Influence of separation interval on weigh-suckle-weigh estimates of milk production and relationships between milk production and physical measurements in Hereford cattle
by John Herbert Williams

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

Abstract:
This study was conducted in an effort to determine whether differences in separation interval affect weigh-suckle-weigh estimates of milk production in beef cattle. Correlations between cow physical traits and production estimates were obtained. Nursing activity of cows and calves in a pasture environment were observed to determine the most natural interval of separation. Data were collected from Hereford cows at the Northern Agricultural Research Center at Havre, Montana. A 3x3 latin square was used to evaluate a 4, 8 and 16 hr separation interval with estimates during two periods (7 to 21 days and 28 to 56 days after calving). A total of 117 cows were used during the 2 years of the study. Squares/year, cows/square/year, separation interval, day of separation, period and the year x period and day x period interactions were significant sources of variation for MP and calf ADG. Mean milk production estimates for 4, 8 and 16 hr intervals were 9.16, 7.61 and 5.94 kg, respectively, adjusted to a 24 hr basis. Repeatabilities for withers height, hip height, weight, weight/hip height, condition score, 4 hr, 8 hr and 16 hr milk production and calf ADG were respectively, .94, .95, .89, .85, .79, .55, .61, .79 and .72. The physical measurements were correlated with each other as were the production estimates and calf ADG, but there was no correlation between physical measurements and production or ADG. The correlation between condition score and weight:height ratio was .59.

Milk production estimates from the 4, 8 and 16 hr intervals were positively correlated with calf ADG (.27, .46 and .46, respectively). Age of dam was a significant factor influencing milk production with 2- and 3-year-old and mature cows, respectively, yielding 7.2, 9.3 and 10.2 kg for the 4 hr; 6.1, 7.4 and 8.8 kg for the 8 hr and 4.6, 5.8 and 6.8 kg for the 16 hr estimate. Days in lactation were significant for 4 hr milk and calf ADG. Year was a significant source of variation for calf ADG with a mean of .46 kg/day in 1975 and .61 kg/day in 1976. Ten cows and their Hereford sired calves were observed in a pasture for two continuous 48 hr periods at 3 and at 7 weeks after calving. Little nursing activity occurred at night. Calves nursed 7.1 times for an average duration of 12.8 min at 3 weeks and 6.4 times at 7 weeks with an average duration of 10.1 minutes. Calves on lower producing cows nursed longer and more often than calves on higher producers. During 14 to 16 hr of daylight calves nursed 3.2 to 3.5 times/day which suggested an average separation of about 4.5 hours. Considering this natural interval and the correlation with calf ADG, the 8 hr interval was recommended as the most appropriate separation interval for estimating milk production by the weigh-suckle-weigh technique.

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INFLUENCE OF SEPARATION INTERVAL ON WEIGH-SUCKLE-WEIGH ESTIMATES OF MILK PRODUCTION AND RELATIONSHIPS BETWEEN MILK PRODUCTION AND PHYSICAL MEASUREMENTS IN HEREFORD CATTLE.

by

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

of

MASTER OF SCIENCE

in

Animal Science

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December, 1977

ACKNOWLEDGMENTS

I wish to extend my appreciation to Dr. D. D. Kress for guidance throughout my graduate program and for advice in the preparation of this manuscript. Appreciation is also extended to Drs. P. J. Burfening and J. R. Dynes for advice and assistance.

Sincere gratitude is expressed to Mr. Don C. Anderson and the staff at Northern Agricultural Research Center for their hospitality and assistance in data collection. I would also like to thank the Research Center for providing my lodging and for the use of animals and facilities.

I would like to acknowledge my indebtedness to Mr. R. L. Friedrich for his assistance with computer programming.

Appreciation is also extended to Mrs. Frankie Larson for typing this manuscript.

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ABSTRACT

This study was conducted in an effort to determine whether differences in separation interval affect weigh-suckle-weigh estimates of milk production in beef cattle. Correlations between cow physical traits and production estimates were obtained. Nursing activity of cows and calves in a pasture environment were observed to determine the most natural interval of separation. Data were collected from Hereford cows at the Northern Agricultural Research Center at Havre, Montana. A 3x3 latin square was used to evaluate a 4, 8 and 16 hr separation interval with estimates during two periods (7 to 21 days and 28 to 56 days after calving). A total of 117 cows were used during the 2 years of the study. Squares/year, cows/square/year, separation interval, day of separation, period and the year x period and day x period interactions were significant sources of variation for MP and calf ADG. Mean milk production estimates for 4, 8 and 16 hr intervals were 9.16, 7.61 and 5.94 kg, respectively, adjusted to a 24 hr basis. Repeatabilities for withers height, hip height, weight, weight/hip height, condition score, 4 hr, 8 hr and 16 hr milk production and calf ADG were respectively, .94, .95, .89, .85, .79, .55, .61, .79 and .72. The physical measurements were correlated with each other as were the production estimates and calf ADG, but there was no correlation between physical measurements and production or ADG. The correlation between condition score and weight:height ratio was .59. Milk production estimates from the 4, 8 and 16 hr intervals were positively correlated with calf ADG (.27, .46 and .46, respectively). Age of dam was a significant factor influencing milk production with 2- and 3-year-old and mature cows, respectively, yielding 7.2, 9.3 and 10.2 kg for the 4 hr; 6.1, 7.4 and 8.8 kg for the 8 hr and 4.6, 5.8 and 6.8 kg for the 16 hr estimate. Days in lactation were significant for 4 hr milk and calf ADG. Year was a significant source of variation for calf ADG with a mean of .46 kg/day in 1975 and .61 kg/day in 1976. Ten cows and their Hereford sired calves were observed in a pasture for two continuous 48 hr periods at 3 and at 7 weeks after calving. Little nursing activity occurred at night. Calves nursed 7.1 times for an average duration of 12.8 min at 3 weeks and 6.4 times at 7 weeks with an average duration of 10.1 minutes. Calves on lower producing cows nursed longer and more often than calves on higher producers. During 14 to 16 hr of daylight calves nursed 3.2 to 3.5 times/day which suggested an average separation of about 4.5 hours. Considering this natural interval and the correlation with calf ADG, the 8 hr interval was recommended as the most appropriate separation interval for estimating milk production by the weigh-suckle-weigh technique.

CHAPTER 1

INTRODUCTION

Milk production in beef cattle has gained increased importance since the beginning of the 20th century. Researchers have developed varied procedures for evaluating milk production. One of the more common techniques, the weigh-suckle-weigh method, involves separating the calf from its dam for a specific time interval. The calf is then weighed, allowed to nurse and reweighed and the difference in weight is taken to be an estimate of milk production. The interval of separation has not been standardized and varies with the researcher.

The purpose of the present study was to determine whether different separation intervals influenced milk production estimates by evaluating 4, 8 and 16 hr intervals. The most appropriate separation interval was then investigated.

Physical traits of height, weight and body condition were studied to determine their usefulness in predicting milk production. Hip height and withers height were compared in an effort to determine the most suitable height measurement. Condition score was compared to the weight:height ratio as an indicator of cow condition.

Nursing habits of cows and their calves in a pasture environment were studied to aid in determining the most appropriate separation interval for estimating milk production during the first two months of lactation.

CHAPTER 2

REVIEW OF LITERATURE

Milk Production Testing Procedures

Due to management systems and the calf producing function of beef cattle, actual milk yield cannot be measured; but must be estimated by representative samples using one of several techniques. The most commonly used techniques are hand or machine milking with or without the artificial stimulation of oxytocin or the calf nursing method. A summary of techniques appears in table 2.1.

Earliest reported estimates of milk production in beef animals came from dairymen who had beef animals included in their herds. Dawson et al. (1960) reported work done in 1915 at Manhattan, Kansas, with beef Shorthorn cows being milked while nurse cows raised their calves. Cole and Johansson (1933) reported an experiment initiated in 1912 to study lifetime performance of Aberdeen-Angus. A comparison was made with Jersey and Holstein, so they were subjected to the same twice daily milkings as the dairy cows. The butterfat percentage was determined once a week on composite samples taken at each milking.

Later techniques involved sampling procedures which left the animals in a more natural environment. When chemical analysis of the milk was needed, a procedure lending to milk collection was used. When an estimate of milk yield was needed, a calf nursing technique was usually used.

TABLE 2.1 MILKING TECHNIQUES

Researcher	Method	Separation interval	Frequency of test
Adadia and Brinks 1972	Machine milked	Twice daily	Daily & bi-weekly
Berg and Peschiera 1967	Machine milked* Teat cannulation*	12 hr 6 hr	Monthly Monthly
Christian *et al.* 1965	Hand milking	8 hr+ 15.5 hr	Bi-weekly
Cole and Johansson 1933	Hand or machine	Twice daily	Daily
Cundiff *et al.* 1974	Calf and machine*	12 hr	2,5,14,29 wks
Dawson *et al.* 1960	Calf nursing	4 hr+4 hr +4 hr	Weekly
Drewry *et al.* 1959	Calf nursing	12 hr+ 10 hr	1st, 3rd & 6th mo
Furr and Nelson 1964	Calf nursing	8 hr+ 8 hr 12 hr+ 12 hr	1st and 2nd 3rd-7th mo
Gifford, W. 1953	Hand milking	Twice daily	Monthly
Gleddie and Berg 1968	Machine milked*	12 hr	Monthly
Holmes *et al.* 1968	Teat cannulation*	6 hr	Monthly
Jeffery *et al.* 1971a	Machine milked*	6 hr	Monthly
Knapp and Black 1941	Calf nursing		Weekly

TABLE 2.1 CONTINUED

Researcher	Method	Separation interval	Frequency of test
Klett et al. 1962	Machine milked*	12 hr	Weekly 1st mo bi-weekly 2-5 mo tri-weekly 6-7 mo
Kress and Anderson 1974	Calf nursing	16-19 hr	4 or 5 times per lactation
Lamond et al. 1969	Teat cannulation*	8 hr, 6 hr and 4 hr	Every 3 days, weekly, monthly
Melton et al. 1967b	Calf nursing	12 hr + 12 hr	Monthly
Neville et al 1974	Calf nursing	17 hr	50 days
Rutledge et al. 1971	Calf nursing	6 hr + 16 hr	Monthly
Schwulst et al. 1966	Calf nursing + machine milked*	12 hr	Once at 2, 3, and 5 wks
Streeter et al. 1974	Calf nursing + machine milked*		Bi-weekly
Totusek et al. 1973	Calf nursing hand milking	12 hr + 12 hr	6 days/wk weekly
Todd et al. 1969	Machine milked	5 hr	Twice/lactation
Vetter and Webber 1974	Calf nursing		3 times/mo
Wilson et al. 1969	Machine milked + 12 hr hand stripping		Bi-weekly
Wistrand and Riggs 1966	Calf nursing*	12 hr	Monthly

*Oxytocin used to stimulate milk ejection.

Abadia and Brinks (1972) machine milked Hereford heifers twice daily. Analysis of milk composition was obtained through the Dairy Herd Improvement Association. Calves were weaned a few days after birth and fed artificially.

Gifford (1953) developed a procedure for estimating milk production on one day each month. On the first of three days, the calves were allowed to nurse their dams twice. On the second day, the calves were allowed to nurse one-half of the udder, while the other half was milked by hand. On the third day, the other half of the udder was milked by hand while the calf nursed the first half and the two day's total was combined as an estimate of one day's production. Christian et al. (1965) used this same basic technique with an 8 hr separation period the first day and an overnight period of nearly 15.5 hr.

Totusek et al. (1973) hand milked one-half of the udder twice daily, one day each week, throughout 30 weeks of lactation. The half of the udder milked was alternated each week. Twice the quantity of milk removed was estimated to be the daily production.

Oxytocin has been used to stimulate milk letdown when production of beef cattle is measured. Anthony et al. (1959) reported using 2 cc of oxytocin (40 U.S.P. units) injected intermuscularly to aid in milking. The cows were injected, milked by machine, carefully stripped out and segregated from their calves. Twelve hours later, another injection of oxytocin was administered and the cows were machine milked and hand stripped for an estimate of production.

Gleddie and Berg (1968) tested production on the first, second, third and fifth months of lactation. The cattle were restrained in a squeeze chute and milk letdown was induced by an intrajugular injection of 20 IU of oxytocin. The milk was removed from the udder by machine and after a 12 hr overnight period, another injection was given and one-half of the udder was milked. Multiplying by a factor of four gave an estimate of 24 hr production. Holmes et al. (1968) and Jeffery et al. (1971a) used the same injection, but with a 6 hr interval between milkings. Klett et al. (1963) used this same method with a 13 hr separation interval. Todd et al. (1969) used 40 units of oxytocin with a 5 hr interval between milkings. Lamond et al. (1969) tested the effect of oxytocin dosage, time of day of test, rate of milk secretion and milk production. After preliminary studies, a 6 hr interval was adopted using 20 IU of oxytocin injected intramuscularly with milk removal from the udder by teat cannulation. The accuracy of this method was checked by using it on six dairy cows which had daily milk production records. The oxytocin-cannulation treatment produced results that were not significantly different from machine milking.

Wilson et al. (1969) collected milk yield data every 2 weeks for 18 weeks. Calves were used to remove the milk from the udder. When the calves had finished, 40 U.S.P. units of oxytocin were injected into the coccygeal vein and the udder was then hand stripped. Twelve hours later, the cows were reinjected and milked by machine, followed by hand stripping. Weight of milk removed by machine and that removed by hand was taken to be the 12 hr milk production.

When total milk yield is the only parameter being measured, the calf nursing technique is commonly used. Totusek et al. (1973) found that this method yielded more milk at every stage of lactation when compared to hand milking and that total yield for 210 days was 29% higher. Milk production is estimated by the difference between the weight of the calf immediately prior to nursing and the weight immediately after nursing. Knapp and Black (1941) used this technique to estimate milk consumption one day each week. Dawson et al. (1960) used weekly estimates and allowed the calf to nurse at 4:00 am, noon and at 8:00 pm after an 8 hr separation from its dam. Furr and Nelson (1964) used an 8 hr separation interval for two tests early in lactation and a 12 hr interval at five subsequent estimates. Drewry et al. (1959) reported a method allowing the calves to initially nurse their dams at 6:00 pm on the day prior to nursing, then after a 12 hr interval, they nursed at 6:00 am for a yield estimate and were immediately separated until another estimate at 4:00 pm. The total milk produced during this 22 hr period was taken to be the daily milk production. After the calves had finished nursing, the cows were checked for additional milk, but none was found except in some heavier producing cows during the first month.

Kress and Anderson (1974) used a separation period of 16 to 19 hr to estimate production and multiplied the yield by the appropriate factor to standardize production for a 24 hr day. Estimates were made four or five times during the lactation period. Melton et al. (1967b) used two 14 hr periods, once each month for 7 months, to estimate production. Neville et al. (1974) used a 17 hr separation and the yield was multiplied by 1.4 to adjust to a 24 hr basis. For each lactation, three nursing observations of 50-day intervals were made and averaged to obtain a mean daily production during the first 210 days of lactation. Pope et al. (1963) used two 12 hr intervals. Rutledge et al. (1971) used an 8 hr and 16 hr separation period to estimate production for a 7 month lactation period on a monthly basis. Totusek et al. (1973) used two 12 hr intervals twice daily, 6 days a week throughout the 30 weeks of lactation. Streeter et al. (1974) used oxytocin to initially remove the milk and after the separation period, the calf was allowed to nurse. When the calf was finished nursing, 2 ml of oxytocin was injected and the cow was milked dry by machine. Production was measured at 14-day intervals for 5 months.

Milk Yield and Constituents

Total milk yield is determined by the daily production of a cow and her ability to persist in production throughout the lactation period. Factors which may influence daily production that will be discussed elsewhere are nutrition, age of cow, breed of cow, sex and size of calf and amount of inbreeding. Lactation length is variable among cows and among breeds with means as short as 95.1 days in registered Hereford heifers reported by Abadia and Brinks (1972) to 365 days reported by Dawson et al. (1960) in Shorthorn cows at Manhattan, Kansas in 1915.

Results discussed here and summarized in table 2.2 are included to provide an overview of milk production research on milk yield and milk constituents. Production varies with breed and consequently will be discussed by breed, but due to different techniques and experimental conditions, there is much variation among reported yields within breeds.

Angus. The Aberdeen-Angus Review, as cited by Cole and Johansson (1933) reported a Scotch herd of Angus which ranged from 2608 kg to 5143 kg with an average of 3568 kg of milk per year. In a report from an English herd, the average production was 4825 kg. Drewry et al. (1959), using the calf nursing technique, reported 6.4 kg per day at the end of the first month, 7.26 kg at the third month and 4.09 kg at six months. Gleddie and Berg's (1968) technique of using oxytocin with a milking machine yielded 8.4 kg/day with 4.0% fat. Cundiff et al. (1974) estimated milk production to be 7.34 and 2.50 kg/day at six weeks and weaning, respectively, while butterfat percentage was 3.8% and 6.7% and solids, not fat (SNF) was 8.4% and 9.6%.

