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Reasons Why Cows Were Removed From the SDSU Fairy Herd 1. Discriminant Analysis to Classify Cows with or without Reproductive Problems

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REASONS WHY COWS WERE REMOVED FROM THE SDSU DAIRY HERD.

1. DISCRIMINANT ANALYSIS TO CLASSIFY COWS WITH OR WITHOUT REPRODUCTIVE PROBLEMS

BY

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

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TABLE OF CONTENTS

Page

INTRODUCTION 1

LITERATURE REVIEW 4

Importance of dairy cow removal 4

Reproductive efficiency and problems 15

Reproductive studies during the 1950's 16

Reproductive studies during the 1960's 16

Reproductive studies during the 1970's 19

MATERIALS AND METHODS 30

Source of experimental data 30

Herd removal data 30

Reproductive problem data 30

Clarification of terms. 31

Yield of 305-ME milk and fat 31

Type score 31

Reproductive problems 31

Groups for analysis 32

Sample group 1 32

Sample group 2 32

Sample group 3 33

Sample group 4 33

Statistical analysis 33

RESULTS AND DISCUSSION 36

Cow removal rate 36

TABLE OF CONTENTS
(continued)

Page

Reproductive problems 36

Type related problems 38

Mastitis problems 41

Low production 41

Other problems 42

Sample group 1 42

Sample group 2 45

Sample group 3 47

Sample group 4 49

SUMMARY 51

REFERENCES 55

APPENDIX 60

LIST OF TABLES

TABLE		Page
1	Summary of research on dairy cow disposals in DHIA herds	6
2	Summary of research on dairy cow disposals in research herds	7
3	Reasons why Holstein cows were removed from the South Dakota State University dairy research herd . .	37
4	Breakdown of type related reasons of removal	40
5	Summary of stepwise discriminant analysis for sample group 1	44
6	Summary of stepwise discriminant analysis for sample group 2	46
7	Summary of stepwise discriminant analysis for sample group 3	48
8	Summary of stepwise discriminant analysis for sample group 4	50

LIST OF APPENDIX TABLES

TABLE		Page
1	Group means, standard deviations, and grand means for 8 variables in sample group 1	61
2	Within groups correlation matrix for sample group 1 .	62
3	Group means, standard deviations, and grand means for 7 variables in sample group 2	63
4	Within groups correlation matrix for sample group 2 .	64
5	Group means, standard deviations, and grand means for 8 variables in sample group 3	65
6	Within groups correlation matrix for sample group 3 .	66
7	Group means, standard deviations, and grand means for 7 variables in sample group 4	67
8	Within groups correlation matrix for sample group 4 .	68

INTRODUCTION

One of the keys to financial success in the dairy business is the ability of management to detect herd problems and correct them instead of culling cows. It is well known that the average productive life of the dairy cow is less than 4 yr, which is short compared with her potential life. Involuntary removal of cows causes economic loss directly as a result of its effect on yearly milk production, increased replacement cost, and indirectly because the potential selection differential is reduced with premature loss of high producing cows.

The degree of culling is related to important economic considerations such as the prices of milk and beef, as well as the prices of feed, and the cost and availability of labor. Studies on the disposal rates of cows from Dairy Herd Improvement Association (DHIA) and research herds have shown that a large portion of the cull cows were removed because of low production, reproductive problems, mastitis, sold for dairy purposes, and type related problems.

Dairymen have indicated that low fertility is their number one herd problem despite the fact that there is no known infectious disease problem. Reproductive problems accounted for the largest amount of involuntary losses in studies of disposal rates of cows from DHIA and research herds. Reproductive failure in dairy cattle causes economic loss directly as a result of its adverse effect on yearly milk production and on surplus calves for sale, and indirectly because the potential selection differential is reduced with fewer replacements.

Infertility in cows appears to be primarily a management problem. Heritability of breeding efficiency is low, thus, selection for breeding efficiency would not be effective and would be at the expense of other traits of economic importance which show a greater response to selection. Researchers have suggested that any effective evaluation of genetic differences for breeding efficiency among cows must await the development of new criteria. These tests should be simple and easily applied on a widespread basis.

Most production variables considered in sire selection have medium to high repeatability and heritability estimates. Young sires are evaluated on first-lactation performance of this progeny, and any relationship with later performance of length of herd life would have an important bearing on the evaluations. Selection of highly productive cows without conscious emphasis on fertility will not lead to a population with markedly altered ability to reproduce.

