758	.282	.547	.184	.096	.154	.284	-.257
HDM								1.000	-.437	.524	.181	.476	.992	-.468	.392	.035	.173	-.059	-.012	-.030	.060	-.111
SDM									1.000	.537	.050	.410	-.453	.953	.592	.107	.316	.175	.164	.087	.291	.221
RDM										1.000	.219	.836	.502	.462	.927	.137	.464	.110	.143	.055	.333	.105
GDM											1.000	.718	.150	-.117	.010	.925	.913	.030	.137	.531	.254	.407
TDM												1.000	-.443	.263	.667	.617	.844	.096	.181	.337	.382	.303
HENE													1.000	-.472	.395	-.017	.124	-.081	-.010	-.049	.050	-.129
SENE														1.000	.624	-.113	.111	.174	.092	-.025	.155	.116
RENE															1.000	-.133	.225	.107	.087	-.068	.206	.005
GENE																1.000	.936	.027	.161	.503	.305	.425
TENE																	1.000	.064	.190	.470	.374	.419
Age																		1.000	.062	.009	.042	.682
DO																			1.000	.173	.181	.001
Perst.																				1.000	.156	.453
BW																					1.000	.352
Eff.																						1.000

[a]Coefficients > .254 are significant at $P \leq .01$.

[b]Coefficients > .195 are significant at $P \leq .05$.

TABLE IX

WITHIN RATION CORRELATION COEFFICIENTS[a,b] OF SELECTED VARIABLES FOR NO GRAIN RATION

	Milk	FCM	Fat	Hay	Silage	Grain	Intake	HDM	SDM	RDM	GDM	TDM	HENE	SENE	RENE	GENE	TENE	Age	DO	Perst.	BW	Eff.
Milk	1.000	.961	.899	.093	.191	.000	.235	.085	.349	.401	.000	.401	.075	.172	.221	.000	.221	.024	.229	.476	.423	.790
FCM		1.000	.885	.082	.173	.000	.212	.075	.363	.406	.000	.406	.069	.170	.214	.000	.214	.081	.228	.458	.503	.827
Fat			1.000	.073	.155	.000	.191	.067	.358	.393	.000	.393	.063	.162	.202	.000	.202	.112	.218	.428	.533	.817
Hay				1.000	-.301	.000	.070	.999	-.394	.506	.000	.506	.991	-.380	.448	.000	.448	-.094	.132	-.146	-.007	-.057
Silage					1.000	.000	.930	-.304	.814	.495	.000	.495	-.319	.868	.552	.000	.552	-.031	-.130	.124	.091	-.035
Grain						.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000
Intake							1.000	.067	.700	.712	.000	.712	.519	.553	.937	.000	.937	-.038	.075	.120	.259	-.058
HDM								1.000	-.390	.510	.000	.510	.994	-.372	.457	.000	.457	-.085	.132	-.148	-.002	-.066
SDM									1.000	.593	.000	.593	-.374	.940	.576	.000	.576	-.067	-.044	.267	.278	.106
RDM										1.000	.000	1.000	.519	.553	.937	.000	.937	-.138	.075	.120	.259	.043
GDM											.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000
TDM												1.000	.519	.553	.937	.000	.937	-.138	.075	.120	.259	.043
HENE													1.000	-.349	.483	.000	.483	-.071	-.151	-.139	-.003	.336
SENE														1.000	.652	.000	.652	-.030	-.093	.163	.129	-.086
RENE															1.000	.000	1.000	-.088	.034	.038	.118	-.149
GENE																.000	.000	.000	.000	.000	.000	.000
TENE																	1.000	-.088	.034	.038	.118	-.149
Age																		1.000	.078	.162	.115	.081
DO																			1.000	.114	-.032	.201
Perst.																				1.000	.335	.421
BW																					1.000	.373
Eff.																						1.000

[a]Coefficients > .254 are significant at $P \leq .01$.