TABLE 2.2 MILK COMPOSITION AND YIELD

Researcher	Breed	Lactation length (days)	Peak production (days	Average milk (kg)	Fat (%)
Abadia & Brinks 1972	Hereford heifers	5-150 $\bar{X}$=95.1	30-45		3.8
Christian *et al.* 1965	Hereford	240			
	2-yr-old			3.7	3.5
	3-4-yr-old			4.3	3.5
Cole & Johansson 1933	Angus	252	30-60		4.1
Dawson *et al.* 1960	Shorthorn	245	60	7.7	3.98
		252	60	8.0	3.98
		365		6.0	3.95
Gifford, W. 1953	Angus	240		3.9	3.48
	Shorthorn	240		3.9	2.96
	Hereford	240		2.7	2.95
Gleddie & Berg 1968	Hereford (mature)			5.2	3.9
	Hereford (2-yr-old)			3.7	3.6
	Galloway (G)			7.8	4.0
	Angus (A)			8.4	4.0
	Charolais x A			7.3	3.7
	Angus x G (2-yr-old)			4.5	3.8
	Total	300		6.4	3.9
Klett *et al.* 1962	Santa Gertrudis			4.1	3.87
	Brahman			3.9	4.55
	Angus			3.9	3.6
	Hereford			2.9	3.0
Kress & Anderson 1974	Hereford	195		3.8	2.68

TABLE 2.2 CONTINUED

Researcher	Breed	Lactation length (days)	Peak production (days)	Average milk (kg)	Fat (%)
Melton *et al.* 1967b	Angus	175		3.8	2.68
	Charolais	175		4.5	2.87
	Hereford	175		3.3	2.82
Neville *et al.* 1974	Hereford	210		4.5	
Rutledge *et al.* 1971	Hereford	210		5.8	
Streeter *et al.* 1974	Hereford (commercial)			5.1	
	Hereford (San Juan Basin)			6.8	
	Brown Swiss			10.2	
	Charolais x Angus			7.5	
Todd *et al.* 1969	Hereford (H)			3.3	3.5
	Brahman (B)			4.4	3.6
	H x B (dam)			6.0	3.9
	B x H (dam)			6.0	4.0
	Angus x B x H			6.6	3.8
	Total			5.3	4.0
Totusek *et al.* 1973	Angus (A)	210	21		
	Hereford (H)		(Hand milked)	4.8	
	Shorthorn (S)				
	Brahman x H		49		
	Santa Gertrudis x H		(Calf nursed)	6.0	
	Angus x H				
	Shorthorn x H				

Todd et al. (1969) reported 6.62 kg of milk during mid and late lactation averaging 3.8% fat which is consistent with the 6.8 kg reported by Streeter et al. (1974). Cole and Johansson (1933) reported a mean yield of 1406 kg milk with 4.1% fat. The fat percentage decreased with increasing age of the cow and a trend for declining protein was shown while other milk constituents remained unaffected. Lower production has been reported by Gifford (1953) with a peak of 4.9 kg of 3.47% milk declining to 3.1 kg of 3.6% milk at eight months. Klett et al. (1962) reported 3.91 kg daily at 3.6% fat and 8.85% SNF which was consistent with Milton et al. (1967b) who reported 3.79 kg/day over a 175-day lactation.

The lactation curve peaked at 50 days (Gifford, 1953), (Streeter et al., 1974) and (Cole and Johansson, 1933).

Shorthorns. Shorthorns are relatively high producers. Dawson et al. (1960) reported that milk production varied from 1143 kg to 2813 kg. Over a 252-day lactation period, milk production averaged 2016 kg for a mean yield of 8.01 kg/day with 3.98% fat. Another group of select Shorthorns produced an average 2205 kg with 3.95% fat over 298 days. Dawson's (1960) results were greater than the reported peak of 6.6 kg/day by Gifford (1953). Dawson et al. (1960) reported that peak production was attained at the end of the second month of production with a high of 10.3 kg/day for the 28-day period which disagreed with Gifford's (1953) reported peak of 6.6 kg during the first month.

Cundiff et al. (1974) reported production of 7.35 kg/day at 6 weeks and 2.34 kg/day at weaning. Butterfat was measured at 3.4% and 6.3% for these respective periods. Solids not fat rose from 8.3% to 9.7%.

Brahman and Santa Gertrudis. Klett et al. (1962) has shown that daily milk production for Santa Gertrudis and Brahman in a fall calving situation was 4.14 kg and 3.97 kg, respectively, with fat contents of 3.87% and 4.66% and with SNF of 8.25% and 8.75%. Todd et al. (1969) reported 24 hr yields compiled from estimates during mid and late lactation of 4.35 kg, 6.01 kg and 6.62 kg for Brahman, Hereford (sire) x Brahman, Brahman (sire) x Hereford and Angus x Hereford x Brahman, respectively, with 3.6, 3.9, 4.0 and 3.8 being mean production from 13 Santa Gertrudis cows at 5.6 and 7.9 kg, respectively, for 1964 and 1965, over a 205-day lactation.

Charolais. Melton et al. (1967b) reported 785 kg of milk from Charolais cows over a 175-day lactation, giving an average 4.48 kg/day of 2.87% fat milk. This was lower than Streeter's et al. (1974) report of 7.5 kg/day from Charolais x Angus cows over a 200-day lactation. Gleddie and Berg (1968) reported 7.3 kg/day of 3.7% fat milk over 150 days from Charolais x Angus.

Hereford. In comparative studies (table 2.2), Herefords were among the lower producers of the beef breeds. Holmes et al. (1968) determined a peak production of 6.99 kg declining to 2.77 kg at 164 days. Kress and Anderson (1974) reported means and ranges at 34 and

183 days, respectively, were 6.1 (3.4-9.2) kg and 2.2 (0-6.8) kg. The predicted lactation period extended over 195 days. Streeter et al. (1974) found a mean yield of 5.1 kg/day from a commercial Hereford herd and a 6.8 kg/day from a registered San Juan Basin Hereford herd. Gleddie and Berg (1968), using oxytocin and a milking machine, reported 5.2 kg/24 hr for mature Herefords and 3.29 kg for 2-year-old cows. Rutledge et al. (1971) reported 5.8 kg during the first month, declining to 4.0 kg at the end of the seventh month, which agreed with the 4.5 kg of milk over 210 days reported by Neville et al. (1974). Christian et al. (1965) reported 3.7 kg milk over 240 days from 2-year-old cows and 4.3 kg/day from 3- and 4-year-old cows. Gifford (1953) reported a peak of 3.86 kg/day at one month and 1.88 kg/day at eight months. Melton et al. (1967a) showed a production of 581 kg over 175 days, giving an average of 3.3 kg/day, which is consistent with the 3.29 kg reported by Todd et al. (1969). Klett et al. (1962) indicated that the mean yield from a fall calving herd is 2.92 kg/day. Abadia and Brinks (1972) reported total milk yield of 379 kg over an average lactation period of 95.1 days. Percent butterfat has been reported at 5.11 to 4.09 (Holmes et al., 1968), 4.09 at six weeks to 6.70 at 200 days (Cundiff et al., 1974), 3.8 (Abadia and Brinks, 1972), 3.7 to 3.5 (Christian et al., 1965), (Gleddie and Berg, 1968), (Todd et al., 1968) 4.06 and 2.88 (Rugledge et al., 1970), 3.0 (Klett et al., 1962), 3.2 to 2.75 (Gifford, 1953) and 2.82 (Melton et al., 1967b). Solids, not fat

(SNF) were reported at 9.06% by Klett et al. (1962), 8.4 to 9.8% by Cundiff et al. (1974) and at 8.68 to 8.40% by Rutledge et al. (1971), which is in close agreement with the 8.49 to 8.28% reported by Holmes et al. (1968) and the 8.7% reported by Abadia and Brinks (1972).

Peak production has been reported at 20 days, (Kress and Anderson, 1974) during the first month, (Rutledge et al., 1971; Holmes et al., 1968) 30 to 45 days, (Abadia and Brinks, 1972) and 60 days for 2-year-old heifers (Gleddie and Berg, 1968).

Totusek et al. (1973) using a group of mixed breed beef cross, found that daily milk by hand milking was 5.49, 5.13 and 4.54 kg at 70, 112 and 210 days, respectively, with a production peak at three weeks. With the calf nursing technique, the peak was reached at seven weeks and a yield of 6.58, 6.44 and 5.85 kg milk was reported at 70, 112 and 210 days, respectively. The greater total yield from the calf nursing technique is probably due to the greater release of oxytocin when the cow is nursed, compared to hand milking. Mean yield estimates from days 10, 30, 70, 112 and 210 were 6.03 kg for the calf nursing technique and 4.85 kg for hand milking. The mean fat content was 3.2%.

Age of Dam Effects

Effects of age of dam are widely reported for weaning weights in the beef industry and for milk production in dairy cows.

Lush and Shrode (1950) reported the following multiplicative factors for Holstein-Friesian cows of various ages:

1.33-121 for 2 yr, 1.21-1.10 for 3 yr, 1.09-104 for 4 hr, 1.03-1.01 for 5 yr, 1.00 for 6 yr 1 mo-7 yr 8 mo, 1.01 for 7 yr 9 mo-8 yr 9 mo, 1.02 for 8 yr 10 mo-9 yr 7 mo, 1.03 for 9 yr 8 mo-10 yr 3 mo, 1.04 for 10 yr 4 mo-10 yr 9 mo, 1.05-10 yr 10 mo-11 yr 2 mo, 1.06 for 11 yr 3 mo-11 yr 7 mo, 1.07 for 11 yr 8 mo-11 yr 11 mo, 1.08 for 12 yr-12 yr 3 mo, 1.09 for 12 yr 4 mo-12 yr 6 mo, and 1.11 for 12 yr 7 mo-12 yr 10 mo.

The B.I.F. (1972) recommends use of multiplicative correction factors of 1.15, 1.10, 1.05, 1.00 and 1.05 for 2, 3, 4, 5-10 and 11-year-olds and older in adjusting dam age for a standardized weaning weight. Nelson and Kress (1976) determined that the appropriate correction factors were 1.11, 1.06, 1.03 and 1.01 for 2, 3, 4 and 11 + Angus dams, respectively and 1.13, 1.08, 1.04 and 1.04 for 2, 3, 4 and 11 + year old Hereford dams.

Neville et al. (1974) estimated that correction factors for milk production for two herds of Hereford cows, three through nine years old averaged respectively, 1.33, 1.19, 1.09, 1.00, 1.00, 1.00 and 1.00 for Herd 1 and 1.21, 1.11, 1.00, 1.00, 1.00, 1.00 and 1.07 for Herd 2. These were higher than the weaning weight correction factors for these two herds, which were 1.12, 1.07, 1.03, 1.00, 1.00, 1.00 and 1.02 for Herd 1 and 1.09, 1.03, 1.00, 1.00, 1.00, 1.00 and 1.02 for Herd 2.

Gifford (1953) found production for 2, 3, 4, 5, 6 and 7 + year old Herefords was 542 kg, 526 kg, 660 kg, 640 kg, 714 kg and 569, respectively; the production from Angus was 667 kg, 902 kg, 1028 kg, 817 kg and 965 kg for 2, 4, 5 and 6 year old cows. Only small numbers of cows were involved, but the trend shows a general increase in production to 6 or 7 year old, which is consistent with Todd's et al. (1969) reported increase in production from 3 to 6 years, then a leveling off between 7 and 9 years and a slight decrease after 10 years of age. The maximum production at 8.4 years reported by Rutledge et al. (1971) is in general agreement with these age categories.

Klett et al. (1962) reported daily milk yield at 3.54 kg, 3.85 kg, and 4.38 kg for age group 3 to 5 years, 6 to 8 years and 9 to 12 years for Angus cows and 2.65, 2.91 and 4.16, respectively, for Hereford cows. Melton et al. (1967b), combining a group of Angus, Charolais and Herefords, determined that milk yields of cows 2, 3 to 5 and 5 + years of age were 553, 667 and 809 kg, respectively. The differences were significant with the older cows producing more milk than younger cows, but their milk was lower in percent fat and total solids.

Christian et al. (1965), in comparing 2- with 3- and 4-year-old cattle, found that the latter group produced more milk, but the 2-year-old dams were more persistent in their production, yielding 4.7% more of their total milk after 60 days postpartum than the older cows.

Drewry et al. (1959) reported that calves suckling older cows made larger total gains from birth to six months and that older cows were more protective to their young and were also heavier milk producers.

Size and Sex of Calf

Milk production is initiated by a nervous stimulation that the animal associates with the milking or suckling process, such as the palpation of the teats or the nursing of the young (Schmidt, 1971). This stimulus reaches the central nervous system and directs the posterior lobe of the pituitary to release oxytocin, which causes the release of milk.

The more often a cows is stimulated, the more milk she will give. In dairy cows, Elliot (1962) reported that cows milked three times per day gave 20% more milk than cows milked twice daily. Dodd (1957) concluded that 5 to 10% of this increase was due to decreased udder pressure from additional milking. It was also concluded that four times daily milking gives a 5 to 10% increase in production over three times daily milking. Cash and Yapp (1950) milked half udders three times daily and half udders twice daily and found that the three times daily milking yielded 32% more milk over the lactation period. Linnerud et al. (1966) reported that massaging the udder between twice daily milking resulted in a nonsignificant 1.0 to 1.5 increase in production.

Researchers in the beef industry have theorized that if additional stimulation affects the production of dairy cows, the larger more aggressive calves would stimulate the udder more often and consequently cause greater milk production from beef cows.

Melton et al. (1967b) has shown that cows nursing bull calves gave .58 kg more milk per day than cows nursing heifer calves during the first period of the study. This sex difference was reduced to .10 kg per day at the end of the lactation. The average 175-day milk production was 53 kg greater for cows nursing bull calves compared with cows nursing heifer calves. Jeffery et al. (1971b) also found that the dams of bull calves produced .26 kg more milk per day than dams of female calves when the experiment was carried out in 1966, however, the next year the dams of female calves yielded .41 kg more milk per day than dams nursing male calves. Cartwright and Carpenter (1961) in correlating lactation gains of Hereford cows with 180-day weights of their calves, reported correlations of -.79, -.62, -.35, -.20, -.19 and -.11, respectively, for crossbred males, crossbreds as a group, males as a group, Herefords as a group, females as a group and Hereford females. These correlations were interpreted to mean that the gain of the dam during lactation is related to the amount of milk she gives, which can be measured indirectly by the 180-day weights of the calves. Pope et al. (1963) found that sex of calf had a significant effect on milk production at the first sampling and on average production for the entire lactation period, with mothers of males having the advantage; however, Rutledge et al. (1971) reported a significant advantage for dams nursing females.

The above work is contrary to reports of Neville et al. (1974), Christian et al. (1965) and Gleddie and Berg (1968), who observed that sex of calf had no effect on the milk yield of the dam.

The weight of the calf at birth may have an effect on its aggressiveness and ability to stimulate milk production. Heyns (1960) observed a .75 correlation of birth weight with milk production and Drewry et al. (1959) observed correlations of .43, .29 and .12, respectively, at 1, 3 and 6 months. Pope et al. (1963) and Jeffery et al. (1971b) observed positive correlations between birth weight and milk production, but concluded birth weight was not an important factor, while Christian et al. (1965) and Gleddie and Berg (1968) reported that birth weight does not influence milk production.

Gifford (1953) has indicated that birth weight of a calf, which is related to calf sex, may exert its influence by determining the calf's capacity to utilize the dam's production. He found that if a calf is unable to utilize the milk shortly after birth, then the dam's overall production will be lower throughout the lactation period.

Nutritional Effects

Klett et al. (1962) has shown that fluctuations in milk yield and composition tend to follow the plane of nutrition of the cows. An increased level of feeding during the winter resulted in increased milk yields. This suggests that beef cattle may be very flexible in milk production in response to feed and environmental conditions, especially in a fall calving management system. This is consistent with work reported by Furr and Nelson (1964) who fed two levels of supplemental feed to 4-year-old fall calving Hereford cows on native grass pasture and found that although the group on higher levels of nutrition outproduced the low level cows through the winter, when spring grass was available, the low level cows outproduced the high level group until weaning. Anthony et al. (1961) also reported that cows on lower nutrition through the winter would outperform cows wintered at a higher level when both were grazed on excellent spring pasture.

Pope et al. (1963) reported that a low level of winter nutrition fed to spring calves carried adverse effects into the following summer, even when good pasture was available. There were no carry over effects from a low level of nutrition the previous year when adequate nutrition was supplied prior to calving. Bond and Wiltbank (1970) and Bond et al. (1964) have shown that heifers on low energy or low protein weighed less and gave less milk than heifers on higher levels during the first lactation.