The reasons why cows were removed from the South Dakota State University dairy research herd were examined in this study. The results will serve as a guide for herdsmen and researchers to technical problems of management, breeding, and of disease on dairy farms. This study also examined the use of stepwise discriminant analysis to identify those cows with or without reproductive problems using the following selected discriminator variables: lactation number, yield of 305-ME milk, yield of 305-ME milk fat, age adjusted type score, difference from herdmates-milk, difference from herdmates-milk fat, percent protein-lactose-minerals (PLM), and yield of PLM. This analysis was also used to find a reduced set of discriminator variables.

LITERATURE REVIEW

Importance of dairy cow removal

The frequency of various reasons for disposal of cows provide timely information concerning management and disease problems on dairy farms. Reviewing studies in this area enable us to enumerate major problem areas that warrant further study.

There were few studies of reasons for disposal of dairy cows in the United States before the 1960 era. In 1940, Seath (48) reported reasons for culling from 37 Kansas Cow Testing Association herds. For 1,264 cull cows, the reason why each cow left the herd was reported by the herd owner to the testing supervisor each month. The reasons and percent of total culled cows were: dairy purposes, 26.1; low production for beef, 23.4; Bang's disease, 13.3; udder trouble, 10.5; sterility, 7.3; died, 6.6; old age, 4.8; reasons unknown, 4.0; accidents, 2.4; miscellaneous diseases, 0.8; tubercullosis, 0.6; and miscellaneous reasons, 0.2.

Asdell (4) in 1951 analyzed extensive cow testing data and reported on culling trends for the period from 1932 to 1949. Data from 17 states and 2,792,188 cows were shown as percentages of total cows on test for states, by years and, where possible, by age groups. He revealed a turnover of about one-fifth of Dairy Herd Improvement Association (DHIA) cows each year, but since those sold for dairy purposes, 5.1%, were not lost to the industry, the net loss of cows on test each year was 16.8%. This level of culling is lower than the 30.9% reported by Seath (48). He concluded that the loss of cows varied from year to year and the main cause of this variation was in the number of cows culled for low production. He suggested that the number of cows culled for low production was a reflection of economic conditions. He also pointed out that culling for sterility was rising steadily and it was then the major reason for culling after low production.

Summarizations of research on dairy cow disposal patterns were numerous in the 1960 era. Disposal patterns of DHIA and research herds are listed in Tables 1 and 2, respectively.

One study, Specht and McGilliard (53) reported the causes of removal as the percentage of cows removed annually from 269 Michigan Holstein DHIA herds during a 3 yr period. Their annual removals for all reasons averaged 26.3%. Percent of cows removed for various reasons were: low production, 36.6; sterility, 15.7; dairy purposes, 15.6; physical injury, 10.2; mastitis, 7.4; death, 6.0; tuberculosis, 3.3; brucellosis, 2.7; and hard milker, 2.5. They also concluded that during the first four lactations one-tenth of the removals were involuntarily with one-fourth involuntary removal in later lactations.

Parker et al. (42) reported on disposal records from a research herd in which no cullings were made for low production or poor type during the 40 yr period of 1919 to 1958. Disposal records were from heifers that had been bred and from the milking cow herd. They reported that 41.3% and 21.3% of the Holsteins and Jerseys, respectively, were removed from the herd as nonbreeders. Cow removal because of udder troubles constituted the second largest group of

TABLE 1. Summary of research on dairy cow disposals[a] in DHIA herds.

Reasons for disposal	Reference									
	48	53	57	37	8	12[b]	56	46	3	25
No. of cows	1,264	--	7,317	27,611	--	19,336	3,475	--	--	3,046
No. of herds	37	269	--	--[c]	2,534	--	188	--[c]	--[c]	42
Low production, %	23.4	36.6	36.9	52.1	14.8	15.5	32.0	54.8	46.9	24.9
Reproduction, %	7.3	15.7	15.7	16.6	22.8	20.8	27.0	16.3	24.2	22.8
Sold dairy, %	26.1	15.6	9.7	9.1	27.0	23.6	--	8.3	6.1	5.8
Mastitis, %	10.5	7.4	5.8	5.5	--	--	22.0	4.9	9.7	9.0
Died, %	6.6	6.0	2.9	4.5	9.5	12.1	--	5.1	5.4	--
Type, %	--	--	13.5	--	13.2	13.4	3.0	--	--	9.9
Injury, %	2.4	10.2	4.7	7.0	--	--	--	6.1	7.7	4.3
Bang's, %	13.3	2.7	0.1	0.2	--	--	--	0.15	--	--
Tubercullosis, %	0.6	3.3	0.4	--	--	--	--	--	--	--
Misc. diseases, %	0.8	--	--	0.7	--	6.9	8.0	0.7	--	8.0
Misc. reasons, %	9.0	2.5	10.4	4.3	12.7	7.9	8.0	3.4	--	14.3

[a]Reported as a percentage of the total cows culled.