[b]Coefficients > .195 are significant at $P \leq .05$.

sire on body weight. The significant effects of body weight on roughage intake variables (Table III, page 19) would appear to support this statement. It is interesting to note that although sire effects were significant for both hay and silage intake, hay dry matter, hay and silage ENE, and closely approached significance for silage dry matter, they were not significant for roughage dry matter or roughage ENE. This occurrence is probably due to a tendency for the animals to compensate for lower quality in one source of roughage by increasing intake of the other. The nonsignificant sire effects on grain variables are peculiar. It is believed that this situation is an artifact of the experimental design which, in effect, halves the variation in grain variables due to sires because no variation in grain variables existed in ration two. The facts that sire effects on total dry matter intake are significant and effects on total intake and total ENE approached significance are probably related to sire effects on hay and silage variables. Significant sire effects on days open are believed to be due to differences in conception rates. Sire effects on persistency are related to effects on milk production and intake variables.

The significant ration effects (Table III) on most variables should be expected. Cows consuming more feed of higher energy value should produce more milk, consume more total feed and less roughage, take in more ENE, be more persistent, lose less weight, and be less efficient (by the present definition), than cows consuming lower energy rations. The least squares constants (Table V, page 21) and the adjusted means (Table VI, page 23) for the rations point up these facts.

The significant sire x ration interaction effects on grain and total intake variables, except total feed intake, and the significant interaction effect on efficiency are interesting and probably related. The significant effects on total intake variables are related to the effects on grain variables. From Table VII, page 25, it will be noted that when sires are ranked according to efficiency on the two rations five of the bulls changed in rank markedly. Three of these bulls, Y-87, 2WO, and X21, showed a tremendous response to grain feeding. This response is believed to be due to the fact that their daughters were on test early in the trial during a period when no analysis of roughages was available. Morrison's (66) average values for composition were used in computing ENE of the roughages and probably overestimated their value. Consequently, daughters of these bulls were credited with more energy than they actually received. Lower milk yields aggravated this condition by decreasing efficiency. Since they were at a lower plane of nutrition than indicated, daughters of these bulls showed a much greater response to grain feeding than did daughters of other bulls. Two other bulls, proven on all forage rations, also changed rank drastically (Table VII). It appears that these bulls' heifers were much more efficient on the all roughage ration. These heifers did not show great deviations in their response to grain feeding (Table V, page 21, and Table VI, page 23). It may be that cows selected for high milk production on all forage rations are more efficient in utilizing body energy stores. Another bull, Diamond, while not changing rank for efficiency drastically (Table VII), dropped from second in production on ration one

to last on ration two. No satisfactory explanation can be found for this occurrence. Both production and intake variables declined drastically for this bull (Table VI, page 23) on ration two. Other bulls reacted similarly; but the decline was less severe.

The significant interaction effects on age are also unexplainable. However, the significant effects on days open may be due to greater stress on the all roughage ration causing longer than normal cycles in early lactation or prohibiting them for a time. Significant sire by ration interactions were not reported in USDA work (54).

Significant age effects on milk production should be expected (Table III, page 19). Also, significant age effects on persistency and grain ENE are not surprising because these variables are highly related to milk production. The significant effects of body weight on FCM and fat and the nearly significant effects on production indicate that large cows produce more milk. Significant effects on intake variables, except grain, indicate that larger cows consume more feed. No effect of size on efficiency is apparent.

Table IV, page 20, is presented to show the relative efficiency of three mathematical models in accounting for variation in selected variables. Model one fitted constants for the effects of year-season subclasses, sires, and rations only; model two fitted these effects plus the sire x ration interaction; model three fitted all four of these effects and included age, days open, and body weight as continuous variables. The increased efficiency is presented as the percentage increase in the total variation accounted for by inclusion of the

effects in the model. A fourth model fitting constants for the effects of year-seasons and sires within ration is presented for comparison although no conclusions can be drawn because it and the others are not strictly comparable. Comparison of the third and fifth columns in Table IV, page 20, indicates that in the majority of cases interaction was more important than the continuous variables in accounting for variation; but in no case was the residual variation reduced materially.