Lamond et al. (1967) demonstrated that milk production was affected by quality and quantity of pasture. This was also reported by Jeffery et al. (1971a) who attributed the difference in August and October milk production for two consecutive years to differences in August rainfall.

When total dry matter intake of cows was compared to their 24 hr milk production, Streeter et al. (1974), found that Brown Swiss consumed 14.7 kg of D.M. per day to produce 10.3 kg of milk, Charolais x Angus consumed 12. 0 kg to produce 7.5 kg milk, San Juan Basin Herefords consumed 10.5 kg for 6.8 kg milk and commercial Herefords consumed 10.3 kg dry matter to produce 5.1 kg milk. These results may indicate that rate of utilization varies with breed.

Date of birth of the calf in early calving cows has been found to have a significant influence on milk production. The effect of date of birth may be related to the nutritional improvement in quality and quantity of available grass as the growing season progresses. Neville et al. (1974) reported that for each day later in a 90-day winter calving period that birth occurred, daily milk production increased .014 kg and .010 kg, repectively, for two herds of Hereford cows. An increase in weaning weight for calves born later in the season has been shown by Koch and Clark (1955).

Feeding growing beef heifers a high level of nutrition has been reported by Pope et al. (1963) to depress their subsequent milk production when compared to heifers fed a moderate plane of nutrition. Christian et al. (1965) reported the dam's weaning weight was negatively correlated to all milk and butterfat measurements. Weight at 180 days has been shown to be negatively correlated with subsequent most probable producing ability (MPPA) by Mangus and Brinks (1971), Ellicott et al. (1970) and Kress and Burfening (1972) who reported a correlation of -.20, -.52 and -.03, respectively. Koch et al. (1972) reported a genetic correlation of -.05 between maternal and individual effects on gain to weaning.

Totusek (1968) indicates that a high level of nutrition before weaning has little permanent effect in terms of body size and productivity, while a low plane of nutrition has a slight depressing effect on body size, but improves productivity in terms of weaning weight of calves produced.

Inbreeding and Crossbreeding

In dairy cattle, inbreeding has been reported to have a detrimental effect on milk production. Von Krosigk and Lush (1958) reported that milk production decreased .24 kg for each 1% increase in inbreeding and that inbreeding's effect on production was not through a decrease in size. Laben et al. (1955) determined that inbreeding caused total milk production to decrease, but did not effect the lactation curve.

Inbreeding depression has a marked influence on preweaning performance of calves. Differences in sex in response to the maternal environment due to inbreeding of the dam were reported by Anderson (1966), Brinks _et al_. (1962), Brinks _et al_. (1965) and Brinks and Knapp (1975) who suggested that bull calves were affected to a greater degree because they had a greater potential for growth and were suppressed more by lower milk production than heifers. Stonaker (1963) has suggested these differences may be due to differences in the sex chromosomes. Brinks _et al_. (1965) also reported that inbreeding of the calf caused a greater suppression of the heifer gains than preweaning gains of bulls.

Abadia and Brinks (1972) reported differences among inbred lines for milk production with significant differences for milk production and duration of lactation. In comparing a crossline mating system to an inbred mating system, there was a difference between milk production and a significant difference for total butterfat. Several lines did have higher milk production than the control line, which agrees with Streeter _et al_. (1974) who reported that an inbred line (San Juan) produced more milk than commercial Herefords. Increased milk production due to heterosis associated with crossbreeding has been reported by Klett _et al_. (1962), Todd _et al_. (1969) and Vernon _et al_. (1964).

Efficiency of Milk Utilization

Differences in the ability of a calf to produce a kilogram of gain exist among and within breeds, with calves on lower producing dams showing better conversion rates. Gifford (1953) indicated that 7.1, 5.4 and 3.12 kg of milk was consumed at 1, 3 and 6 months, respectively, in Herefords while Klett et al. (1962) reported that 5.6, 4.9 and 3.5 kg of milk were needed per kg of gain during early, mid and late lactation. In the same study, Klett et al. (1962) reported that Angus calves consumed 5.0, 4.9 and 4.3 kg of milk. When the combined milk production records from the Angus and Herefords were stratified into groups of high, medium and low producers, the amount of milk consumed per kg of gain was 4.5, 3.4 and 2.5 kg, respectively, over the lactation period. Melton et al. (1967) found the conversion ratio to be 5.7, 4.7 and 5.2, respectively, for Angus, Herefords and Charolais over a 175-day lactation. Todd et al. (1969) has shown that 4.53, 7.64 and 7.22 kg milk/kg gain were needed by a group of Hereford, Hereford x Brahman, and Brahman, respectively.

Higher conversion rates have been reported by Drewry et al. (1959) which indicate Angus calves needed 12.5, 10.8 and 6.3 kg of milk/kg of gain at the first, third and sixth month of lactation. This is in agreement with Totusek et al. (1973) who reported that 10.0, 10.5 and 9.1 kg of milk was needed at 70, 112 and 210 days of lactation, respectively, for a group of mixed breed beef cows.

Vetter and Weber (1974) reported that from 10.0 to 10.8 kg of milk was consumed per kg gain by calves nursing Holstein x Hereford and Holstein x Angus cows during the first three months of lactation. Wilson et al. (1968) reported the ratio of milk yield to daily gain in Holstein x Angus cows to be 11.2 to 1.

Traits Related to Milk Production

Milk production in beef cattle is an economically important trait, especially when the profit margin for the cow-calf producer is narrow, but due to the nature of beef cattle and the management regime associated with them, actual milk production data is difficult to obtain. Often, it would be more practical for the cow-calf producer to select for highly correlated traits rather than actual milk production.

Average daily gain from birth to weaning may be one of the most accurate indicators of milk yield. Furr and Nelson (1964) reported the correlation between milk yield and average daily gain (ADG) in 2-year-old Hereford cows fed a high plane of nutrition in drylot to be .91. A low correlation of .52 was reported by Knapp and Black (1941). Other reports, summarized in table 2.3, give most correlations between .6 and .7. Neville et al. (1962) indicated that as pasture condition improved, the correlations between ADG and milk yield decreased. This is in agreement with Pope et al. (1963) who reported that the correlation between ADG and milk yield had decreased from .8 to .15 to .25 for the last period of lactation. Dawson et al. (1960) reported creep feeding calves caused correlation to decrease.

TABLE 2.3 CORRELATIONS WITH MILK PRODUCTION

Researchers	Traits	r=
Abadia & Brinks 1972	Milk yield - lactation length	.78
	Milk yield - total butter fat (BF)	.98
	Milk yield - total solids, not fat (SNF)	.99
	Milk yield - % BF	-.34
	Milk yield - % SNF	.02
	Lactation length - total BF	.78
	Lactation length - total SNF	.73
	Lactation length - % BF	-.37
	Lactation length - % SNF	-.17
Abadia & Brinks 1972	Total BF - total SNF	.97
	Total BF - % BF	-.20
	Total BF - %SNF	.06
	Total SNF - % BF	-.30
	Total SNF - % SNF	.19
Christian et al. 1965	Birth weight - ADG to 60 days	.32
	ADG to 60 days - milk 60-240 days	.64
	ADG to 60 days - butterfat 0-60 days	.73
	ADG to 60 days - butterfat 60-240 days	.44
	ADG to 60 days - dam weaning weight	-.07
	Milk 0-60 days - milk 60-240 days	.80
	Milk 0-60 days - butterfat 0-60 days	.92
	Milk 0-60 days - butterfat 60-240 days	.65
	Milk 0-60 days - weaning weight of dam	-.10
	Milk 60-240 days - butterfat 0-60	.78
	Milk 60-240 days - butterfat 60-240 days	-.76
	Milk 60-240 days - weaning weight of dam	-.20
	Butterfat 0-60 days - butterfat 60-240 days	.67
	Butterfat 0-60 days - weaning weight of dam	-.27
Drewry et al. 1959	Daily milk - total suckling time 3 mo	.03
	Daily milk - total suckling time 6 mo	.21
	Daily milk - number times nursed 6 mo	.22
	Daily milk - kg milk/kg gain 6 mo	.93

TABLE 2.3 CONTINUED

Researchers	Trait	r=
Furr & Nelson 1959	Daily gain - milk yield (low nutr) 80-120 days	.84
	Daily gain - milk yield (low nutr) 150-180 days	.80
	Daily gain - milk yield (low nutr) 180-120 days	.59
	Daily gain - milk yield (low nutr) 220-235 days	.45
	Daily gain - milk yield (low nutr) overall	.81
	Daily gain - milk yield (high nutr) 120-150 days	.65
	Daily gain - milk yield (high nutr) 150-180 days	.73
	Daily gain - milk yield (high nutr) overall	.85
	Daily gain - milk yield (low nutr) drylot	.75
	Daily gain - milk yield (high nutr) drylot	.91
	Daily gain - milk yield (low nutr) range	.80
	Daily gain - milk yield (high nutr) range	.80
Gifford 1953	Milk yield - body weight 1 mo	.52
	Milk yield - body weight 2 mo	.66
	Milk yield - body weight 4 mo	.67
	Milk yield - body weight 6 mo	.63
	Milk yield - body weight 8 mo	.60
Gleddie & Berg 1968	Milk yield - ADG	.84
Holmes *et al.* 1968	Calf gain - birth weight	.28
	Calf gain - milk yield	.82
	Calf gain - milk solids	.84
	Calf gain - milk energy	.82
	Calf gain - milk protein	.83
Jeffery *et al.* 1971a	Milk yield - ADG (1966)	.78
	Milk yield - ADG (1967)	.76
Knapp & Black 1941	Milk yield - ADG	.52
Kress & Anderson 1974	Milk at 34 days - milk at 65, 110 days	.54, .31
	Milk at 34 days - milk at 150, 183 days	.43, .06
	Milk at 65 days - milk at 110, 150 days	.53, .52
	Milk at 65 days - milk at 183 days	.23
	Milk at 110 days - milk at 150, 183 days	.46, .26
	Milk at 150 days - milk at 183 days	.42

TABLE 2.3 CONTINUED

Researchers	Trait		r=
Melton et al. 1967b	Age of calf - total milk yield		-.48
	Butterfat - total solids		.94
	% SNF - total solids		.56
Neville et al. 1962	Milk yield - ADG (1st 60 days)		.74
	Milk yield - ADG (2nd 60 days)		.63
	Milk yield - ADG (3rd 60 days)		.59
	Milk yield - ADG (4th 60 days)		.66
Pope et al. 1963	Milk yield - ADG (1st 60 days)	.65	-.80
	Milk yield - ADG (2nd 60 days)	.55	-.70
	Milk yield - ADG (3rd 60 days)	.30	-.45
	Milk yield - ADG (4th 60 days)	.15	-.25
	Milk yield - ADG (overall)	.60	-.70
Rutledge et al. 1971	Weaning weight - milk yield (1st mo)		.49
	Weaning weight - milk yield (4th mo)		.38
	Weaning weight - milk yield (7th mo)		.25
	Weaning weight - age of dam		.29
	Weaning weight - birth weight		.48
Totusek et al. 1973	Milk yield (210 days) - milk yield (70 days)		.82
	Milk yield (210 days) - milk yield (112 days)		.92
	Milk yield (210 days) - weaning weight		.88
	Milk yield (210 days) - ADG (70 days)		.69
	Milk yield (210 days) - ADG (112 days)		.80
	Milk yield (210 days) - ADG (210 days)		.88

Weaning weight of the calf is also correlated to milk production. This involves only one measurement and it is only slightly less accurate than the ADG, because the effect of birth weight has not been removed. Gifford (1953) reported calf weights at 8 months were correlated to total milk yield by .60. Jeffery et al. (1971a) has shown that 42 to 57% of total variation in weaning weight could be explained by milk yield. An increase of 1 kg per day caused a corresponding increase of 11.3 to 14.6 kg in weaning weight. Neville et al. (1962) reported correlations of .69 to .81, depending on the combination of milk estimates used, which is in agreement with within herd correlations reported by Rutledge et al. (1971).

Weight gains of the cow during the lactation period are thought to be related to milk production due to the fact that a cow converting feed to fat may produce less milk than one converting feed to milk. Jeffery et al. (1971b) reported correlations between summer gain and milk yield to be -.12 and -.21 for 1966 and 1967, respectively. The higher negative relationship was manifested under the limited grazing conditions of 1967 when a 10 kg gain in body weight resulted in a decrease of .1 kg daily milk yield.

Work by Singh et al. (1970) has shown that the summer weight change of the cow significantly influenced ADG and weaning weight of calves. The difference between preweaning ADG of calves whose mothers lost weight during lactation and those whose mothers gained weight was highly significant. It was estimated that for each 1% loss in body weight, a corresponding increase of .14 to 1.09 kg increase in calf weaning weight results. Greatest effects were noticed in cows 5 to 7 years of age. Reports by England et al. (1961) and Hohenboken et al. (1973) also showed that weight gain during lactation is antagonistic to milk production.

Several workers have shown that cow size does not significantly affect milk production (Jeffery et al., 1971b), (Wilson et al., 1969), (Christian et al., 1965) and (Pope et al., 1963) although (Singh et al., 1970) and (Vacaro and Dillard, 1966) have shown that larger cows wean larger calves, which disagrees with Wilson et al. (1969) who reports that larger cows tended to produce lesser quantities of milk and total milk energy when comparing Holstein x Angus cows.

Total milk yield is highly correlated to lactation length and total milk constituents (Abadia and Brinks, 1972; Christian et al., 1965; Melton et al. 1967; Gifford, 1953) although the percentage of constituents had low reported correlations.

Milk yield at one period of lactation was positively correlated to milk yield at another period, although the correlations decreased, depending on the difference in time between the two periods (Kress and Anderson, 1974; Christian et al., 1965; Totusek et al., 1973).

Drewry et al. (1959) reported that the correlation between number of times sucked and average daily milk yield at the 1st, 3rd and 6th months was -.30, -.18 and .22, respectively. Total time spent nursing at 1, 3 and 6 months was correlated to milk yield by -.40, .03 and .21, respectively, reported by Drewry *et al*. (1959) and Koch (1972).

Christian *et al*. (1965) found that the correlation between milk yield and weaning weight of the dam at 0 to 60 and 60 to 240 days, respectively, was -.10 and 0.20. Butterfat correlation to milk yield for these two periods was -.27 and -.18, respectively. It was not determined whether this was due to environmental or to genetic effects, but if it is genetic, this suggests that selection of replacement heifers by weaning weight will have a detrimental effect on milk production and consequently lower weaning weights in her progeny.

Heritability of Milk Production

Advances in the dairy industry due to selection give testimony to the fact that progress is possible. Schmidt (1971) reported that percentages of milk fat, protein, SNF and lactose are about 50% heritable. According to Laben (1963) total milk yield has a heritability of .20 and fat yield has a heritability of .30.

Due to the numbers of records needed for heritability studies and the difficulty of obtaining records from beef animals, few estimates are available. Yao *et al*. (1954) estimated heritabilities for milk, butterfat and peak-daily-production to be 28.4, 36, 8 and 16.9, respectively, in Milking Shorthorn Cattle, using paternal half-sib correlation. After removing 40 cows which were not considered a representative sample, the respective heritabilities were 14.2, 24.5 and 14.8 for milk, butterfat and peak-production.

Koch (1972) estimated the heritability of maternal ability for gain to weaning ranged between 30 and 36% in Herefords.

Physical Characteristics

The difference between body types of dairy and beef cattle have led to speculation that milk production may be associated with some physical characteristics.

Cole and Johansson (1933) observed that the most long-bodied and high-legged cow was the best milker, while the poorest milker was a more blocky type.

Brown and Franks (1964) estimated the heritability of weight and body measurments to be .44 for weight, .41 for wither height, .69 for hip height, .40 for shoulder width, .11 for hip width, .71 for chest depth, .39 for rear flank depth, .46 for heart girth and .48 for body length. Dry cows averaged 45 kg heavier than lactating cows and were larger in the dimensions influenced by fat thickness.

Brinks et al. (1962b) indicated that cow weights increased up to 8 years with the heritability of spring and fall weights being .75 and .73, respectively, using multiple records. Repeatabilities for the two weights were .76 and .84, respectively. Weight gain in winter tended to be associated with faster gaining calves, while weight gain over the lactation period was negatively correlated with calf gain. This is in agreement with Hohenboken et al. (1973) and with Vaccaro and Dillard (1966) who observed that young cows which were heavier

90 days before calving and lost less weight for 90 days prepartum to 60 days postpartum, produced faster gaining calves. However, in older dams with faster gaining calves, there was a larger weight loss at 60 days postpartum, but there was a tendency to gain more weight thereafter. Singh et al. (1970) also found weight loss during lactation was positively correlated to calf gain.