[b]Includes only data for Holsteins from this study.

[c]Data from DHIA annual summarization of an entire state.

TABLE 2. Summary of research on dairy cow disposal[a] in research herds.

Reasons for disposal	Reference			
	42[b]	17[c]	29	1
No. of cows	409	2,297	1,762	7,813
No. of herds	1	1	7	12
Low production, %	--	17.1	23.4	19.0
Reproduction, %	41.3	23.5	32.0	34.0
Sold dairy, %	--	--	13.1	--
Mastitis, %	10.5	13.8	8.4	13.0
Died, %	10.3	--	1.9	--
Type, %	--	--	7.1	11.0
Injury, %	1.1	--	2.9	--
Bang's, %	3.2	--	--	--
Tubercullosis, %	15.2	--	--	--
Misc. diseases	11.8	--	--	11.0
Misc. reasons	6.6	--	11.4	6.0

[a]Reported as a percentage of the total cows culled.

[b]Includes only data for Holsteins from this study.

[c]Excluding cows sold for dairy purposes.

reasons for disposal, with percentages being 10.5 and 9.6 for the two breeds, respectively. Longevity of individual cows was measured in terms of age at last calving prior to disposal. The average age at disposal was 5.7 years in the Holstein herd and 5.4 in the Jersey herd. Their results were influenced by a tubercullosis outbreak early in the study.

In 1962, O'Bleness and Van Vleck (39) conducted a mail survey over a 6 month period of New York DHIA herds. They reported that the chief reasons for disposal were low production, 27 to 32%; sold for sterility, 16 to 19%; dairy purposes, 14 to 15%; and udder dificulities, 14 to 20%. Brucellosis and tuberculosis reactions were relatively unimportant, each accounting for about 1% of the reasons for disposal. Culling for undesirable dairy type was not very intense, since only 2 to 4% of the cows were disposed of for this reason. They also concluded that since only a part of a calendar year was included in the survey, their results may not be representative of the remainder of the year. They also warned that significant differences were found between the two reporting sheets which were used which cast doubt on the validity of the survey.

In a 1964 study, Evans et al. (17) reported the principal reasons for disposal of females from the Louisiana Research Holstein herd during the period of 1927 to 1961. When cows sold for dairy purposes were excluded principal reasons for disposal included nonbreeders, 23.5%; low production, 17.1%; and mastitis and udder problems, 13.8%. Their reported averages of age at disposal and length of productive life were 6.9 and 4.2 years, respectively. The average number of lactations initiated was 3.73.

White and Nichols (57) reported in 1965 the following disposal reasons: low production, 36.9%; sterility, 15.7%; udder troubles, 13.5%; other reasons, 9.8%; dairy purposes, 9.7%; mastitis, 5.8%; injury, 4.7%; old age, 0.6%; tuberculosis, 0.4%; brucellosis, 0.1%; and died, 2.9%. Their data were from 7,317 Holstein cows on DHIA in Pennsylvania, and disposal reasons were obtained by the testing supervisor at the time of removal. Chi-square of contingency test for age-specific disposal rates showed that there was a relationship between the cow's age and the reason for her disposal. Low production was a major reason for disposal and was more important for young cows. Udder trouble and mastitis were major problems as age increased. Sterility was a major problem, but affected all age groups equally.

Meadows (37) reported in 1968 the disposal records from Michigan DHIA herds from 1963 to 1965. Reasons for disposal were low production, 52.1%; sterility, 16.6%; dairy purposes, 9.1%; physical injury, 7.0%; mastitis, 5.5%; old age, 2.3%; hard milker, 1.1%; temperament, 0.9%; hardware, 0.7%; brucellosis, 0.2%; and died, 4.5%. Sterility was by far the most important reason for involuntary losses. Sterility and low production appeared to be the most important items for creating need for replacements in milking herds. Deaths were not important; however, half of all deaths were accounted for by either an accident or calving.

In 1969, Andrus and Freeman (2) developed age distributions and life expectancy tables for six dairy breeds by using age at freshening for 252,470 DHIA lactation records. Average useful herd life of all cows was 3.12 yr and registered cows had a greater life expectancy than grade cows. Cows kept for another lactation were superior to those culled, as compared to herdmates, for milk and milk fat production through the sixth lactation. They concluded that management appeared to be the greatest factor in determining age distribution, life expectancy, and culling practices.