The least squares constants in Table V, page 21, are presented to give an idea of the magnitude of the effects fitted. Year-season constants are not presented because they have effects for only small discrete lengths of time. The range of the constants gives an indication of the dispersion of the means, for each effect, for each variable.

Table VI, page 23, presents means for production and intake variables adjusted for effects of sires, rations and interaction. Sire groups were ranked according to FCM production. In order to remove the effects of maintenance (body size) on production, a maintenance requirement of 116.2 kcal. ME per kg. $BW^{.75}$ was assumed. It was also assumed that ME was utilized for maintenance with an efficiency of 75 percent. Valid issue could be taken with both these assumptions (35,51,52,53). Because of results in the literature (12,22,63,64,65,69,70,74,79) and the high correlation between TDN and ENE in this analysis, it was felt advisable to reduce total ENE for the grain ration by the percentage decrease in TDN values caused by increased plane of nutrition. This was done by multiplying TENE by the relative TDN percentage value obtained by the method of Tyrrell et al. (79). Ranking of the bulls, within ration,

according to "gross" and "net" efficiencies (Table VII, page 25) shows that rankings change when the effects of size are eliminated. However, the changes were not drastic. Higher efficiencies on all roughage rations (Table VI, page 23) could be largely due to very efficient utilization of body energy stores in lactation, especially the early stages.

Table VII, page 25, presents the ranking of sires within rations on the basis of FCM, "gross" efficiency, and "net" efficiency.

Tables VIII and IX, pages 26 and 27, present the within ration correlations of selected variables for the grain and no grain rations, respectively. For the grain ration, production variables were highly correlated with grain variables, total dry matter and total ENE. The correlation between yield and efficiency is much lower than those reported in the literature (45,59,75). This is believed to be due to the small variation within sires in efficiency (Tables V and VI, pages 21 and 23) and to high energy intakes in relation to milk output. Grain and roughage intakes are not highly correlated. However, hay and silage variables are highly and negatively correlated. Apparently compensation took place. Grain variables are highly related to measures of total intake, efficiency, and milk production. Efficiency appears to be related to age, total energy intake, persistency, and body weight.

Within the no grain ration, efficiency and production variables are highly correlated. Efficiency, persistency, and body weight are significantly correlated; but efficiency is not significantly related to intake variables except hay ENE. Production, total intake variables,

and silage dry matter are significantly correlated. Production does not appear to be related, significantly, to other intake variables. The compensatory effects on hay and silage consumption mentioned before are evident.

The high correlation between production and efficiency and the low correlation between intake variables and production may be related. Limited capacity to consume feed could restrict energy intake while efficient utilization of body reserves, which were unaccounted for in computing efficiency, in early lactation could support high milk production until they were depleted. The low correlations between energy intake variables and production are probably a result of this situation. Thus, although all heifers ate to appetite, those with larger energy reserves or that were more able to catabolize fat reserves produced more milk and consequently were more efficient. The significant correlation between persistency and efficiency is also believed to show the effects of body reserves on production and efficiency.

Table X presents heritability estimates for selected variables calculated on across and within ration bases by the paternal half-sib method. Sampling variances for inter-class correlations are relatively small ranging from .00 to .20. However, a large portion of the sampling error is due to the small number of sires represented in these data.