Wilson et al. (1969) grouped cows as either large or small and found that body size did not significantly influence milk yield. Marchello et al. (1960) found that cow weight at 18 months had little influence on subsequent milk production.

Nursing Behavior of Calves

No study of milk production estimation techniques can be complete without some comparison to the natural milk removal system. A study of the behavior of cows and calves in a range environment becomes almost impossible, but using a relatively small number of cows in a restricted area conclusions can be drawn about actual conditions.

Calves on Aberdeen-Angus cows confined in a 1.6 ha pasture, nursed 4.7±1.8 and 4.5±1.3 times per day, respectively, during the first month of lactation in 1957 and 1958, reported by Drewry et al. (1959). At three months, the respective number of times nursed was 6.0±1.6 and 3.2±.7 during the two years and at six months the number was reduced to 3.1±.7 and 2.9±.8. The combined two year average total time spent nursing was 38.8±18.4, 55.9±14.8 and 30.7±9.4 minutes per day at the first, third and sixth month, respectively, and the interval between nursing was 3.2±1.4, 4.2±1.5 and 5.5±1.8 hr at these respective months.

With Angus and Angus crossbred 2-yr-old cows, Walker (1960) indicated that 22% nursed their calves three times daily, 38% nursed four times, 24% five times and 13% nursed more often than five times when averaged over the entire lactation period. There was a trend for calves to nurse more frequently the first month than later on with the Hereford x Angus group reaching a high of 6.3 times per day during the first month. Average duration of nursing for the lactation period was 40, 45 and 32 min per day for the Angus, Hereford x Angus and Jersey x Angus groups, respectively. The average interval between nursing was 3.5 hr at one month and increased to 6 hr between nursing at 10 months.

Cartwright and Carpenter (1961) observed that Hereford x Brahman calves on Hereford dams nursed 4.2 times per day with the total duration lasting 38 min while Hereford calves on Hereford dams nursed an average of 3.5 times, with a duration of 28.7 min; however, the stage of lactation was not reported.

A higher frequency of nursing was observed by Hutcheson _et al._ (1962) in Zebu cattle. Average number of times nursed was 9.5, 6.7, 7.1, 6.0, 5.2 and 5.6 for the first through sixth month, respectively. The total duration of nursing decreased from 93.3 min at the first month to about 50 min during the last three months.

Nursing activity at night was minimal (Drewry _et al._, 1969; Walker, 1960; Cartwright and Carpenter, 1961); however, Hutcheson _et al._ (1962) reported an increase in night-time nursing activity as the stage of lactation increased when the cows and calves were confined to a lighted lot at night.

CHAPTER 3

EXPERIMENTAL CONDITIONS

Climatic Conditions

The Northern Agricultural Research Center at Havre, Montana is located at a latitude of 48°34' N and at 109°40' W longitude and elevation is approximately 762 meters above sea level. The area is typical of the northern glaciated plains and is bordered on the south by the Bear Paw Mountains.

The lowest recorded temperature of -50°C occurred in January, 1953, while the highest temperature ever recorded was 42°C in June 1900. The normal annual precipitation is 31.3 centimeters. The average April temperature ranges between a normal high of 14°C and a low of 0°C with 2.3 cm of precipitation normally occurring. Average snowfall for April is 9.4 cm. The average May temperature ranges between a high of 20°C and a low of 6°C with 3.8 cm of precipitation. Average snowfall during May amount to .7 centimeters.

The experiment was conducted during the years of 1975 and 1976 and they were contrasting years. Average maximum and minimum temperatures for April were 7.6°C and -4.6°C, respectively, for 1975, while in 1976 they were 18.3°C and 0.4°C. May temperatures showed the same trend with the respective maximum and minimum being 18.7°C and 4.4°C during 1975, while 1976 temperatures were 25.3°C and 4.5°C.

Precipitation during April and May of 1975 was 7.3 and 5.4 cm, respectively. During the same respective months in 1976, only 2.3

and 2.6 cm of precipitation was recorded. April snowfall in 1975 amounted to about 60 cm, while none was reported in May of 1975 or April or May of 1976.

Experimental Animals

Data for the present study were collected at the Northern Agricultural Research Center, Havre, Montana. These cows were maintained in the commercial herd and were the resulting product of crossline studies. The foundation stock of these cows were the results of a 20-year linebreeding project initiated in 1947-1948. Five separate lines were maintained, consisting of the Havre Line 1, a Polled Hereford line, Havre Lines 2 and 3 which were horned, Havre Line 4 which was straight Miles City Line 1 breeding, and the R.O.P. Line from Montana State University. In 1963, the cows from all lines had a mean inbreeding percentage of 15.29 reported by Anderson (1966). The latest estimates of inbreeding percentages of dams (unpublished) for lines 1, 2, 3, 4 and the R.O.P. line were 13, 11, 11, 2 and 10%, respectively.

Beginning in 1967 and continuing for three years, these lines were crossed in all possible combinations resulting in 25 subgroups of breeding. All female progeny from these crosses were saved. In October, 1970, 144 surplus registered and commercial cows were dispersed at auction. The cows remaining in the commercial herd, selected on the basis of their performance, and their subsequent progeny which were sired by Hereford bulls (predominately Havre Lines 1 and 4) were experimental animals used.

During the two years of this study, all cows included in the experiment had calves sired by Hereford bulls. Cow ages ranged from two years (first calf heifers) to eight years. Data were collected in April and May of 1975 and 1976 and represented the first two months of lactation.

Management of Experimental Animals

Cattle were wintered on a maintenance ration consisting of corn silage and hay. Cows were calved in a large pasture where they were kept under surveillance 24 hr per day. Shortly after calving the calf was weighed and tagged and then the pair were moved to a larger pasture. The cattle were maintained on a ration of hay and corn silage until mid April (depending on availability of spring grass) when they were turned onto an early spring range, consisting largely of crested wheatgrass (*Agropyron desertorum*) and some blue gramagrass (*Bouteloua gracilis*) and needle-and-threadgrass (*Stipa comata*). In order to prevent overstocking of this pasture, older calves were moved to a larger pasture farther way from the corrals, as more cows and calves were added during the calving season.

After calving, cattle were still checked at least once a day. Sick animals were usually treated on the range, but if it was determined that a cow was producing more milk than her calf could consume the pair was isolated and placed on reduced feed until the calf could take all the milk the cow was producing.

Cows and calves were moved to summer pasture during the first week in June.

CHAPTER 4

LATIN SQUARE MILK PRODUCTION

Introduction

The weigh-suckle-weigh method of estimating milk production has been used extensively for beef cattle research. The period of time the calves are separated varies among research reported in the literature review. The purpsoe of this experiment was to determine whether length of separation time influences estimates of milk production.

Materials and Methods

Experimental Design. The experiment was replicated over two consecutive years during April and May of 1975 and 1976. Each year was divided into two periods. The first period (p1) corresponded to days 7 to 21 of the lactation period and the second period (p2) corresponded to days 28 to 56 of the lactation period. Each animal included in the experiment was tested first in p1 and again in p2.

The basic experimental design was a 3 x 3 latin square where cows were assigned to rows, days were assigned to columns and treatment 1 (tr1), treatment 2 (tr2) and treatment 3 (tr3) was a 4, 8 and 16 hr separation interval, respectively. The latin square was necessary to insure that the groups were composed of similar cows which was necessary to show the true relationship among treatments. A 3 x 3 latin square has only two possible ways that treatments can be arranged; tr1 can follow tr3 or tr2 can follow tr3 as shown in figure 1. These two types of treatment sequence were designated as

	Day 1	Day 2	Day 3
Cow 1	tr1	tr2	tr3
Cow 2	tr2	tr3	tr1
Cow 3	tr3	tr1	tr2

tr1- 4 hr separation
tr2- 8 hr separation
tr3-16 hr separation

Type 1

	Day 1	Day 2	Day 3
Cow 1	tr3	tr2	tr1
Cow 2	tr1	tr3	tr2
Cow 3	tr2	tr1	tr3

tr1- 4 hr separation
tr2- 8 hr separation
tr3-16 hr separation

Type 2

Figure 1. Two types of treatment sequence using a 3 x 3 latin square.

Type 1 with the 4 hr treatment following the 16 hr treatment and as Type 2 with the 8 hr treatment following the 16 hr treatment. Each type was alternated throughout each period so that if there were any residual or "carry over" effects from one treatment to the next, they would average out over the period. Figure 2 shows the alternation of types of squares with the squares spread out so that each day of the period was represented.

In order to test whether treatment effects alone were creating differences in milk estimates, it was necessary to reduce variation as much as possible among cows and among days. Similar feeding and management should reduce variation among days. In order to assure that similar cows were assigned to each square, the criterion that received top priority was that days in lactation be the same ± 1 day. The next criterion was that cows be from the same age group with the groups being composed of 2, 3 or 4-year-old and mature cows. Because there were only four 4-year-old cows, they were included with the mature group which were six to eight years old.

In 1975, 20 squares composed of 60 cows were tested in each period while in 1976 only 19 squares were used due to the lower number of Hereford sired calves. One calf in the second period in 1976 refused to nurse after a 4 hr separation interval which necessitated the removal of the entire square. This left 18 squares representing the second period in 1976. Although eight of the cows were included

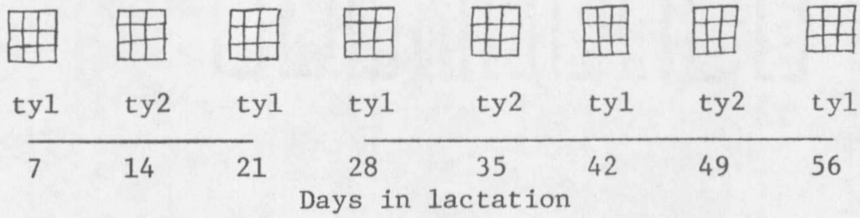


Figure 2. Experimental design for 1975 and 1976.

in squares in both years, they were considered to be different cows for purposes of the analysis. Due to the limited number of experimental animals to choose from, it was necessary to compose 24 squares of calves of different sex and 32 squares were composed of cows of different ages of which eight were composed of combination of 2.5 and mature. After cows were assigned to a square, they were randomly assigned a row (cow number) within the square.

Experimental Procedure. The cows and calves were on pasture until time for the milk production test, when they were brought into the corrals and were confined in a dry lot. Feed levels (approximately 10 kg of hay in 1975 and the equivalent of silage + hay in 1976) were comparable to levels being fed to their contemporaries in an early spring management regime. During late spring after new pasture growth had appeared, the cows were placed on pasture, but cows on test were put on drylot for the 3 days they were on test.

Normally, three or four squares were tested together. The general procedure called for stirring up the cows and calves about 5:30 pm on the day they were brought in. Usually anytime the cows were disturbed and then left alone, the calves would nurse. At 6:00 pm, the calves to go on 16 hr separation were removed from their dams. In 1975, the cows were weighed and condition scored at this time. (In 1976, it was necessary to wait until the third day and weigh the cows just before returning them to pasture). The next day, on day 1 of the experiment at about 7:30 am, the remaining cows and calves were disturbed. After the calves had nursed, the 4 hr and the 8 hr separation calves were removed from their dams at 8:00 am. The cows were then visually inspected to determine if their udders were completely empty. Those cows that were questionable were restrained in a squeeze chute and milked out by hand. The wet snowy spring of 1975 seemed to cause problems with younger calves not completely nursing their dams and some of their dams had to be milked out. As the weather turned more favorable in 1975 and then in 1976, even the younger calves were able to remove all of the available milk.

At 10:00 am, the calves on the 16 hr separation were weighed to the nearest .23 kg and then turned to their dams. The calves nursed until they were done (approximately 20 min) and were then immediately reweighed. The cows whose udders were incompletely nursed were restrained and milked dry. During 1975 when the weather reduced the vigor of the calves and when some of the cows had sunburned udders, there were some problems with calves not completely nursing out the cows after a 16 hr separation, but generally during more favorable weather conditions, only a few high producing cows with young calves had to be milked out after the calves had finished nursing. The milk removed by hand was weighed and added to the difference of the calf weights taken before and after nursing and this total was then multiplied by 1.5 to give a 24 hr milk production estimate. The cows and calves were then turned back together.

At 12:00 noon, the calves on the 4 hr separation were weighed, allowed to nurse and reweighed. This weight difference was multiplied by a factor of 6 to obtain a 24 hr estimate of milk production. The cows were visually inspected for empty udders and the calves were turned in. The calves on 8 hr separation were weighed at 4:00 pm and allowed to nurse and then were reweighed. This weight difference was multiplied by three to obtain a 24 hr estimate of milk production. The cows were inspected and turned in with their calves.

At 5:30 pm the same day, the calves to go on the 16 hr separation were allowed to nurse and separated from their dams about 6:00 pm.

The typical testing schedule for the 3 days for types 1 and 2 are shown in figure 3.

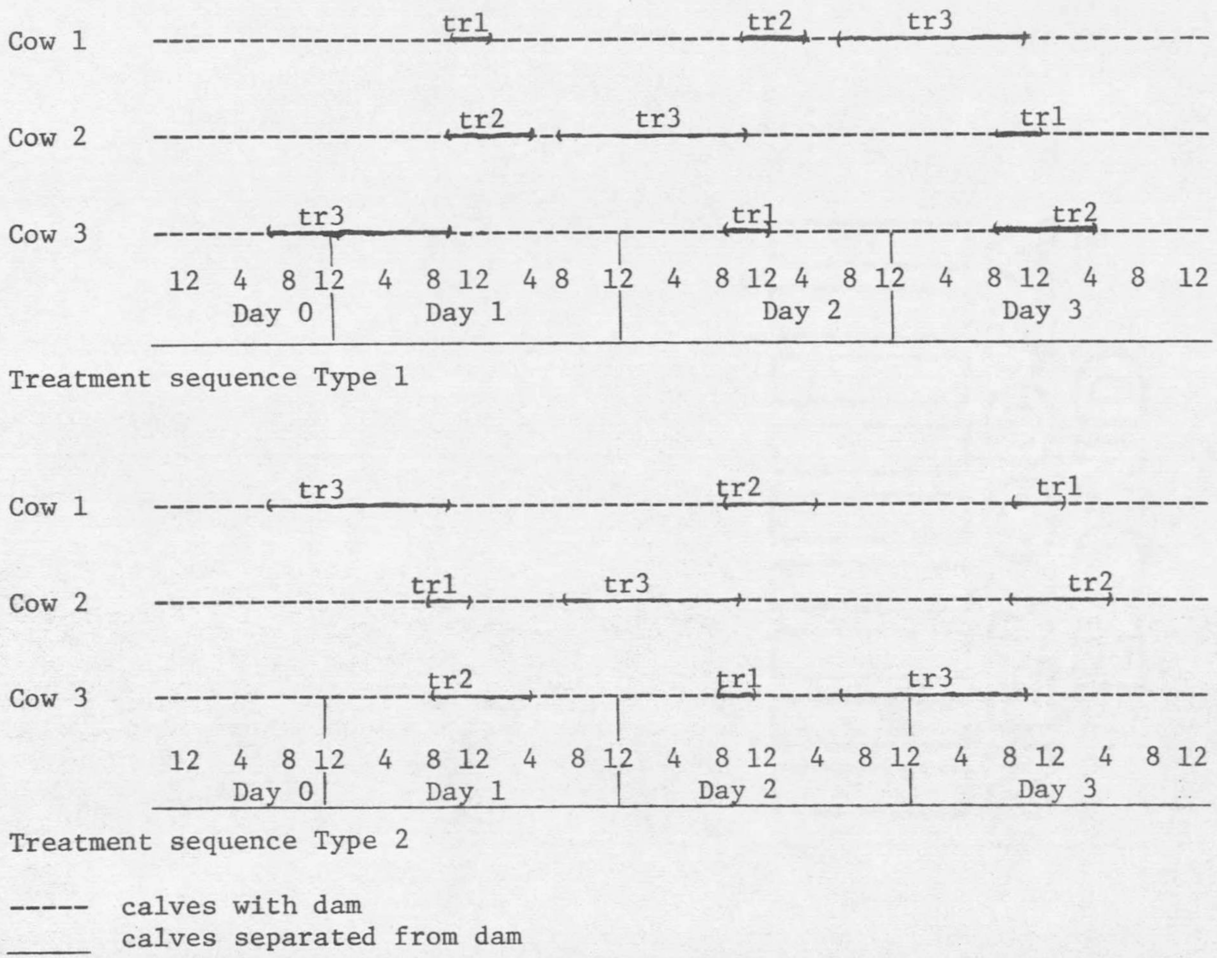


Figure 3. Normal procedure for estimating milk production.

Method of Analysis

Analysis of these data followed procedures used by Cochran et al. (1941) for a similar latin square design.