In a 1969 report, Hargrove et al. (29) looked at reasons why lifetime performance was terminated in the seven herds of the North Carolina Institutional Breeding Association. Reasons for termination for 1,762 Holsteins were as follows: reproduction, 32.0%; low production, 23.4%; dairy purposes, 13.1%; mastitis, 8.4%; abortion, 3.2%; udder, 3.1%; feet and legs, 3.1%; injury and hardware, 2.9%; died from causes unknown, 1.9%; undesirable type, 0.9%; not recorded, 3.0%; and miscellaneous, 5.2%.

Batra et al. (8) looked at the effect of herd size and production level on dairy cow disposal patterns. Herds were categorized by size if they were constant, increasing, or decreasing in size during the period from July 1, 1967 to July 1, 1968. Reasons for disposal for 2,534 herds over all groups were: dairy purposes, 27.0%; breeding and calving problems, 22.8%; low production. 14.8%; poor type, 13.2%; died, 9.5%; and other reasons, 12.7%. In herds of constant size; milk production increases were associated with increases in total percent of cows disposed, percent sold alive for breeding purposes, and poor type but showed a decreased level of culling for low production. Their results showed that herd size had no effect on cow disposal patterns.

In 1971, Canadian researchers (12) reported the primary reasons for disposal of 26,651 dairy cows of the Ayrshire, Guernsey, Holstein, and Jersey breeds from the Canadian Records of Performance (ROP) herds. The major reasons for disposal were reported to ROP milk recording inspectors when making their monthly calls. Reproduction and low milk production were major causes of voluntary herd removals and ranged from 13.4 to 24.4% and from 15.5 to 28.3%, respectively. They considered culling for reproduction as a voluntary loss whereas another study (37) considered it an involuntary one. Holsteins had the lowest (15.5) percentage culled because of low production, but highest (10.2) in percent removed because of udder problems. Younger cows were culled more heavily for low production while their older herdmates were culled more heavily for reproduction, diseases, and weaknesses in udders. Monthly trends showed only a statistically significant increase in summer sales for dairy purposes with a parallel decrease in beef sales.

Work in 1972 by Van Vleck and Norman (56) involved looking at reasons for disposal of 3,475 cows from 188 New York Holstein herds. They compared type appraisal and milk yield in first lactation to study the relationship between type traits measured in early life and later reasons for disposal. Percent of cows removed for various purposes were: low production, 32; reproduction, 27; udder, 22; inabilities or disease, 8; workability, 3; type, 3; and other, 5. Few traits measured before 49 mo of age were found to have significant value in predicting the reason for a cow's eventual disposal.

In 1973, Powell et al. (46) reported the percent of removals that were voluntary from Michigan DHIA records for the years from 1965 to 1968. The four yearly levels of voluntary removal were: 65.7%, 66.5%, 67.1%, and 66.8%. The voluntary disposals were: low production, 54.8%; dairy purposes, 8.3%; old age, 1.7%; temperament, 0.95%; and hard milker, 0.7%. Involuntary losses were: sterility, 16.3%; physical injury, 6.1%; deaths, 5.1%; mastitis, 4.9%; hardware, 0.7%; and brucellosis, 0.15%. Other researchers (39, 53) showed between 68 and 74% of first lactation removals were voluntary, substantially higher than for later lactations. First lactations terminated by disposal have been reported to range from 18.8 and 25.2% (30, 37, 53), lower than reported levels for all lactations (30, 53). Their (46) annual removal rate was 17.8% for first lactation records, but individual sire values ranged from 10.3 to 26.2%. Voluntary removals accounted for 82.4% of all removals with a range of 68.3 to 92.9% for individual sires.

Summarization of Illinois herds on DHI test (3) showed that approximately one of every five cows leaves the herd during the year. Culling reasons for these herds were: low production, 46.9%; breeding problems, 24.2%; udder problems, 9.7%; sick or injury, 7.7%; sold for dairy, 6.1%; and died, 5.4%. Low production was the most frequent reason, although half of the cows were being culled because of reproduction, udder troubles, sickness or injuries, and death.