The effects of ration on the heritability estimates are evident. It is possible that .00 heritabilities for some intake variables are due to physical limitations on intake imposing a ceiling, thereby reducing genetic variation. No explanation for ration effects on other estimates

TABLE X

HERITABILITY ESTIMATES FOR SELECTED VARIABLES ON ACROSS AND WITHIN RATION BASES

	Across Ration	Within Ration	
		Grain	No Grain
Milk	.35	.41	.57
Fat	.22	.50	.35
Hay	.28	.15	.41
Silage	.15	.76	.00
Intake	.15	.97	.00
HDM	.29	.13	.42
SDM	.14	.74	.01
RDM	.05	.61	.00
HENE	.22	.15	.36
SENE	.17	.75	.00
RENE	.05	.67	.00
BW	.47	.69	.32
Eff.	.00	.00	.00

can be offered. However, since the bulls were selected on the basis of milk production which was shown to be highly related, genetically, to efficiency (59), and since there was little variation in efficiency attributable to sires on either ration (Table V, page 21), it is possible that intense selection of sires on production reduced the variation in efficiency due to sires greatly. This could account for the .00 estimates of efficiency obtained.

The heritability estimates of efficiency are much lower than those reported in the literature (45,59).

CHAPTER V

SUMMARY AND CONCLUSIONS

Milk production and feed intake data on a total of 228 first lactations by daughters of 13 sires on two rations in a comparative feeding trial were subjected to least squares analysis to fit constants for the effects of year-season of freshening, sire, ration, and sire x ration interaction on selected variables. Regression coefficients were derived for age, days open, and body weight. Within ration correlation analysis was also performed on the data. Heritabilities of selected variables were calculated from sire components of variance.

Year-season effects were highly significant for most variables and were attributed in increases in overall management during the trial. Significant sire effects on milk production and body size were considered normal. Sire effects on roughage intakes were believed to be related to a combination of sire effects on milk production and body weight, and inherent differences in sire groups in their capacity to consume roughages. Sire effects on efficiency were not significant. As expected, ration effects were highly significant for most variables. The few significant interaction effects were attributed to abnormal reaction to the treatments by five sire groups. For most variables, body weight had greater effects than age or days open. In general, interaction was more efficient than the continuous variables in decreasing residual variation; but neither reduced it markedly.

The greater efficiencies of the heifers on the no grain ration could have been due to lower energy intakes and greater utilizations of body energy reserves for production by these cattle than by those on the grain ration and more efficient digestion and utilization of energy on the no grain ration. It was evident that compensatory consumption of roughages occurred on both rations.

Although the heritability estimates were subject to considerable sampling error, they indicated that efficiency was not heritable. Ration effects on estimates for roughage consumption variables were evident.

REFERENCES

REFERENCES

1. Armstrong, D. G., and Blaxter, K. L. 1965. Effects of Acetic and Propionic Acids on Energy Retention and Milk Secretion in Goats. Energy Metabolism. Ed. K. L. Blaxter. Europ. Assn. Animal Prod. Publ. No. 11:59. Academic Press, London.

2. Balch, C. C., and Campling, R. C. 1962. Regulation of Voluntary Feed Intake in Ruminants. Nutr. Abstr. and Rev., 32:669.

3. Bath, D. L., Ronning, M., Meyer, J. H., and Lofgreen, G. P. 1965. Caloric Equivalent of Live Weight Loss of Dairy Cattle. J. Dairy Sci., 48:374.

4. Blaxter, K. L. 1962. The Energy Metabolism of Ruminants. Hutchinson and Company LDT, London.

5. Blaxter, K. L. (Editor). 1965. Energy Metabolism. Europ. Assn. Animal Prod. Publ. No. 11:453. Academic Press, London.

6. Blaxter, K. L., and Wainman, F. W. 1964. The Utilization of Different Rations by Sheep and Cattle for Maintenance and Fattening. J. Agr. Sci., 63:113.

7. Blaxter, K. L., Wainman, F. W., and Wilson, R. S. 1961. The Regulation of Food Intake by Sheep. Animal Prod., 3:51.

8. Bloom, S., Jacobson, N. L., Allen, R. S., McGilliard, L. D., and Homeyer, P. G. 1957. Effect of Various Hay-Concentrate Ratios on Nutrient Utilization and Production Responses of Dairy Cows. I. Relationship Among Feeding Level, Predicted Producing Ability, and Milk Production. J. Dairy Sci., 40:81.