Analysis was according to least squares procedures using a nested mixed model (Model 5) (Harvey, 1972). Each variable was described by the following linear statistical model:

$$Y_{ijklmn} = u + Y_i + S_{ij} + C_{ijk} + t_l + d_m + p_n + (yp)_{in} + (dp)_{mn} + e_{ijklmn}$$

where Y_{ijklmn} = each individual observation

u = fixed underlying population mean

Y_i = effect of the $i^{\underline{th}}$ year

s_{ij} = effect of the $j^{\underline{th}}$ square nested within the $i^{\underline{th}}$ year

c_{ijk} = effect of the $k^{\underline{th}}$ cow nested within the $j^{\underline{th}}$ square within the $i^{\underline{th}}$ year

t_l = effect of the $l^{\underline{th}}$ treatment

d_m = effect of the $m^{\underline{th}}$ day

p_n = effect of the $n^{\underline{th}}$ period

$(yp)_{in}$ = interaction of the $i^{\underline{th}}$ year with the $n^{\underline{th}}$ period

$(dp)_{mm}$ = interaction of the $m^{\underline{th}}$ day with the $n^{\underline{th}}$ period

e_{ijklmn} = random, uncontrolled errors

The following assumptions were made regarding the distribution of the effects: $s_{ij} = \text{NID}(0, \sigma_S^2)$ (random); $C_{ijk} = \text{NID}(0, \sigma_C^2)$ (random); y_i(fixed); t_l(fixed); d_m(fixed); p_n(fixed); $(yp)_{in}$(fixed); $(dp)_{mn}$ (fixed); $e_{ijklmn} = \text{NID}(0, \sigma_E^2)$ (uncontrolled, uncorrelated, random effect that varied among individuals). The decision to consider years as a fixed effect was made due to the fact that the treatments being investigated were influenced by the specific years of 1975 and 1976, without inference to other years.

Cows assigned to the squares were considered to be a random sample of the population. Squares were considered as a random effect due to the fact that they were composed and assigned to a time period due to the availability of a random group of cows. The natural randomization of calf sex also contributed to the randomization of the squares.

Days were not nested within squares as cows were because the specific days investigated were the first, second and third days of each square although it was recognized that day 1 in April may not have been the same as day 1 in May.

Preliminary analyses indicated that type of square effects and the effects of the type x treatment, treatment x period and the treatment x year interaction were not significant sources of variation; consequently, they were not included in the final model. A preliminary least squares analysis using a fixed model (model I) (Harvey, 1975) was used to determine the suitability of the assumptions made in the composition of the 3 x 3 squares. This model included year (either 1975 of 1976) weeks in lactation (1-7 + weeks), sex of calf (male or female) and age of dam (2, 3, or mature). Dependent variables were milk production estimates from the 4, 8 and 16 hr separation intervals and calf ADG from birth to time of test. Two hundred thirty-two observations were used in this analysis.

Results and Discussion

The assumptions used in assigning cows to squares were that (1) the amount of milk produced is determined to the greatest extent by the length of time the cow has been milking (2) age of cow is the next most important variable in determining milk production (3) the agressiveness of the calf, as influenced by calf sex is the third most important factor influencing production.

The analysis of variance (table 4.1) indicated that age of dam was a significant source of variation for all of the traits measured. Lactation stage was a significant source of variation for the 4 hr milk production and for average daily gain. Year was a highly significant source of variation for ADG of the calf; however, there was no significant difference between years for the milk production estimates. Sex of calf was not a significant source of variation for any of the traits measured during this period in early lactation. A more complete discussion of these factors appears in Chapter 5. This analysis as related to the latin square design indicated that the assumptions made concerning major factors that infleunce milk production were basically correct; however, the analysis of the data showed that age of cow should have received top priority in composing the squares with lactation stage being secondary. Sex of calf need not have received any consideration.

TABLE 4.1. LEAST SQUARES ANALYSES OF VARIANCE FOR PRODUCTION TRAITS

		Mean squares of traits			
Source	df	4 hr milk production (kg)	8 hr milk production (kg)	16 hr milk production (kg)	Average daily gain of calf (kg/day)
Year	1	.18	.83	1.58	1.39**
Lactation stage	6	18.38*	2.52	1.75	.18*
Sex of calf	1	.017	.15	1.85	.05
Age of dam	2	139.78**	121.63**	89.2**	1.12**
Residual	221	7.99	4.05	1.60	.04

*P<.05.
**P<.01.

The analysis of variance for the complete latin square design (table 4.2) indicated that all factors included in the model significantly influenced milk production, with the exception of years. Assuming that milk production follows closely with the quality and quantity of feed available as reported by Klett et al. (1962), Pope et al. (1963) and Lamond et al. (1967), the same feeding management during both years would explain the insignificant effect of years.

The composition of each individual 3 x 3 latin square was such that within square variability was reduced to a minimum. With within square variation reduced, the variation between squares manifested itself as a significant effect. The differences between squares were due primarily to differences in ages and to differences in stage of lactation. Even though the three cows within each square were deliberately chosen to be as similar as possible, the fact that cows/square/year was a significant effect indicated that something other than age, stage of lactation and sex of calf had an important influence on milk production. This influence in the common environment of the square could be attributed to differences in genetic potential. Differences in genetic potential are of paramount importance to the livestock industry because selection for milk production in beef cattle is possible if the superior genotype can be identified.

TABLE 4.2. LEAST SQUARES ANALYSIS OF VARIANCE FOR MILK PRODUCTION FOR 1975 AND 1976 COMBINED

Source	df	Mean squares (kg)
Year	1	9.73
Squares/year	37	22.25**
Cows/square/year	78	9.04**
Treatment	2	596.94**
Day	2	12.51*
Period	1	27.68**
Year x period	1	12.58*
Day x period	2	19.35**
Remainder	568	3.98

*P<.05.
**P<.01.

The question of whether differences in separation interval influence 24 hr milk production was answered by the highly significant effect of treatments. The least squares means (table 4.3) for the 4-, 8- and 16-hr treatments were 9.16, 7.61 and 5.94 kg, respectively, and differed significantly from each other as tested by least significant difference (Snedecor and Cochran, 1967). The shorter interval between nursings yielded more milk which agreed with reports from the dairy industry (Elliot, 1962; Cash and Yapp, 1950) indicating that the additional milk was due to more frequent oxytocin release. Another factor may have been the decreased udder pressure associated with frequent milking (Dodd, 1967). Udder pressure was probably the most important factor causing reduced production for the 16-hr interval. After 16 hr, the cows were noticeably uncomfortable as evidenced by nearly constant bawling and the distended condition of the udder and teats. Some cows were in pain and would kick as the calf initially made contact. It was thought that the quantity of milk received would increase the incidence of scours in the calves, however, in this group of cows, no justification was found for this hypothesis.

TABLE 4.3. LEAST SQUARE MEANS BY YEARS, TREATMENTS, DAYS AND PERIODS FOR 24-HOUR MILK PRODUCTION 1975 AND 1976 COMBINED

Variable	Observations	Means (kg)	Standard error
Year			
1975	360	7.45	.250
1976	333	7.69	.259
Treatment			
4 hr	231	9.16[a]	.209
8 hr	231	7.61[b]	.209
16 hr	231	5.94[c]	.209
Days			
day 1	231	7.64[a]	.209
day 2	231	7.31[b]	.209
day 3	231	7.76[a]	.209
Periods			
7-21 days	315	7.37[a]	.195
28-56 days	342	7.77[b]	.096

[abc]Means/variable with different superscript differ significantly ($P<.05$).

After 8 hr, the cows would bawl occasionally; however, this may have been due to mothering instinct, rather than physical discomfort. Calves were hungry after 8 hr and were ready to start nursing.

After a 4 hr interval, many calves would not start nursing immediately, but would find their mother and then wander away or allow their mother to lick them for a few minutes before nursing. However, only one calf refused to nurse after a 4 hr interval and this may have been due to his unhealthy condition. The 4 hr estimate was the least precise of the three estimates from a measurement standpoint because the scale was calibrated in .23 kg increments and when the production was multiplied by six to put it on a 24 hr basis, an error of up to ±1.4 kg could result, compared with an error of ±.7 and ±.3 kg for the 8-hr and 16-hr treatments, respectively.

When types of squares proved to be an insignificant effect, it was concluded that the treatment sequence was unimportant and that no measurable "carryover" effect existed from one treatment to another.

Days refers to consecutive days 1, 2 and 3, corresponding to the columns of the 3 x 3 latin square. Days were a significant source of variation and the least squares means of 7.64 kg for day 1 and 7.76 kg for day 3 were significantly different from the 7.31 kg of milk produced on day 2 as tested by least significant difference. Because feeding and management remained constant throughout the days of the test, the decrease in production on day 2 may indicate that stress affected production. The stress of being separated from their calves was particularly noticeable in the younger cows which spent very little time at the feed bunk and most of their time bawling over the fence at their calves. On day 1 of the experiment, the stress condition was not noticeable due to carryover nutritional effects from the day before. By day 2, milk production had dropped due in part to little feed the day before. As cows became acclimated to the drylot environment, milk production increased as was shown on the third day.

Milk production from the first period of 7 to 21 days (the design specified calf ages to be 7 to 21 days, but a few calves were up to 24 days old before testing; by the same token some calves were only 27 days old and were included in period 2) was significantly different from milk production in period 2 at 28 to 56 days. Period 1 was shorter than period 2 because a large concentration of cows was needed to determine the shape of the lactation curve in this early period of lactation. Kress and Anderson (1974) had reported peak milk production at 20 days in this herd and one objective of this study was to determine whether the peak occurred earlier than 20 days. Milk production increased from 7.37 kg during period 1 to 7.78 kg during period 2. This conflicts with Kress and Anderson (1974), but is in agreement with other reports of increases in milk production to 30 to 45 days (Abadia and Brinks, 1972) and up to 60 days (Gleddie and Berg, 1968).

The significant period by year interaction is illustrated in figure 4. This was difficult to interpret due to the fact that squares from period 1 were distributed during both April and May; consequently, it is difficult to relate to available feed, but it is correct to assume that the majority of cows in period 1 were tested in April while the majority of cows in period 2 were tested in May. During 1975, when snow covered the ground during much of April, the cattle may have had to depend more on being fed than they did in 1976 when green grass was not snowcovered. In 1976, the green grass was more palatable than hay even though hay was available and milk production more closely followed the quantity of the grass.

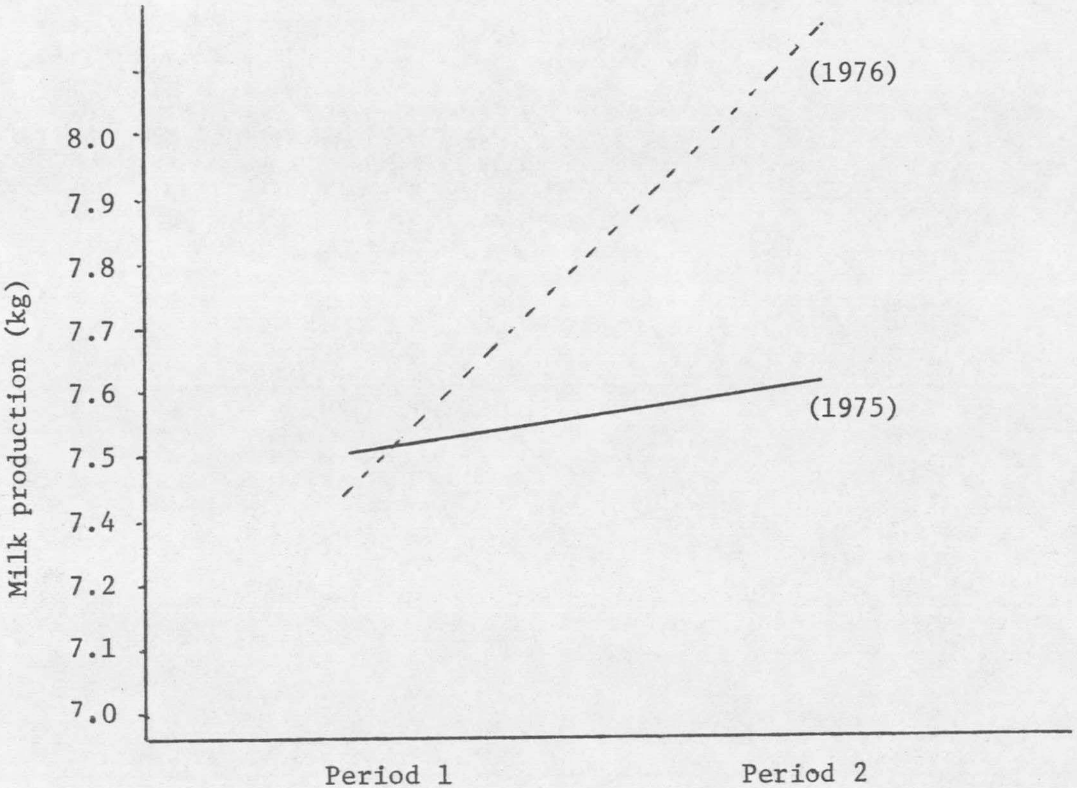


Figure 4. Milk production means for each year and period illustrating the year by period interaction.

Figure 5 illustrates the significant period x day interaction and shows a decrease in production on day 2 of period 2. The stress factor and the adaption to a drylot condition may affect milk production more when the cows come from a pasture environment dependent on green grass than when they come from a more confined management regime such as was the case with most of the cows in period 1.

Appendix tables 1 and 2 contain separate analyses for 1975 and 1976, respectively, with the model including type. Appendix table 3 contains the analysis for both years with treatment x year and treatment x period interactions included in the model.

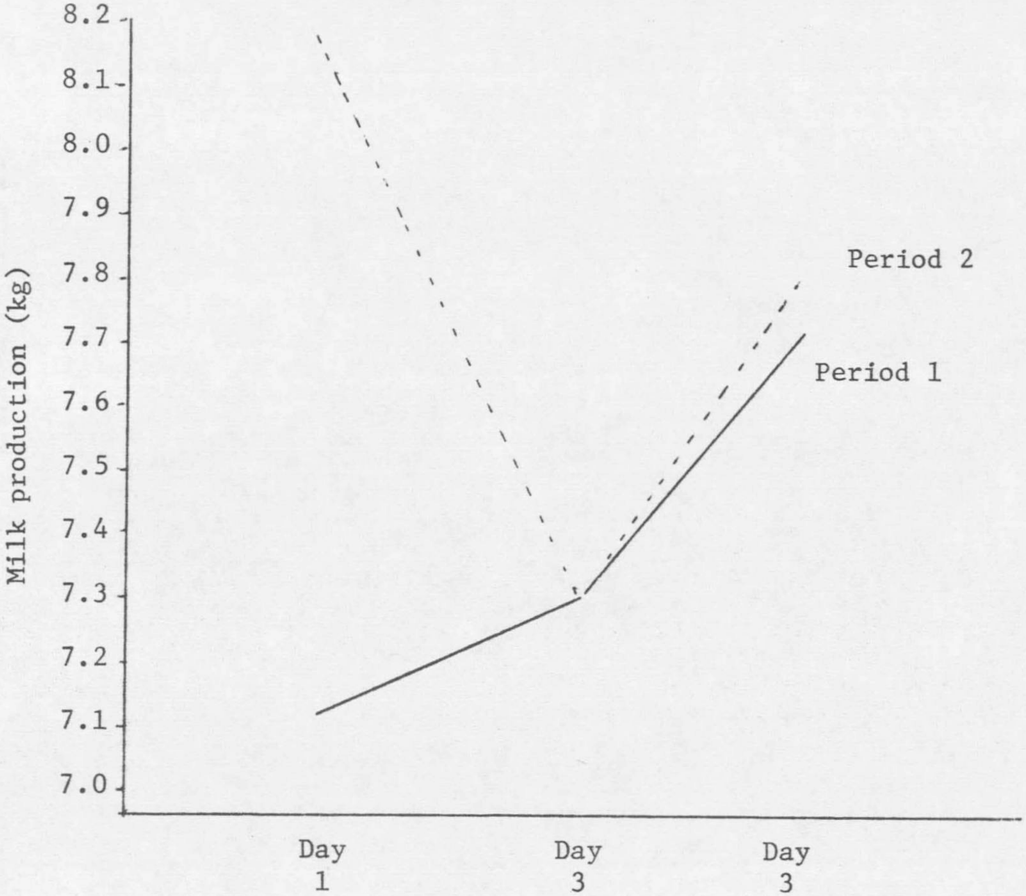


Figure 5. Milk production means for each day and period illustrating the period by day interaction.

CHAPTER 5

PHYSICAL TRAITS AND PRODUCTION ESTIMATES

Introduction

Milk production in beef cattle is difficult to measure, thereby making any highly correlated trait an important tool in practical selection for milk production.