In 1976, Allaire et al. (1) looked at variations in removal rates with age, bull progeny groups, and herds in dairy females from twelve herds involving 7,813 Holstein females. Removal rates were: reproduction, 34%; low production, 19%; mastitis, 13%; type, 11%; general health, 11%; and others less than 6% for cows after first calving. Culling rates among survivors after 24 mo of age were 15.3, 17.9, 21.5, 23.1, 24.7, 26.2, 29.9, and 34.5% for 8 yearly age intervals. Bull progeny variability increased with age for mastitis and type, but declined from 6.0 to 2.4% for total culling rate. Herd-year standard deviations in total culling rate (5.0 to 9.0%) increased with age. Reasons in decending order for bull progeny standard deviation in culling rates were: reproduction, mastitis, type, production, and disease. They concluded that variation in culling rates at younger ages may be more indicative of bull progeny variation, rather than the length of herdlife.

Gaunt (25) reported why Massachusetts dairy cows were culled from 42 DHIA herds. A personal interview survey was used to determine specific reasons why producing cows left the herd during the 5 yr period 1971-75. Herds averaged 64 cows and all were on some kind of a monthly or periodic pregnancy check. Many cows were reported to be culled for more than one reason: 2,481 were culled for one reason, 511 for two reasons, 53 for three reasons, and one for four reasons. Nearly one-fourth of the cows were culled for reproductive troubles, more than 15% because of repeat breeders. Low production was the reason given for culling another 25%, while culling for mastitis was listed at 9%. Intensity of culling at a young age (under 4 yr) was much higher (twice) for low production than it was for mastitis or repeat breeders. Considerable attention (5.38% of the reasons) was given to culling for poor udder quality, while it was reported that only 2.86% of the reasons were for feet and legs and 1.6% for other type traits.

Everett et al. (19) used 558,654 Holstein cows in the Northeastern United States to calculate sire summaries milk, fat, and stayability for 36, 48, 60, 72, and 84 mo. Data were edited so that cows sold for dairy purposes were eliminated as an observation. All cows had to have a first lactation on test, and the herd must have been enrolled continuously on test when the cow reached or could have reached ages of 36 through 84 mo. They found phenotypic and genetic relationships between sire summaries for production and stayability ranged from .20 to .55 and the relationships Predicted Difference for Type (PDT) and production were approximately -.30. Their phenotypic and genetic relationships between PDT and stayability ranged from -.08 to -.15. They concluded that sires selected for high production in first lactation will have daughters which last longer.

Everett et al. (20) studied 1,133,804 records of artifically sired cows and estimated genetic and environmental trend in milk, fat, and stayability for 36, 48, 60, 72, and 84 mo. They found a positive genetic trend of AI sires for both milk and fat, suggesting that daughters of AI sires produced higher levels of milk and milk fat than the previous generation of cows. All breeds had experienced a genetic decrease in fat test, but environment produced much larger decreases in fat test than genetics, except in Holsteins. Guernseys and Holsteins had negative genetic trends for stayability while the other breeds were positive.

Reproductive efficiency and problems

Low reproductive efficiency continues to be a major problem in dairy herds. It causes economic loss directly as a result of its effect on yearly.milk production and on surplus calves for sale, and indirectly because the potential selection differential is reduced with fewer replacements (34). Surveys of culling reasons from DHIA and other testing associations (3, 37, 39, 46, 53, 56, 57) show that infertility is the second most frequent cause of culling. The only more important cause is low production.

Reproductive efficiency or problems can be measured by many methods. Researchers have used calving intervals, days open, services per conception, days to first breeding, days from first breeding to conception, days between heats and service, the number of cows culled for infertility, and the percent pregnant from first, second, and third services separately and combined. Foote (23) published an excellent review on inheritance of fertility and concluded that infertility in cows is primarily a management rather than a genetic problem. Recognizing that little improvement in fertility can be accomplished through selection, herd breeding efficiency and herd profitability need to gain importance from management improvement.

Reproductive studies during the 1950's

In 1954, Boyd et al. (9) used the number of services per conception to identify the breeding efficiency of 29 DHIA herds. Data was from single records of 225 Jerseys, 208 Holsteins, and 86 Guernseys that were bred by artificial inseminations. The correlation coefficient between milk production and services per conception was -0.04. Average services per conception was 1.68. Analysis of covariance, to segregate difference due to herd and level of production, showed that production level had no effect on services per conception.

Days to first estrus, days open and services per conception were used to study the relationship between milk production and breeding efficiency in a 1955 study by Carman (13). Days to first estrus was found to be influenced by the level of production in the previous lactation. Breeding variables, when grouped by current production, showed significant differences between days open and the number of services per conception. Days open increased as production increased. Age of cow, parity or lactation number, year, and season had little effect on breeding efficiency.