9. Bloom, S., Jacobson, N. L., Allen, R. S., McGilliard, L. D., and Homeyer, P. G. 1957. Effect of Various Hay-Concentrate Ratios on Nutrient Utilization and Production Responses of Dairy Cows. II. Observations on Ration Digestibility and on the Excretion Pattern of Chromic Oxide. J. Dairy Sci., 40:240.

10. Brody, S. 1945. Bioenergetics and Growth. Reinhold Publ. Corp., New York.

11. Brody, S., and Proctor, R. C. 1935. Energetic Efficiency of Milk Production and the Influence of Body Weight Thereon. Univ. of Mo. Agr. Exp. Sta. Res. Bull. 222.

12. Brown, L. D. 1966. Influence of Intake on Feed Utilization. J. Dairy Sci., 49:223.

13. Buchman, D. T., and Hemken, R. W. 1964. Ad Libitum Intake and Digestibility of Several Alfalfa Hays by Cattle and Sheep. J. Dairy Sci., 47:861.

14. Coppock, C. E., Flatt, W. P., Moore, L. A., and Stewart, W. E. 1964. Effect of Hay to Grain Ratio on Utilization of Metatolizable Energy for Milk Production by Dairy Cows. J. Dairy Sci., 47:1330.

15. Corbett, J. L., Langlands, J. P., and Boyne, A. W. 1961. An Estimate of the Energy Expended for Maintenance of Strip Grazed Dairy Cows. Intern. Congr. Animal Husbdry. Gen. Reports, 1:193.

16. Davis, C. L., Brown, R. E., Staubus, J. R., and Nelson, W. O. 1960. Absorption and Metabolism of Acetate. J. Dairy Sci., 43:237.

17. Dawson, J. R., Kopland, D. V., and Graves, R. R. 1940. Yield, Chemical Composition, and Feeding Value for Milk Production of Alfalfa Hay Cut at Three Stages of Maturity. USDA Tech. Bull. 739.

18. Edwards, J. 1936. Effect of Breed, Size of Cow, Yield of Milk, and Stage of Lactation upon Efficiency of Milk Production. J. Dairy Res., 7:211.

19. Elliot, J. M., and Loosli, J. K. 1959. Effect of Dietary Ratio of Hay and Concentrate on Milk Production, Ration Digestibility, and Urinary Energy Loss. J. Dairy Sci., 42:836.

20. Es, A. J. H. Van. 1961. Between Animal Variation in the Amount of Energy Required for the Maintenance of Cows. Thesis, Wageningen, Netherlands.

21. Es, A. J. H. Van, Brower, E., and Nijkamp, H. J. 1965. The Feeding Value for the Maintenance of Cows of Hays from Six Parts of the Netherlands. Energy Metabolism. Ed. K. L. Blaxter, Europ. Assn. Animal Prod. Publ. No. 11:95. Academic Press, London.

22. Flatt, W. P. 1966. Energy Metabolism Results with Lactating Dairy Cows. J. Dairy Sci., 49:230.

23. Flatt, W. P., Coppock, C. E., and Moore, L. A. 1965. Energy Balance Studies with Lactating Non-Pregnant Dairy Cows Consuming Rations with Varying Hay to Grain Ratios. Energy Metabolism. Ed. K. L. Blaxter. Europ. Assn. Animal Prod. Publ. No. 11:121. Academic Press, London.

24. Flatt, W. P., Coppock, C. E., Moore, L. A., and Hemken, R. W. 1965. Energy Balance Studies with Dry Non-Pregnant Cows Consuming Pelleted Forages. Energy. Metabolism. Ed. K. L. Blaxter. Europ. Assn. Animal Prod. Publ. No. 11:131. Academic Press, London.

25. Flatt, W. P., Moe, P. W., Moore, L. A., Hooven, N. W., Lehmann, R. P., Ørskov, E. R., and Hemken, R. W. 1966. Energy Utilization by High Yielding Dairy Cows. Paper Presented 61st Annual Meeting, ADSA. Corvallis, Oregon.