Body height, weight, weight:height ratio and condition score were analyzed to determine their relationship to 24 hr milk production and calf ADG. Both hip and withers height measurements were used in an effort to determine whether one more accurately measured height.

Materials and Methods

Each animal was weighed, measured and assigned a condition score once during period 1 and once during period 2 at 7 to 21 days and 28 to 56 days, respectively, into the lactation period.

Cattle were weighed and measured on an indoor scale on a wooden platform approximately 1 x 2.5 meters. Weights were taken to the nearest .45 kg. Height measurements were taken with a tool constructed of 1.27 cm electrical conduit calibrated in centimeters, with a sliding horizontal member attached at a right angle. A line level attached to the horizontal member aided in keeping it level, assuring that only vertical distance from the floor to the hips or withers was being measured. Withers height measurements were taken when the cow was standing evenly on her feet and when her neck was elevated to a position level with her back. Hip height was measured directly over the hip bones when the animal was standing squarely over all four legs.

Condition score was assigned according to visual inspection with all scoring done by the same person. Scores ranged from one for a cow in extremely "thin" condition to 10 for a cow in extremely "fat" condition. Ultrasonic estimates of fat thickness over the 12th rib were used during the 1976 study to aid in condition score determination. Results were unsatisfactory due to lack of measureable variation so the ultrasonic measurement was discontinued.

Repeatability from period 1 to period 2 for withers and hip height, $\frac{\text{weight}}{\text{withers height}}$, $\frac{\text{weight}}{\text{hip height}}$, condition score and 4-, 8- and 16-hr milk production were obtained from the 115 cows that had complete data for both periods. Repeatability was estimated by $\frac{\hat{\sigma}^2 \text{cows}}{\hat{\sigma}^2 \text{cows} + \hat{\sigma}^2 \text{error}}$ with the variance components obtained from least squares analysis of variance (Model II) (Harvey, 1972). The model included period, year-age of cow and cow nested within ages in each year. Coefficients of variation were calculated by $\frac{\hat{\sigma}}{\hat{\mu}}$.

Milk production was measured by the 4-, 8- and 16-hr separation interval and indirectly by average daily gain of the calves. A preliminary analysis included the year, cow age and actual condition score as discrete variables and days in lactation, hip height and cow weight as covariates (Appendix table 4). Height was not a significant source of variation for any of the production traits. The quadratic regression of 16-hr milk on weight was significant; however, when condition score was run as a covariate, as in Appendix table 5, this effect was reduced to a nonsignificant effect. Calf sex was previously shown to be nonsignificant effect for milk production and calf ADG.

It is possible that cow condition could be measured more accurately by weight:height ratio than by a visual score. Preliminary analyses were made comparing the weight:hip height ratio and condition score as estimates of cow condition. The weight:height ratio was grouped as high, medium and low and used as a discrete variable, while condition score was grouped by actual score and analyzed as a discrete variable. Lactation stage was then considered to be a continuous variable representing days 6 to 56. Appendix tables 6 and 7 show this comparison. Appendix table 8 also indicated that $\frac{\text{weight}}{\text{hip height}}$ and condition score measured the same effect. The visual score for cow condition was used as the most suitable indicator of cow condition.

Another preliminary analysis indicated that neither the quadratic regression on days in lactation nor the quadratic regression on condition score was significant (Appendix table 9).

The analysis of variance was according to least squares procedures using a fixed model including year, age of cow, linear regression on days in lactation and linear regression on condition score. Primary dependent variables were milk production estimates from the 4-, 8- and 16-hr separation intervals and calf average daily gain. Dependent variables also included were withers height, hip height, weight, metabolic size and weight:height ratios using both actual weight and metabolic size in an attempt to determine their correlation with milk production.

Means were compared by least significant difference (Snedecor and Cochran, 1967).

Results and Discussion

Repeatability estimates were calculated from the analyses of variance in tables 5.1 and 5.2. Repeatability estimates the correlation between measurements in period 1 and period 2 for each cow. High repeatability estimates indicate that cows with high relative measurements in period 1 also had high relative measurements in period 2 and cows low in the first period were also low in the second period.

A comparison of repeatabilities for hip and withers height should reflect the accuracy of the measurement since height, as determined by bone growth, would have changed little during the short time between measurements in period 1 and measurements in period 2. Repeatabilties were .940 and .951 for withers and hip measurements, respectively, (table 5.3). Coefficients of variation for withers and hip heights, respectively, were 3.6% and 3.1%. When care was taken to insure that each measurement was an accurate as possible these results indicate that both measurements are an accurate estimate of height and that hip measurements may have a slight advantage due to higher repeatability.

In a situation where rapid measurements are necessary, the hip measurement may be advantageous since cows tend to be less upset by measurements over the rump and will stand still more quietly while the measurement is being made. Many cows, especially the younger ones, get restless when someone is working near their heads and a considerable amount of time is used waiting for them to quiet down and hold their necks level with their backs while they are being measured.

Repeatability of weight was relatively high at .89. Cows tended to have the same weights relative to each other in periods 1 and 2 although the mean weights increased from period 1 to period 2. Cows had reached or were close to the maximum postcalving weight loss in period 1 and were starting to gain weight during period 2. Bellows and Thomas (1976) had reported that maximum weight loss occurred between the first and second month of lactation which is in agreement with these data. Mean weights for period 1 and period 2, respectively, were 445.5 kg and 451. 2 kg (table 5.4). Cow condition also reflected the weight gain as the mean score increased from 6.58 during period 1 to 6.73 during period 2 although this was not significant.

TABLE 5.1 LEAST SQUARES ANALYSIS OF VARIANCE FOR PHYSICAL TRAITS

Source	df	Mean squares of traits: Withers height (cm)	Hip height (cm)	Weight (kg)	$\frac{\text{Weight}}{\text{Withers height}}$	$\frac{\text{Weight}}{\text{Hip height}}$	Condition score
Ages-years	5	393.85**	179.70**	127038.58**	5.841**	6.459**	4.53**
Cows/ages-years	109	19.62**	23.04**	2990.24**	.143**	.127**	1.26**
Period	1	.35	.36	1877.61**	.148*	.131*	1.22
Residual	114	1.26	1.18	353.80	.025	.022	.33

**P<.01.
*P<.05.

TABLE 5.2. LEAST SQUARES ANALYSIS OF VARIANCE FOR MILK PRODUCTION AND CALF ADG

Source	df	Mean squares of traits: 4-hr milk production (kg)	8-hr milk production (kg)	16-hr milk production (kg)	Calf ADG (kg/day)
Ages-years	5	70.35**	53.95**	34.95**	.838**
Cows/ages-years	109	9.05	4.93	2.60**	.059**
Period	1	32.74*	7.44*	1.27	.779**
Remainder	114	7.32	3.14	.70	.023

**P<.01.
*P<.05.

TABLE 5.3. REPEATABILITY ESTIMATES AND COEFFICIENTS OF VARIATION FOR PHYSICAL AND PRODUCTION TRAITS

Trait	Repeatability estimate	Coefficient of variation
Withers height	.940	3.56
Hip height	.951	3.11
Weight	.894	14.45
$\frac{\text{Weight}}{\text{Withers height}}$	.850	12.08
$\frac{\text{Weight}}{\text{Hip height}}$	.853	12.73
Condition score	.795	13.93
4-hr milk production	.553	33.98
8-hr milk production	.610	29.64
16-hr milk production	.788	25.82
Calf ADG	.721	45.18

TABLE 5.4. LEAST SQUARES MEANS FOR PERIODS 1 AND 2

Trait	Mean Period 1	Mean Period 2	Standard error
Withers height (cm)	120.3	120.2	.34
Hip height (cm)	125.9	125.9	.37
Weight (kg)	445.5	451.2	4.30
Weight / Withers height	3.74	3.79	.030
Weight / Hip height	3.53	3.58	.029
Condition score	6.58	6.73	.093
Calf ADG (kg/day)	.477	.594	.021
24-hr milk production			
4-hr interval (kg)	8.59	9.35	.289
8-hr interval (kg)	7.31	7.67	.204
16-hr interval (kg)	5.71	5.86	.133

The repeatabilities for 4-, 8- and 16-hr milk production estimates were .553, .610 and .788, respectively. This indicated that production of cows with a 4-hr separation was not as consistent from period 1 to period 2 as the production estimates from longer intervals. The means for the 4-hr interval were 8.59 for period 1 and 9.35 for period 2 and differed significantly. The 8-hr and 16-hr means for periods 1 and 2 did not differ significantly. The higher repeatabilites for the 8-hr and 16-hr milk production may mean that the 4-hr milk production estimate was measuring more variation than was actually present or that with the 8-hr and especially the 16-hr estimate, the udder had filled and the milk production estimates were measuring udder capacity rather than actual milk production. The coefficient of variation decreased as separation time increased which also leads to speculation that some factor was reducing natural variation in milk production or that measurement error is less for the longer intervals due to lower conversion factors for 24-hr production.

Average daily gain of the calves had a repeatability estimate of .721. This comparatively low estimate was expected due to the fact that gains were affected by many external factors such as milk production of the dam, weather and calf sickness. The high coefficient of variation could also be explained by the influences of these factors and differences in individual gaining ability of the calves. Average daily gain increased significantly from .47 kg/day during period 1 to .59 kg/day during period 2. The increased gain could be a result of increased milk production of their dams or increased forage utilization by calves or by a combination of both.

The ratios of weight to withers and hip heights were highly repeatable due to the high repeatabilities of the numerator and denominator. Because the weight:height ratio is a continuous variable and condition score was relative within the herd and determined to be a continuous variable, a linear regression best represented cow condition. Analyses indicated that both condition score and weight:height ratio were measuring similar effects (Appendix table 8) with condition score account for .69%, .18%, .65% and .2% of the total variation in 4-hr, 8-hr and 16-hr production and calf ADG, respectively; while weight:height ratio accounted for .36%, .14%, 1.4% and .08%, respectively. The residual correlation between weight:height ratio and condition score was determined to be .59 (Appendix table 11) from the model in Appendix table 10. This was lower than the correlation of .89 reported by Klosterman et al. (1969). Body types vary a great deal within a herd and a length measurement has been used in addition to weight and height measurments by Wilson et al. (1967) to account for different body types and the reported correlation with condition score was .22. Condition score was compared to weight as an indicator of cow condition. Condition score explained .49%, .46%, .73% and .29% of the total variation in 4-, 8- and 16-hr milk production and ADG, respectively, while weight explained .46%, .10%, 1.53% and .06% of the respective variation. Metabolic size, which is weight to the .75 power (Kleiber, 1961), was substituted for weight but tables 5.5 and 5.6 showed no higher correlations with this substitution. Due to the fact that the correlation between condition score and weight:height ratio was not higher and that the weight:height ratio is influenced more by differences in body type it was decided that the visual score would more suitably define cow condition.

TABLE 5.5. CORRELATIONS[a] BETWEEN DAYS IN LACTATION AND CONDITION SCORE AND PHYSICAL AND PRODUCTION TRAITS AND THE RESPECTIVE REGRESSION COEFFICIENTS

Trait	Days in lactation	b=( )	Condition score	b=( )
Withers height	-.017	(-.0182)	.215	(.5404)
Hip height	-.007	(-.0137)	.208	(.7295)
Weight	.054	(.0219)	.558	(26.29)
Metabolic size	.053	(.0029)	.556	(4.233)
Weight / Withers height	.070	(.0008)	.599	(.1984)
Weight / Hip height	.063	(.0006)	.579	(.1860)
Metabolic size / Hip height	.065	(.0011)	.581	(.2884)
4-hr milk	.206	(.0372)	.173	(.2865)
8-hr milk	.035	(.0018)	.164	(.1077)
16-hr milk	.064	(.0036)	.231	(.1475)
Calf ADG	.273	(.0043)	.085	(-.0144)

[a]Overall correlations.

TABLE 5.6. RESIDUAL CORRELATIONS AMONG PHYSICAL AND PRODUCTION TRAITS

Variable	Symbol	B	C	D	E	F	G	H	I	J	K
Withers ht	A	.85**	.63**	.64**	.32**	.39**	.28**	.04	.08	-.03	.07
Hip ht	B		.64**	.64**	.40**	.33**	.19**	.01	.02	-.05	-.03
Weight	C			1.00**	.94**	.94**	.87**	.01	.01	.04	-.02
Metabolic size	D				.94**	.94**	.87**	.01	.01	.03	-.02
Weight / Withers ht	E					.97**	.93**	.00	-.03	.01	-.01
Weight / Hip ht	F						.93*	.01	.01	.07	-.01
Metabolic size / Hip ht	G							.01	.01	.07	.00
4-hr milk	H								.36**	.38**	.27**
8-hr milk	I									.51**	.46**
16-hr milk	J										.46**
Calf ADG	K										.46**

**P<.01.

Analysis of variance for milk production estimates (table 5.7) indicated that year was not a significant source of variation for any estimate except average daily gain of the calf. Similar management and feed levels each year reduced the year effect on actual milk production. The wet snowy April of 1975 may have been responsible for the reduced daily gain of calves in 1975. The .46 kg gain/day in 1975 (table 5.8) differed significantly from the .61 kg gain/day in 1976. Scours and general health problems were more prevalent in 1975 and this stress may have caused lower average gain in 1975 even though calves received the same amount of milk both years.

The significant age of dam effect is in agreement with reports in the literature of milk production increasing with age and peaking at 6 to 9 years of age (Gifford, 1953; Neville et al., 1974; Todd et al., 1969; Rutledge et al., 1971) or 5 to 10 years of age (Melton, 1967b). Production was significantly different for each age group with the exception of the 3-year-old and mature cows with the 4-hr estimate (table 5.8).

Milk production differed by estimates as was discussed in the preceding chapter with the shortest separation interval yielding the highest estimate.

The linear regression on days in lactation was significant for the 4-hr estimate and is shown in figure 6. The regression line was defined as $\hat{M}=\bar{M}+.0369$ where x=days in lactation -28.9 days (table 5.5). The fact that the regression on days for the 4-hr and 16-hr was not significant may indicate that limitations in udder capacity limited full expression of milk production potential for the longer separation intervals. An alternative explanation would disregard the 4-hr estimate and explain the lack of significance of the 8- and 16-hr estimate by the fact that feed levels remained constant while the cows were on drylot during the 3 days of the test throughout the 56 days of the experiment and that milk production was directly influenced by feed levels. The latter explanation would seem inprobable since a carryover effect from previous feedings should influence milk production and if production were directly influenced by the daily ration, then the 4-hr estimate should also exhibit this effect.