Reproductive studies during the 1960's

In 1962, the relationships between days open, days dry, and 90 day and 305 day milk production were investigated by Smith and Legates (51). Data represented 4,385 lactation records from nine

Holstein research herds. Intra-herd-year season phenotypic correlations between 90 day milk production and days open were not significant and ranged from 0.05 to 0.08, suggesting that level of production had very little influence on this measure of fertility. Heritability estimates for days open were very low, ranging from 0.01 in first lactation to 0.09 for all lactations. Days open during the lactation influenced production; while length of previous dry period had little influence on production.

Poston et al. (45) analyzed the effect of month of calving on length of subsequent calving interval. The study covered a 10 yr period of six Holstein research herds involving 2,514 records. The average calving interval ranged from 397 to 422 days for calving in October and May, respectively. Differences in calving interval were highly significant for both among months in the same year and herd, and also among herds, but not different among years for each herd.

Phenotypic and genetic parameters of milk and fat production with five measures of breeding efficiency were studied by Everett et al. (18) in 1966. Breeding efficiency was measured by days open, calving interval, days from parturition to first breeding, days from first breeding to conception, and services per conception. Breeding and production records of 10,907 Holstein and Guernsey lactations were the source of data. The relationships between 120 day milk and fat production and breeding efficiency were essentially zero or independent of breeding efficiency. Regressions of breeding efficiency on production indicated that breeding efficiency increased slightly as production increased. The same relationship was found for breeding efficiency and ages. Regressions of breeding efficiency on 120 day lactation production was slightly negative for all measures of breeding efficiency, except services per conception. They concluded as 120 day production increased, breeding efficiency did not increase significantly. They also indicated that selection for production or breeding efficiency will not increase or decrease breeding efficiency.

Olds et al. (40) looked at the breeding records of 22 local units (districts) of a Wisconsin breeding stud. Fertility and delayed return data were from 23 herds from each local unit with records for 20 or more cows. Cows had to be serviced by bulls of the stud for 4 consecutive yr. Delayed returns were defined as those cows returning to heat 26 or more days after service. Herds were subsampled by assigning consecutively cows into alternate ten cow groups. They found that 19.8% of the variation in annual herd fertility of ten cow herds was due to difference among years, local units and herds; while 80.2% of the variation was random.

In 1967, Speicher and Meadows (55) studied DHIA records of 4,285 Holsteins and found that a delay of conception beyond 86 days and up to 116 days after freshing resulted in an average decrease in returns of $0.50 for each day beyond 86 days. When extended beyond 117 days they calculated a decrease of $0.78 for each day. They also found that an increase in length of calving interval resulted in fewer but longer lactations with greater production per lactations. Shorter calving intervals resulted in higher average daily production and higher annual returns over feed cost.

Miller et al. (38) studied DHIA first calf records of 100,280 cows that were sired by artificial insemination and had calved before 35 months of age. The average calving interval was 381.5 days. High producing cows tended to have longer calving intervals, which were probably influenced by more days open during lactation, more intense culling of low producers with longer calving intervals, and/or a longer delay or postpartum estrus in high producers. They also concluded that selection of females for shorter calving intervals than 381.5 days would not be advantageous.

North Carolina researchers (34) reported that the combination of low conception and failure to observe estrus resulted in an average of 116 days open or 13 mo calving interval. Data was from 4,910 complete lactations of 756 Holstein cows of the North Carolina Institutional Breeding Association and reported in 1968.

Reproductive studies during the 1970's

An average conception rate of 43.3% of first service was reported by Pelissier (43) in a 1970 study. For 5,000 cows in ten herds, services per conception averaged 2.67, with 18.3% of the cows requring four or more services. He reported that 45.2% of the cows were open 120 days or more, 27.9% were open at least 150 days, and 17.8% were open 180 days or more. Only 65.5% of the cows had a heat period recorded before 60 days postpartum; 34.5, 11.9, and 3.9% of the cows had no heat period recorded 60, 90, and 120 days postpartum, respectively. He concluded that one of every six heat periods was either missed or not recorded subsequent to the first recorded heat period.

In a 1972 field study, the breeding records from 24 California commercial dairy herds representing a variety of management systems were investigated by Pelissier (44). Problem areas were identified as low conception rates, repeat services, and the heavy sale of cows due to conception failures or delays. Only 57.7% of the study cows conceived during the usually considered optimum 61 to 120 days after calving. A third of the cows in the study were open more than 120 days and 12.5% remained open more than 180 days. The percentage of cows that conceived with three services or less was 77.3 with a range of 58.9 to 89.3 among herds. Cows needing four or more services were considered to be breeding problems. The study average for services per conception was 2.44. Days open were also influenced by delayed detection of first heat which showed that 41.6% of the cows had their first heat recorded later than 60 days after calving, 12.5% had none reported 90 days postpartum. Pelissier also concluded that retained placentas were predisposing causes of low fertility; metritis and other abnormal conditions were the immediate causes of reduced fertility in many cows.