26. Forbes, E. B., Braman, W. W., and Kriss, M. 1930. Further Studies of the Energy Metabolism of Cattle in Relation to Plane of Nutrition. J. Agr. Research, 40:37.

27. Forbes, E. B., and Kriss, M. 1931. The Nutritive Requirements of the Dairy Cow Expressed in Accord with a New Method of Application of the Net Energy Conception. Am. Soc. Animal Prod. Proc., 113.

28. Forbes, E. B., and Voris, L. 1932. The Economy of Conversion of Feed Energy to Milk Energy by Dairy Cows. J. Nutrition, 5:395.

29. Fries, J. A., Braman, W. W., and Cochrane, D. C. 1924. Relative Utilization of Energy in Milk Production and Body Increase of Dairy Cows. USDA. Dept. Bull. 1281.

30. Gaines, W. L. 1928. The Energy Basis of Measuring Milk Yield in Dairy Cows. Ill. Agr. Exp. Sta. Bull. 308.

31. Garrett, W. N., Meyer, J. H., and Lofgreen, G. P. 1959. The Comparative Energy Requirements of Sheep and Cattle for Maintenance and Gain. J. Animal Sci., 18:528.

32. Graves, R. R., Dawson, J. R., and Kopland, D. V. 1938. Relative Values for Milk Production of Hay and Silage Made from Immature Pasture Herbage. USDA Tech. Bull. 649.

33. Graves, R. R., Dawson, J. R., Kopland, D. V., Watt, A. L., and Van Horn, A. G. 1938. Feeding Cows on Alfalfa Hay Alone. USDA Tech. Bull. 610.

34. Haecker, T. L. 1914. Feeding Dairy Cows. Minn. Agr. Exp. Sta. Bull. 130.

35. Hashizume, T., Morimoto, H., Masubuchi, T., Abe, M., and Hamada, T. 1965. Some Aspects of Energy Utilization by Cows During Gestation and Lactation. Energy Metabolism. Ed. K. L. Blaxter. Europ. Assn. Animal Prod. Publ. No. 11:111. Academic Press, London.

36. Hawkins, G. E., Parr, G. E., and Little, J. A. 1964. Composition Intake, Digestibility, and Prediction of Digestibility of Costal Bermudagrass Hays, J. Dairy Sci., 47:865.

37. Hazlewood, B. P. 1948. All-year Pasturing With and Without Concentrates for Dairy Cows. Tenn. Agr. Exp. Sta. Bull. 207.

38. Hinders, R. G., and Owens, F. G. 1963. Relationships Between Efficiency of Milk Production and Ruminal Volatile Fatty Acids of Cows Fed Isocaloric (ENE) Rations of Varied Concentrate Levels. J. Dairy Sci., 46:1246.

39. Hodgson, R. E., Knott, J. C., Miller, V. L., and Murer, H. K. 1938. The Nutritive Value of Home Grown Roughage Rations for Dairy Cattle. Wash. Agr. Exp. Sta. Bull. 366.

40. Holmes, J. C., and Lang, R. W. 1963. Effects of Fertilizer Nitrogen and Herbage Dry Matter Content on Herbage Intake and Digestibility in Bullocks. Animal Prod., 5:17.

41. Hooven, N. W., and Matthews, C. A. 1958. Analysis of Feed Efficiency on Six Sire Groups in the Beltsville Holstein Herd. J. Dairy Sci., 41:747.

42. Hooven, N. W., Plowman, R. D., and Miller, R. H. 1966. Relationship between Growth and Production Traits of Holstein and Crossbred Females. Paper Presented 61st Annual Meeting ADSA Corvallis, Oregon.

43. Hotchkiss, D. K. 1960. The Effects of Various Dietaries on Milk Composition and Efficiency of Production of Dairy Cows. Ph.D. Thesis, Iowa State University, Ames.