TABLE 5.7. LEAST SQUARES ANALYSIS OF VARIANCE FOR MILK PRODUCTION AND CALF ADG (FINAL MODEL)

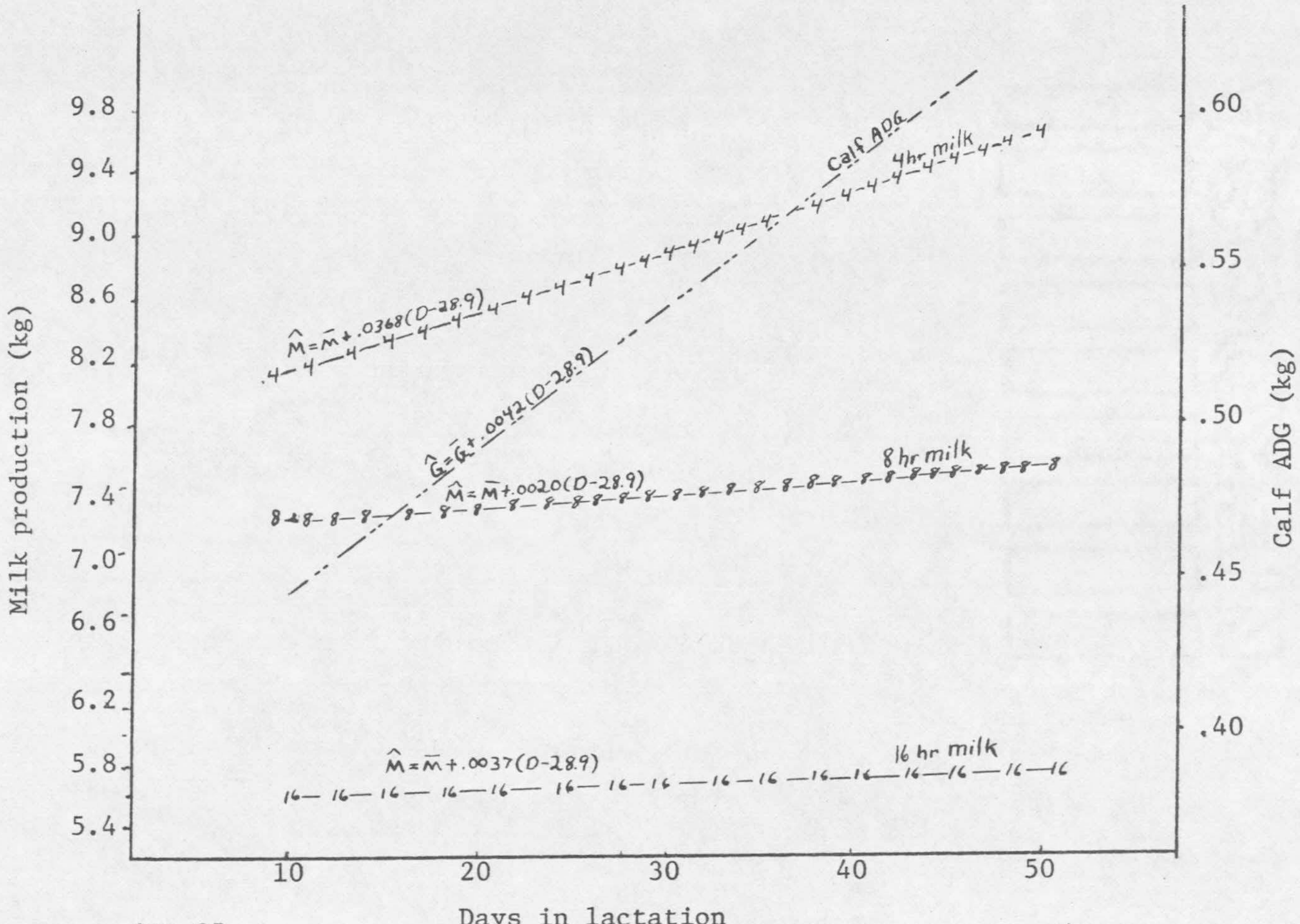
		Mean squares of traits			
Source	df	4-hr milk (kg)	8-yr milk (kg)	16-hr milk (kg)	Calf ADG (kg/day)
Year	1	.83	.66	1.73	1.21**
Age	2	135.72**	112.53**	74.16**	1.17**
Day in lactation linear	1	68.54**	.16	.66	.90**
Condition score linear	1	14.56	2.05	3.86	.04
Residual		7.92	4.01	1.60	.04

**P<.01.

TABLE 5.8. LEAST SQUARES MEANS BY YEARS AND AGES FOR 4-HR, 8-HR, 16-HR MILK PRODUCTION ESTIMATES AND CALF ADG

	Traits			
	4-hr milk (kg)	8-hr milk (kg)	16-hr milk (kg)	Calf ADG (kg/day)
Years				
1975	8.93±.26	7.37±.18	5.85±.12	.46±.018[a]
1976	8.80±.29	7.48±.21	5.67±.13	.61±.021[b]
Ages				
2-yr-old	7.18±.41[a]	6.08±.29[a]	4.63±.18[a]	.42±.029[a]
3-yr-old	9.26±.31[b]	7.40±.22[b]	5.81±.14[b]	.50±.022[b]
Mature	10.17±.31[b]	8.78±.22[c]	6.84±.14[c]	.68±.022[c]

[abc]Means/variable by traits with different superscript differ significantly ($P<.05$).



*P<.05

Figure 6. Linear regression of production traits on days in lactation.

Average daily gain of the calves increased significantly as they grew older. The regression line was defined by $\hat{G}=\bar{G}+.0042\,x$ where $x=$ days in lactation -28.9. This was expected because gain should follow milk production and if milk production actually increased as the 4-hr estimate indicated, then ADG would also increase. Also, as a calf gets older, it can supplement its diet from forage sources.

Regression of milk production on condition score (Figure 7) was not a significant effect although it approached significance. The regression coefficients for milk production was positive indicating that milk production increased with improvement in condition. This initially appears to be contradictory to reports by Singh *et al.*, 1970; England *et al.*, 1961 and Hohenboken *et al.*, 1973 who show antagonism between milk production and weight gain. This discrepancy may be due to the fact that factors affecting condition in early lactation were different from those in late lactation. Cows in poor condition in late lactation were thought to be concentrating their resources on milk production. Cows in poor condition during early lactation were often cows which have been subjected to stress during calving or have other health problems and were consequently lower milk producers.

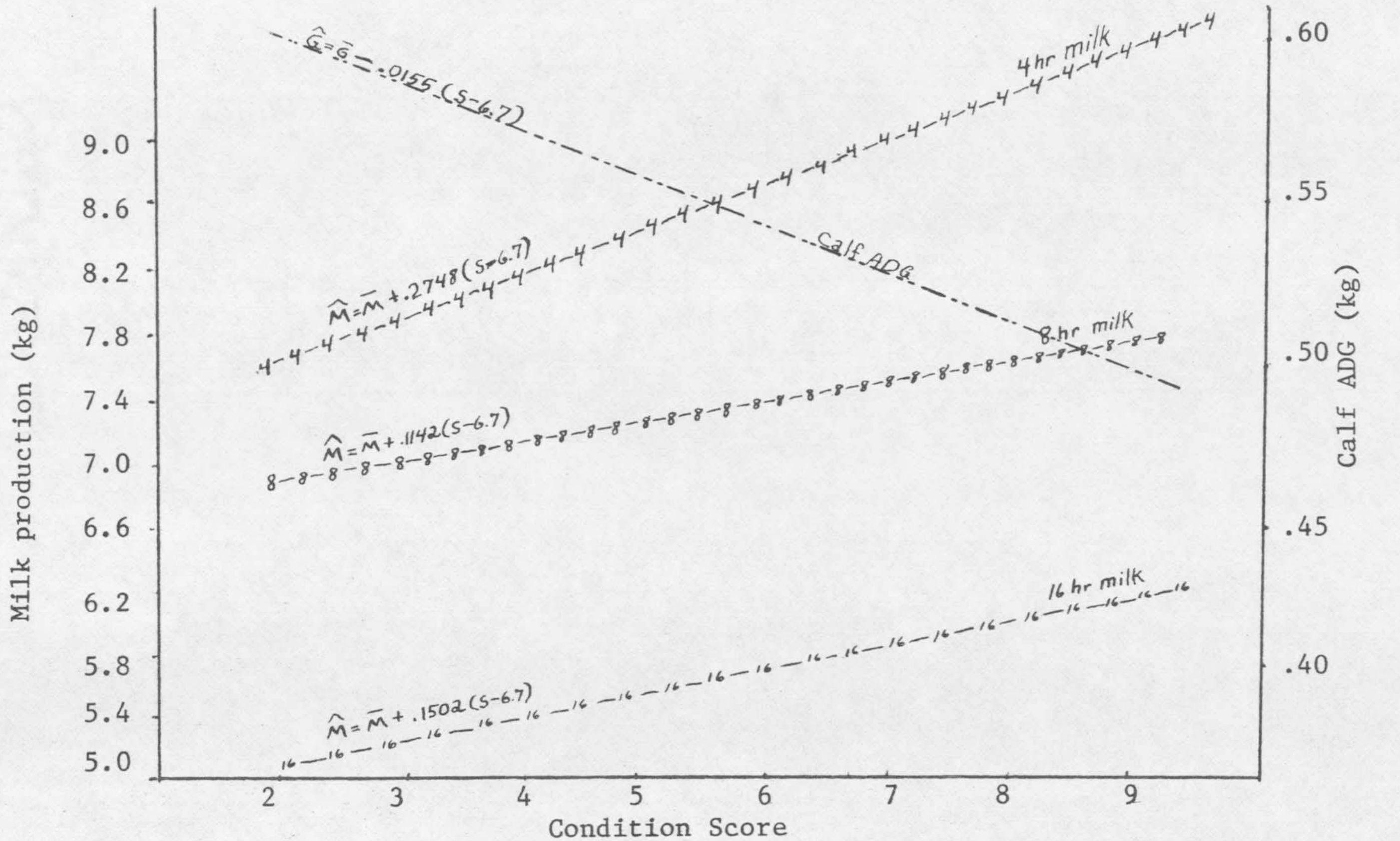


Figure 7. Linear regression of milk production traits on condition score.

The negative regression coefficient is harder to explain for the regression of average daily gain on condition score. This may be a completely nonsignificant regression, or it could be explained by calves on cows in poorer condition compensated by being more efficient converters of milk to gain or because they started foraging earlier.

Correlations among the dependent variables using the present model (table 5.7) are given in table 5.6. Withers height was determined to be correlated with all physical traits, with correlations for hip height, weight and weight:hip height ratio, respectively, at .85, .63 and .39. Withers height and hip height were expected to be correlated because both are measures of height. As height increases, the larger frame will support more weight, thereby causing a positive correlation. The positive correlations between withers height and the weight:height ratios means that tall cows are more likely to be proportionally "fatter" than shorter cows. The positive correlation between hip height and the weight:height ratio also supports this hypothesis.

The .94 correlations between weight and the weight:height ratios indicates that as a weight increases the cow becomes proportionally "fatter". Comparing the correlations with height and weight indicates that weight is much more influential in determining the weight:height ratio than height since weight varied much more than height.

All estimates of milk production were postively correlated as would be expected since cows producing more milk in the 4-hr estimate should also produce more milk at the 8-hr and 16-hr estimate. Calves on cows producing more milk should have better gains than calves on lower producing cows. The correlations of .51 between the 8-hr and 16-hr estimate was higher than the .36 and .38 between the 4-hr and 8-hr and 16-hr, respectively. The higher correlation between the longer separation estimates may mean that the 4-hr separation was measured with more error.

Average daily gain of the calf should be an accurate indicator of milk production since calves early in the lactation period are not able to utilize forage very efficiently. The correlation between milk production and ADG to weaning has been reported as high as .91 with cows on a high level of nutrition in drylot by Furr and Nelson (1969). Other reports (Christian _et al_., 1965; Gleddie and Berg, 1968; Holmes _et al_., 1968; Neville _et al_., 1962 and Pope _et al_., 1963) indicate the correlation is between .6 and .85, Christian _et al_. (1965) reported a correlation of .48 between milk production and ADG for the first 60 days. The present study indicated correlations between ADG and the 4-hr, 8-hr and 16 hr production estimates, respectively, were .27, .46 and .46. The higher correlations for the longer separation intervals may indicate that they more accurately reflect actual milk production than the 4-hr separation interval.

None of the physical traits were significantly correlated with milk production.

From the available data it can be concluded that high producing cows cannot be selected by the use of physical traits and that the best method of indirectly estimating milk production comes from comparison of calf ADG. The 8-hr estimate indicated that an average of 16.8 kg of milk were required per kg of gain in 1975 while 12.3 kg was needed in 1976. These efficiency figures are in agreement with the 12.5 kg milk/kg gain reported by Drewry et al. (1959) at one month; however, they are lower than the 7.1 kg/kg gain for Hereford calves at one month reported by Gifford (1953). The regression on days in lactation (Figure 6) indicates that efficiency of gain as determined by kg of milk required per kg gain, increases with time for the 4-, 8- and 16-hr estimates. Forage utilization was not separated from milk utilization in determining efficiency. Gifford (1953), Drewry et al. (1959) and Klett (1962) have shown that efficiency increases from the first to the second month.

When comparing the 4-hr, 8-hr and 16-hr separation intervals, the factors discussed with this chapter tend to give more credence to the 8-hr and 16-hr interval than the 4-hr interval as estimates of milk production. When the natural interval of 3- to 8-hr is considered as reported in the following chapter, the 16-hr interval appears to be too long to be acceptable for this stage of lactation. Due to the correlation with ADG, the 8-hr interval appears to be the most appropriate of the three. A compromise between the 4-hr and 8-hr interval (6-hr) would perhaps be more acceptable and would better fit the 8-hr work day of government institutions.

An area that needs additional investigation is the suitability of the multiplicative factors used to adjust the milk from different separation intervals to 24-hr production. Twenty-four hour production may not be appropriate when calves limit nursing activity to the daylight hours as is discussed in the following chapter.

Means by ages for physical traits measured are given in Appendix table 12.

CHAPTER 6

NURSING BEHAVIOR

Introduction

In order to determine the most appropriate separation interval to be used in milk production estimates, it is necessary to make a comparison with the interval that normally occurs between nursings with cows and calves in natural surroundings.

The objectives of this study were to 1) determine the normal interval between nursing activity in a natural environment, 2) determine periods of most active nursing activity, 3) determine the amount of time spent nursing under natural conditions and 4) to determine correlations between nursing habits and milk production.

Materials and Methods

A group of 10 Hereford cows with Hereford sired calves were observed for two continuous 48-hr periods at 3 and 7 weeks after calving. The cows ranged from 3 to 8 years of age and their calves were born between March 26 and 30, 1976. The observation periods were planned in conjunction with a full moon, but weather patterns reduced the incidence of natural moonlight.

During the first observation period at 3 weeks after calving, the animals were observed in an 8.1 ha pasture of which 4.5 ha was seeded to grass so that no supplemental feed was needed. The cows were identified by number brands and the calves were number branded with aluminum paint. Observations were made from a truck with the aid of binoculars. Fresh straw was scattered to attract the cows to a single bed ground at night to make observation easier. A spotlight was used to assist with identification at night.

The second observation was conducted 4 weeks after the first observation. The cows were confined in a 2.0 ha pasture during this 48-hr period and were fed hay and silage in addition to the available pasture on both days.

The time and duration of any suckling activity was recorded. Milk production estimates were taken within one week of the observation, using the weigh-suckle-weigh technique with an 8-hr separation interval. Originally, milk production was not included in the design, however, since milk production estimates were being made concurrently on these cows, estimates on all but three cows during the first observation were suitable for analysis.

Data were analyzed according to least squares procedures (Harvey, 1975) and the model included age of cow (3, 4 and mature) and observation period. The dependent variables were number of times nursed, total time spent nursing during the 48-hr period, average time taken for each nursing and 24-hr milk production.

Results and Discussion

The analysis of variance (table 6.1) indicated that age of dam significantly affected the amount of time spent nursing and that observation period, which reflected calf age and stage of lactation,

TABLE 6.1. LEAST SQUARES ANALYSES OF VARIANCE FOR NURSING TRAITS

		Mean squares of traits			
Source	df	No. times nursed	Total time nursing (min)	Nursing time (min)	Milk[a] production (kg)
Age of dam	2	1.03	262	8.53*	.11
Period	1	2.45	3519**	36.72**	.64
Residual	16	1.82	338	2.26	5.13

[a] Milk production degrees of freedom for esidual were 13 because not all cows had milk production data at the first observation period.
*P<.05.
**P<.01.

was a highly significant source of variation for both average and and total time spent nursing. Neither source of variation significantly affected milk production or number of times nursed. Although a great deal of variation appeared to occur in each trait (table 6.2), the coefficients of variation for times nursed, average nursing time, total nursing time and milk production were 4.8%, 3.1%, 5.7% and 8.2%, respectively. These are all within an acceptable range.

The least squares means for average nursing time decreased significantly (table 6.3) from 12.8 min for the 3-year-olds to 11.2 min for the 4-year-old group to 10.3 min for the 6- to 8-year-old cows included in the mature group. This may have been due to the fact that young cows usually have smaller, less agressive calves or it may be

TABLE 6.2 DATA FOR NURSING TRAITS

Age of dam	Times nursed 48-hr	Avg nursing time (min)	Total time nursed (min)	24-hr[a] milk prod. (kg)	Times nursed 48-hr	Avg nursing time (min)	Total time nursed (min)	24-hr milk prod. (kg)
3	5	15.7	78.5	8.9	7	8.7	60.9	6.8
3	7	14.0	98.0		6	12.7	76.2	9.1
4	8	11.3	90.4	7.5	7	7.8	54.6	9.5
4	6	12.7	76.2	8.9	6	10.3	61.8	12.3
4	9	14.6	131.4	4.8	7	10.5	73.5	5.4
6	5	9.3	46.5	10.9	6	8.4	50.4	7.5
6	7	11.6	81.2	6.1	5	9.0	45.0	6.1
7	7	11.0	77.0		6	9.2	55.2	7.3
8	8	13.0	104.0		5	11.3	56.5	7.5
8	9	11.2	100.8	10.9	9	9.4	84.6	7.5
Least squares means	7.1	12.8	89.9	8.3	6.4	10.1	63.3	7.9
Standard error	.44	.49	6.02	.89	.44	.49	6.02	1.15

[a]Twenty-four hr milk production taken from 8-hr separation using wiegh-suckle-weigh technique.

TABLE 6.3. LEAST SQUARES MEANS FOR NURSING TRAITS

	Age of Dam		
	3	4	Mature
Avg nursing time (min)	$12.8\pm^{a}.75$	$11.2\pm^{ab}.61$	$10.3\pm^{b}.48$

	Period	
	Observation 1	Observation 2
Times nursed during 48 hr	7.1± .44	6.4± .44
Avg nursing time (min)	12.8± .49	10.1± .49
Total time nursed (min)	89.9±6.0	63.3±6.0
24-hr milk production (kg)	8.3± .89	7.9±1.15

abcMeans with different superscripts differ significantly ($P<.05$).

that younger cows with smaller, less developed mammary systems are harder to nurse.