Kansas workers (10) looked at factors affecting calving intervals and breeding efficiency of 40 DHI Holstein herds. Herds were selected for either long (405+ days) or short (360 to 374) calving intervals. Evaluation of managerial abilities and goals, considering heat detection and reproductive consciousness were determined by interviews with owner-operators. The long calving interval group had a 28-day longer interval from parturition to first service and a longer interval between services. They reported that 24% of the short interval group had first services by 60 days postpartum, 73% by 90 days, and 92% by 120 days compared with 13, 50, and 74% for the long interval group. Both groups showed similar first-service conception rates of 56%. Reproduction consciousness of the short interval group of operators was higher in that they were breeding cows earlier after calving and they had fewer problems detecting heat.

Within-herd heritabilities of days open were estimated to be 0.02, 0.04, 0.00, and 0.10 for first, second, third, and later lactations by Schaeffer and Henderson (47). This indicates that reproductive efficiency, measured by days open is really not genetic but environmental. As days open increased, cumulative milk production also increased at each successive stage of lactation. Open periods were longer for cows that freshened during the summer months than for winter and spring freshening cows. Dry periods of 50 to 59 days resulted in the highest production in the subsequent lactation with the averages for 40 to 49 and 60 to 69 days dry not greatly different.

In 1973, factors affecting conception rates for first calf heifers and lactating dairy cows in a Florida research herd were investigated by Gwazdauskas et al. (27). Uterine temperature at insemination; maximum, minimum, and average temperature the day of insemination, and maximum, minimum, and average temperature the day after insemination were associated with variations in conception. Uterine and average ambient temperatures on day of insemination were inversely related to fertility.

Early postpartum breeding (first postpartum estrus) versus breeding at first estrus after 74 days postpartum were compared for future reproductive performance by Wisconsin workers (58) in 1974. Data represented 393 calving intervals of 168 Holstein cows. Interval to first postpartum estrus increased for cows with high genetic potential cows for milk production than for genetically low producers and also increased for cows on a high level of nutrition compared to average nutrition. Cows bred on the first postpartum estrus had lower conception rates than the group bred after 74 days. Early breeding had no detrimental effect on fertility for the second through fourth breeding with both groups having similar averages.

In 1975, Elmore et al. (16) discussed the causes of repeat breeder cows and classified the causes as: abnormal genital traits, defective eggs and/or sperm, hormonal disfunctions, and managerial deficiences. They concluded that with normal conception rate in cattle of 60% on 1.6 services per conception; and when breeding 100 normal cows, 6.4% will require four or more services.

Gwazdauskas et al. (28) studied 5,062 services from a Florida research herd and used least squares analysis to delineate factors affecting conception rates. Overall conception rate was 37.9%. From 21 climatological measurements, the five selected as most important ranked: 1st, maximum temperature the day after insemination; 2nd, rainfall the day of insemination; 3rd, minimum temperature the day of insemination; 4th, solar radiation the day of insemination; and 5th, minimum temperature the day after insemination. As values for measurements 1, 2, and 4 increased, conception rates decreased. Measurements of 3 and 5 had no significant effect on conception rates. Conception rates were lower during the warm months (33.7%) than during cool months (40.1%). Conception rates declined with age: heifers 47.6, young cows, 42.7; and old cows, 31.9%.

Gomila and Roussell (26) studied the timing of postpartum breeding for their effect on calving interval and fertility. Four treatment groups were formed by randomly assigning each of 150 lactating dairy cows to one of the groups. Group one animals received their first service between 46 and 65 days postpartum. Groups two and three were serviced 66 to 85 and 86 to 105 days postpartum, respectively. Group four animals exhibited heat between 46 to 65 days but were not bred at this time. After eliminating animals considered to be problem breeders (four or more services), average days open were: 76.0, 108.1, 127.9, and 113.7 for group one through four, respectively. The average services per conceptions were 2.14, 2.65, 2.34, and 1.93. After elimination of problem breeders, average services per conception were 1.51, 1.82, 1.75, and 1.58.