44. Huffman, C. F., Duncan, C. W., and Chance, C. M. 1952. Unidentified Dietary Factors on Dairy Cattle Nutrition. II. Further Evidence of an Unidentified Factor(s) in Grain Needed to Balance Roughage in Milk Production. J. Dairy Sci., 35:41.

45. Huston, Keith. 1958. Influence of Various Environmental Factors on Feed Efficiency in Milk Production. Feed Utilization by Dairy Cows. Ed. C. R. Hoglund. Iowa State College Press, Ames.

46. Jacobson, D. R., and Hatton, R. H. 1966. Alternate Roughage and Grain Feeding Practices for High Milk Production. Paper Presented 61st Annual Meeting ADSA. Corvallis, Oregon.

47. Jarl, F. 1952. Use of Forage in Dairy Production. 6th Intern. Grassland Congr. Proc., 2:119.

48. Jensen, E., Klein, J. W., Rauchenstein, E., Woodward, J. E., and Smith, R. H. 1942. Input-Output Relationships in Milk Production. USDA Tech. Bull. 815.

49. Jumah, H. F., Poulton, B. R., and Apgar, W. P. 1965. Energy and Protein Utilization During Lactation. J. Dairy Sci., 48:1210.

50. Kesler, E. M., Spahr, S. L., Branding, A. E., and Cloninger, W. H. 1966. Effect of Fiber on Total Feed Intake by Lactating Cows. Paper Presented 61st Annual Meeting ADSA. Corvallis, Oregon.

51. Kleiber, Max. 1961. The Fire of Life. An Introduction to Animal Energetics. John Wiley and Sons, Inc., New York.

52. Kleiber, Max. 1965. Metabolic Body Size. Energy Metabolism. Ed. K. L. Blaxter. Europ. Assn. Animal Prod. Publ. No. 11:472. Academic Press, London.

53. Kleiber, M., Regan, W. M., and Mead, S. W. 1945. Measuring Food Values for Dairy Cows. Hilgardia, 16:511.

54. Lamb, R. C., and Anderson, M. J. 1966. Comparative Gross Feed Efficiencies in 14 Holstein Sire Groups. Paper Presented 61st Annual Meeting. ADSA. Corvallis, Oregon.

55. Leighton, R. E., and Rupel, I. W. 1956. Effects of Fiber Content of the Ration on Milk Production and Hot Weather Discomfort of Producing Dairy Cows. Texas Agr. Exp. Sta. Prog. Reports. 1889.

56. Leroy, A. M. 1966. Analysis of the Energy Expenditure by Dairy Cows in a State Near to Maintenance, Fed on Meadow Hay. Energy Metabolism. Ed. K. L. Blaxter. Europ. Assn. Animal Prod. Publ. No. 11:49. Academic Press, London.

57. Loosli, J. K., and Putnam, P. A. 1958. Roughage Grain Ratios and Levels of Intake in Relation to Feed Efficiency. Feed utilization by Dairy Cows. Ed. C. R. Hoglund. Iowa State College Press, Ames.

58. Martin, T. G., Stoddard, G. E., and Allen, R. S. 1954. The Effects of Varied Rates of Hay Feeding on Body Weight and Production of Lactating Dairy Cows. J. Dairy Sci., 37:1233.

59. Mason, I. L., Robertson, A., and Gjelsdat, B. 1957. The Genetic Connection Between Body Size, Milk Production and Efficiency in Dairy Cattle. J. Dairy Res., 24:135.

60. Mather, R. E. 1959. Can Dairy Cattle Be Bred for Increased Forage Consumption and Efficiency of Utilization? J. Dairy Sci., 42:879.

61. McCullough, M. E., 1962. Some Factors Influencing Intake of Direct Cut Silage by Dairy Cows. J. Dairy Sci., 45:116.

62. Miller, W. M. 1965. U. T. Forage Testing Service Memograph. Personal Communication.

63. Mitchell, H. H., Hamilton, T. S., McClure, F. J., Haines, W. T., Beadles, J. R., and Morris, H. P. 1932. The Effect of the Amount of Food Consumed by Cattle on the Utilization of Its Energy Content. J. Agr. Res., 45:163.