The significant decrease in average nursing time and total time spent nursing from 3 to 7 weeks may be attributed to larger, stronger calves nursing faster.

The average number of times nursed during the first 48-hr period was 7.1 compared to 6.4 times for the same group of cows and calves four weeks later. Although this difference was nonsignificant, the trend suggested that as a calf gets older, its capacity to store milk increases and it nurses less often. When put on a 24-hr basis, these figures were 3.5 and 3.2 times, respectively, which were in general agreement with Walker (1962) who reported that the majority of calves nursed 3 to 5 times per 24-hr period. Drewry et al. (1959) reported the average to be 4.6, 4.8 and 3.0 times during 24 hr at the first, third and sixth month, respectively, Hutcheson *et al*. (1962) has shown that with Zebu cattle there was little variation from the average nursing time of 9.2 min, but the frequency of nursing decreased from 9.5 times per day during the first month to 5.6 times at six months. Table 6.4 shows the correlations among dependent variables. The small number of observations limit conclusions. However, the fact that all correlations were small, with the exception of the significant correlations between total time nursed and average nursing time and number of times nursed, which were both factors of the total times nursed, suggested that no close relationships existed among these traits. This work agrees with correlations reported by Drewry *et al*. (1959) of .74 between times nursed and total nursing time, -.30 between number of times nursed and milk production and -.40 between number of times nursed and total nursing time. The very small correlation between the number of times nursed and the time spent nursing was indicative of the inconsistency in the habits of the calves, with some calves nursing frequently and for long periods of time, while other calves nursed less frequently but also nursed for long periods of time. The negative relationship between nursing time and milk production was expected because a calf that has less milk available will spend more time nursing in an effort to satisfy hunger. The same explanation can be applied to the negative relationship between number of

TABLE 6.4. RESIDEUAL CORRELATIONS AMONG NURSING TRAITS

Traits	Correlation[a]
Times nursed-nursing time	-.02
Times nursed-total time nursed	.82**
Times nursed-milk production	-.24
Nursing time-total time nursed	.53*
Nursing time-milk production	-.25
Total time nursed-milk production	-.39

[a]Degrees of freedom were 13 for correlations involving milk production and were 16 for all other traits.
* P<.05.
**P<.01.

times nursed and milk production.

During the second observation period, the calves nursed an average of 2.4 times the first day and 4.0 times the second day. This inconsistency between days could be attributed to the small pasture and the fact that most of the succulent new growth was grazed off during the first day; consequently, the calves grazed very little the second day. With no interest in grazing and with their mothers near, the calves sought them out more often to nurse. This leads to speculation that pasture size may be a factor in number of times nursed.

During both observation periods, the greatest nursing activity occurred just as it began to get light in the morning and just prior to darkness in the evening. Little regularity was observed during the day with nursing during the first observation initiated when the cow found it convenient to quit grazing and seek out her calf. During the second period, the calves seemed to take the initiative to find their dams when they became hungry.

Nursing at night was negligible, although calves may stand to change positions or a cow may stand to change positions or to graze. This is consistent with work reported by Drewry _et al_. (1959) but conflicts with Hutcheson _et al_. (1962) who reported that Zebu cattle confined at night in a lighted lot, spread nursing activity evenly over a 24-hr period during the first two months, but during later months, nighttime nursing became more prevalent.

The available data indicated that calves in their natural environment have a 3- to 8-hr interval between nursings. The average number of times nursed, in early lactation, during a period of 14 to 16 hr of daylight, (3.2 and 3.5) suggested an average separation time of about 4.5 hr.

CHAPTER 7

SUMMARY

Milk production estimates and height, weight and condition measurements were made on 117 Hereford cows during two periods of the first 50 days of lactation. Investigations were carried out at the Northern Agricultural Research Center, Havre, during April and May of 1975 and 1976.

Milk production was estimated using the weigh-suckle-weigh technique with 4-hr, 8-hr and 16-hr separation intervals in a latin square design. Least squares procedures with a model including years, squares/year, cows/square/year, separation interval, day of separation, period, year x treatment interaction and day x period interaction were used for the analysis. All effects were significant with the exception of year. Treatment means for the 4-hr, 8-hr and 16-hr intervals, respectively, were 9.16 kg, 7.61 kg and 5.94 kg. Each mean was significantly different from the others.

In an effort to determine which treatment was most appropriate, least squares procedures were used with the model including years, cow ages and linear regressions on days in lactation and cow condition score. Cow age was a significant factor for all estimates of production which were 4-hr, 8-hr and 16-hr milk estimates adjusted to 24 hr and calf ADG. Similar feeding and management reduced the effect of years on milk production, but the wet snowy spring of 1975 may have stressed the calves enough to cause gain to be .46 kg compared to .61 kg in 1976. Regression on days in lactation was significant for 4-hr milk production and calf ADG with both increasing as days in lactation increased. Regression on condition score was not significant.

The correlations between ADG and the 4-hr, 8-hr and 16-hr production estimates, respectively, were .27, .46 and .46. The higher correlations for the longer separation intervals may indicate that they more accurately reflect actual milk production. Correlations between production traits and withers height, hip height, weight, $\frac{\text{weight}}{\text{withers height}}$ and $\frac{\text{weight}}{\text{hip height}}$ were not significant, indicating that milk production cannot be predicted by physical measurements.

Repeatability estimates for withers height and hip height, respectively, were .940 and .951. The respective coefficients of variation were 3.6% and 3.1%. The measurements were made in both periods and since growth would not have caused any measurable change in height between the two measurements then repeatability is measuring the accuracy of the measurements. These results suggest that neither measure has an advantage over the other as an estimate of height. Hip height measurement may be less time consuming than withers height measurement due to the fact that the cow usually stands quieter for measurements farther from her head.

Repeatabilities of the milk production estimates were .55, .61 and .79 for the 4-hr, 8-hr and 16-hr estimates, respectively. The higher repeatability for the 16-hr estimate may mean that it is measuring udder capacity rather than milk production.

A study of nursing intervals under natural conditions was also conducted. Data on nursing behavior on 10 Hereford cows and their Hereford sired calves were obtained during two 48-hr periods at 3 and 7 weeks after calving. The number of times nursed during 48 hr was 7.1 at 3 weeks and 6.4 at 7 weeks. These results suggested that as calves get older they tend to nurse less often as their capacity for milk increases and they can supplement their diet from other sources. The average time spent nursing was reduced from 12.8 to 10.1 min from the third week to the seventh week, which may have been due to larger calves being able to nurse faster. There was no signficiant correlations among milk production, times nursed and time spent nursing. The most active periods of nursing were just after break of day and just prior to darkness with negligible nursing at night.

When considering a proper separation interval for the weigh-suckle-weigh technique of estimating milk production, it is necessary to consider that calves in their natural environment nursed an average of 3.2 to 3.5 times per day during 14 to 16 hr of daylight in mid-spring. This suggests an average separation interval of about 4.5 hr.

Due to the fact that the 16-hr separation interval did not occur naturally, the often distended condition of the udder and speculations that lack of udder capacity limits full expression of milk production, it was decided that a 16-hr separation interval was not suitable for this stage of lactation.

In comparing the 4- and 8-hr intervals, it is necessary to consider that the 4-hr interval adjusted to a 24-hr basis magnifies any error twice as much. The higher correlation with calf ADG indicates that the 8-hr interval is perhaps the best estimate of the three. A compromise between 4- and 8-hr would perhaps be more appropriate and would better fit the schedule of an 8-hr workday.

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APPENDIX

APPENDIX TABLE 1. ANALYSIS OF VARIANCE FOR MILK PRODUCTION IN 1975 WITH TYPE INCLUDED

Source	df	Mean squares
Type	1	19.85
Squares/type	30	13.23**
Cow/square/type	64	11.02**
Treatment	2	279.29**
Days	2	23.99**
Period	1	16.14*
Type x treatment	2	3.58
Remainder	257	3.78

* P<.05.
**P<.01.

APPENDIX TABLE 2. ANALYSIS OF VARIANCE FOR MILK PRODUCTION IN 1976 WITH TYPE INCLUDED

Source	df	Mean squares
Type	1	.96
Squares/type	28	12.99
Cows/squares/type	60	8.26**
Treatment	2	319.54**
Days	2	4.79
Period	1	31.57**
Type x treatment	2	2.39
Remainder	236	2.75

**P<.01.

APPENDIX TABLE 3. ANALYSIS OF VARIANCE FOR MILK PRODUCTION 1975-1976 WITH TREATMENT X YEAR AND TREATMENT X PERIOD INTERACTION INCLUDED

Source	df	Mean squares
Year	1	9.73
Squares/year	37	22.25**
Cows/square/year	78	9.04**
Treatment	2	599.97**
Day	2	12.51*
Period	1	27.67**
Year x period	1	17.58*
Day x period	2	19.35*
Treatment x period	2	6.28
Treatment x day	2	1.95
Remainder	564	3.99

* $P<.05$.
**$P<.01$.

APPENDIX TABLE 4. LEAST SQUARES ANALYSIS OF VARIANCE FOR PRODUCTION TRAITS WITH YEAR, AGE AND CONDITION SCORE AS DISCRETE VARIABLES AND DAYS IN LACTATION, HIP HEIGHT AND WEIGHT AS COVARIATES

		Mean squares			
Source	df	4-hr milk production (kg)	8-hr milk production (kg)	16-hr milk production (kg)	Calf ADG (kg)
Year	1	.61	.73	5.50	.79**
Age	2	46.56**	36.06**	26.24**	.38**
Score	6	3.37	2.33	3.53	.14**
Days in lact					
linear	1	69.17**	.26	.36	.94**
Hip height					
linear	1	.06	.12	2.39	.01
quad	1	15.24	3.98	1.77	.04
Weight					
linear	1	.37	.11	.71	.001
quad	1	1.36	3.23	8.99*	.03
Residual	218	8.11	4.09	1.53	.04

**P<.01.
*P<.05.

APPENDIX TABLE 5. LEAST SQUARES ANALYSIS OF VARIANCE FOR PRODUCTION TRAITS COMPARING CONDITION SCORE WITH WEIGHT AS INDICATORS OF CONDITION

		Mean squares							
		4 hr milk production (kg)		8 hr milk production (kg)		16 hr milk production (kg)		calf ADG (kg/day)	
Source	df	Score[a]	Weight[b]	Score	Weight	Score	Weight	Score	Weight
Years	1	.82	.00	.82	.62	2.05	1.69	1.17**	1.03**
Ages	2	111.99**	41.69*	83.58**	39.93**	63.93**	23.78**	.93**	.56**
Days in lactation linear	1	68.50**	71.67**	.19	.19	.56	.39	.89**	.87**
Hip height linear	1	.59	.52	.10	.02	1.07	3.59	.01	.002
Condition linear	1	6.49	7.17	3.14	.29	3.61	3.59	.007	.007
quad	1	3.73	2.02	1.90	.71	.008	2.76	.03	.001
Residual	224	7.98	8.02	4.04	4.05	1.61	1.58	.04	.04

ab Condition score and weight were included separately in the model as estimates of cow condition.
**P<.01.
*P<.05.

APPENDIX TABLE 6. LEAST SQUARES ANALYSIS OF VARIANCE INCLUDING WEIGHT: HIP HEIGHT RATIO AS A DISCRETE VARIABLE

		Mean squares			
Source	df	4 hr milk (kg)	8 hr milk (kg)	16 hr milk (kg)	calf ADG (kg/day)
Years	1	.01	.32	1.02	1.15**
Ages	2	43.88**	56.74**	31.11**	.58**
Weight					
Hip height	2	19.69	.56	.63	.02
Days in lactation					
linear	1	74.23**	.48	1.63	1.03**
quad	1	2.36	.13	1.06	.15*
Residual	224	7.89	4.05	1.07	.04

**P<.01.
*P<.05.

APPENDIX TABLE 7. LEAST SQUARES ANALYSIS OF VARIANCE INCLUDING CONDITION SCORE AS A DISCRETE VARIABLE

		Mean squares			
Source	df	4 hr milk (kg)	8 hr milk (kg)	16 hr milk (kg)	calf ADG (kg/day)
Years	1	.58	.62	2.48	1.17**
Ages	2	129.10**	90.08	69.02**	.90**
Score	5	4.52	2.58	3.05	.14*
Days in lactation					
linear	1	68.51**	.53	1.34	1.13**
quad	1	1.52	.35	1.15	.16*
Residual	221	8.07	4.06	1.58	.04

**P<.01.
*P<.05.

APPENDIX TABLE 8. LEAST SQUARES ANALYSES OF VARIANCE WITH COW CONDITION IN THE MODEL COMPARING CONDITION SCORE AND WEIGHT:HIP HEIGHT RATIO AS ESTIMATES OF CONDITION

		4 hr milk production (kg)		8 hr milk production (kg)		16 hr milk production (kg)		calf ADG (kg/day)	
Source	df	Score[a]	Ratio[b]	Score	Ratio	Score	Ratio	Score	Ratio
Years	1	.27	.006	.83	1.31	.97	.19	1.35**	1.24**
Ages	2	136.65**	53.01*	112.65**	40.07**	74.65**	21.07**	1.19**	.50**
Days in lactation									
linear	1	69.48**	72.77**	.27	.33	1.19	1.27	1.04**	1.02**
quad	1	1.95	2.36	.25	.33	1.22	1.63	.15*	.15*
Condiation									
linear	1	14.94	7.22	2.11	1.39	4.02	5.62	.03	.008
Residual	225	7.96	7.99	4.03	4.03	1.60	1.59	.04	.04

[ab] Condition score and weight:hip height ratio were included separately as estimates of cow condition.
**P<.01.
*P<.05.

APPENDIX TABLE 9. LEAST SQUARES ANALYSIS OF VARIANCE INCLUDING LINEAR AND QUADRATIC REGRESSIONS ON CONDITION SCORE AND DAYS IN LACTATION

		Mean squares of traits			
Source	df	4 hr milk (kg)	8 hr milk (kg)	16 hr milk (kg)	calf ADG (kg/day)
Years	1	.40	1.07	1.05	1.40**
Ages	2	132.19**	94.69**	67.35**	.93**
Days in lactation					
linear	1	67.17**	.40	1.17	1.05**
quad	1	1.5	.45	1.12	.18
Condition score					
linear	1	7.60	3.85	3.26	.006
quad	1	2.29	1.95	.01	.054
Residual	224	7.97	4.04	1.60	.039

**P<.01.

APPENDIX TABLE 10. LEAST SQUARES ANALYSIS OF VARIANCE FOR CONDITION SCORE AND WEIGHT: HEIGHT RATIO

		Mean squares	
Source	df	Condition score	Weight:height (hip)
Year	1	.003	.75**
Age	2	11.72**	15.50**
Days in lactation			
linear	1	1.67	.13
Residual	227	.78	.08

**P<.01.

APPENDIX TABLE 11. RESIDUAL CORRELATIONS AMONG PHYSICAL MEASUREMENTS AND CALF ADG

Variable	Symbol	B	C	D	E	F	G	H	I
Weight	A	.99**	.95**	.96**	.93**	.62**	.60**	.56**	-.05
Metabolic size	B		.95**	.95**	.93**	.62**	.60**	.56**	-.05
Weight / Hip ht	C			.98**	1.00**	.36**	.39**	.59**	-.04
Weight / Withers ht	D				.98**	.42**	.34**	.60**	-.08
Metabolic size / Hip ht	E					.25**	.31**	.61**	-.04
Hip ht	F						.85**	.18**	-.04
Withers ht	G							.15**	.06
Cond score	H								-.07
Calf ADG	I								

**P<.01.
*P<.05.

APPENDIX TABLE 12. LEAST SQUARES MEANS BY AGES FOR PHYSICAL TRAITS

Variable	2-yr-old cows	3-yr-old cows	Mature cows
Withers height (cm)	116.02[a]±.48	121.58[b]±.36	122.98[c]±.37
Hip height (cm)	123.10[a]±.51	127.09[b]±.39	127.10[b]±.39
Weight (kg)	392.78[a]±5.01	445.98[b]±3.79	507.96[c]±3.85
$\frac{\text{Weight}}{\text{Withers height}}$	3.39[a]±.03	3.67[b]±.03	4.13[c]±.03
$\frac{\text{Weight}}{\text{Hip weight}}$	3.19[a]±.03	3.51[b]±.02	4.00[c]±.02
Metabolic size	88.15[a]±.81	96.96[b]±.61	106.86[c]±.62

[abc]Means/variable with different superscripts differ significantly ($P<.05$).

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