64. Moe, P. W., Flatt, W. P., and Moore, L. A. 1966. Effects of Level of Feed Intake on Energy Losses by Dairy Cows. Paper Presented 61st Annual Meeting ADSA. Corvallis, Oregon.

65. Moe, P. W., Tyrrell, F. H., and Reid, J. T. 1963. Further Observations on Energy Requirements of Milking Cows. Cornell Nutrition Conf. Feed Mfgrs. Proc. 66.

66. Morrison, F. B. 1959. Feeds and Feeding. 22nd Edition. The Morrison Publishing Co., Clinton, Iowa.

67. National Research Council. 1966. Nutrient Requirements for Farm Animals. No. 3. Nutrient Requirements for Dairy Cattle. Washington.

68. Nordfeldt, S., Iwanaga, I., Morita, K., Kenke, L. A., and Tom, A. S. K. 1950. Influence of Crude Fiber in the Ration on Efficiency of Feed Utilization by Dairy Cows. J. Dairy Sci., 33:473.

69. Poulton, B. R. 1966. Symposium: Re-Evaluation of Nutrient Allowances for High-Producing Cows. J. Dairy Sci., 49:237.

70. Putnam, P. A., and Loosli, J. K. 1959. Effect of Feeding Different Ratios of Roughage to Concentrate upon Milk Production and Digestibility of the Ration. J. Dairy Sci., 42:1070.

71. Reid, J. T. 1956. Some Nutritional Effects of Varying Concentrate-Roughage Ratios in Relation to Feed Input-Milk Output by Dairy Cows. Cornell Agr. Exp. Sta. Memior. 344.

72. Reid, J. T. 1958. Pasture Evaluation in Relation to Feed Efficiency. Feed Utilization by Dairy Cows. Ed. C. R. Hoglund. Iowa State College Press, Ames.

73. Reid, J. T., et al. 1959. Effect of Growth Stage, Chemical Composition, and Physical Properties upon the Nutritive Value of Forages. J. Dairy Sci., 42:567.

74. Reid, J. T., Moe, P. W., and Tyrrell, H. F. 1966. Energy and Protein Requirements of Milk Production. J. Dairy Sci., 49:215.

75. Smith, W. T., and Rice, V. A. 1934. Efficiency of Feed Utilization in Dairy Cattle. Guernsey Breeder's J., 46:176.

76. Stone, J. B., Trimburger, G. W., Henderson, C. R., Reid, J. T., Turk, K. L., and Loosli, J. K. 1960. Forage Intake and Efficiency of Feed Utilization in Dairy Cattle. J. Dairy Sci., 43:1275.

77. Thomas, J. W., and Moore, L. A. 1960. Maintenance Requirements of Dairy Cows (Abstract). J. Dairy Sci., 43:889.

78. Thomas, J. W., Moore, L. A., Okamoto, M., and Sykes, J. F. 1961. A Study of Factors Affecting Rate of Intake of Heifers Fed Silage. J. Dairy Sci., 44:1471.

79. Tyrrell, H. F., Reid, J. T., and Moe, P. W. 1966. Further Observations on the Effect of Level of Intake on Digestibility of Dietary Energy by High Producing Cows. Paper Presented 61st Annual Meeting ADSA. Corvallis, Oregon.

80. Wallace, L. R. 1959. The Nutrients Required for Milk Production at Successive Stages of Lactation: A Study with Identical Twins. XVth Intern. Dairy Congr. Proc., 1:196.

81. Winchester, C. F. 1953. Energy Requirements of Beef Calves for Maintenance and Growth. USDA Tech. Bull. 1071.

82. Zermiski, D., Van Horn, H. H., McGilliard, A. D., and Jacobson, N. L. 1965. Effects of the Net Energy Concentration of the Total Ration on Milk Production and Composition. J. Dairy Sci., 48:1467.