Seven studies were summarized by Britt (11) on the relationship between early postpartum breeding and fertility. Early breeding in dairy cattle resulted in more calves and higher milk yield per day of herd life, but required more inseminations per conception. He concluded that breeding can normally begin at about 40 days postpartum with an acceptable reproductive performance and with current management practices. He suggested that a 12 mo or less calving interval can only be achieved by shortening the interval to first insemination to an average of about 50 to 60 days postpartum.

Barr (6) looked at 10 Ohio herds on a herd reproductive status program to study the influence of estrus detection on days open. Conception rates for all cows and fertile cows were 2.3 and 2.1 services per conception. Estimations of lost reproductive days per cow year due to conception failure and missed heats as 23 and 10 days, respectively. He concluded that herd conception rates were not extremely variable and our ability to influence substantially these rates is limited. He also suggested that dairymen appeared to be losing about twice as many days due to missed heats as due to failure to conceive.

In another study, using the same ten herds, Barr (7) reported that days open were not highly correlated with conception rates. He noted that in two herds that had the same conception rates, they still differed by 30 days in average days open. He also noted that the herd that had the highest services per conception (2.8), still maintained a satisfactory average of 103 days open.

Spalding et al. (52) investigated the fertility of 125 New York DHI Holstein herds representing 9,750 cows. All breedings to milking cows were by artificial insemination. Herds were further selected with equal numbers of small (40 to 69 cows) and large herds (70+ cows) and free stall and stanchion housing. Days to first service averaged 87 days and days open averaged 116 days. Conception on first service averaged 50% and the 60 to 90 day nonreturns (cows which were bred to an artificial inseminating firm the first service and assumed pregnant if not serviced by same firm within 60 to 90 days) was 58%. Cows that were pregnant by the first three services totaled 89%. When age, herd size, and other variables were not allowed to vary, cows producing more than 907 kg above herdmates were 20.5 percentage units lower in conception on first service than the base group. Fertility declined with age beyond 4 yr of age. As the size of herds increased, conception rates declined; however, milk production per cows also increased.

Workers in New Hampshire (35) used the records of 370 Holstein and 223 Jerseys, from four research herds, to study factors of reproductive efficiency. Reproductive efficiency was measured by services per conception, days from first breeding to conception, and calving interval. Herd differences were found for the Holstein data ranging from 1.66 to 2.54 services per conception, from 18.5 to 43.5 days from first breeding to conception, and from 388 to 419 day calving intervals. Increase in parity (successive lactation) resulted in increased days from first breeding to conception and calving intervals for the Holstein data. Breeding efficiency was affected by year or seasonal effects for the Holstein data. They suggested that there was a small antagonistic relationship between production and breeding efficiency, but it was concluded that this may be biased by the fact that lower producing cows were culled sooner and, therefore, had fewer services than higher producers.

In a 1976 study, Kentucky researchers (41) investigated the effect of 120 day milk yield on the fertility of 17,693 Holstein cows in 181 herds. They used 120 day yield in preference to 305 day yields, which are known to be affected by days open. Average 120 day milk yield was 2669 kg and each additional 500 kg resulted in 2.6 more days open. Days from calving to first breeding and days from breeding to conception accounted for 0.5 and 2.1, respectively, of the 2.6 lost days. Among herds, the relationship between yield and days open was not significant. However, the trend was similar with 500 kg of additional milk yield being associated with an increase of 1.4 days open.

Slama et al. (50) used 696 calving intervals from 370 cows, from four breeds, to study breeding efficiency and factors affecting calving interval within breeds. Fertility of bulls differed within breeds. Analysis by fitting constants revealed that days from calving to first services, from first service to conception, and services per conception were major factors affecting calving intervals. Calving intervals ranged from 396 days for Holsteins to 414 days from Guernseys. Days from calving to first services ranged from 83 days for Ayrshires to 90 days for Guernseys. Days from first service to conception ranged from 33 days for Holsteins to 40 days for Ayrshires. Holsteins required 1.95 services per conception with approximately 90% of the Holsteins conceiving by three services. Days open were decreased by first-estrus breeding, but required more services.

Galton et al. (24) paired, within parity and breed, 144 dairy cows and randomly assigned them to either a reproductive herd health program or a control group. Both groups received reproductive examinations when the following existed: postpartum (15 to 30 days), anestrus, abnormal estrus length, postbreeding (four or more services), and/or pregnancy examinations. Management decisions were made from these examinations only in the program group. In both groups, animals exhibiting abnormal vaginal discharges received veterinary care. Services per conception, days to first service, and days open were 1.74, 73.10, and 99.24 for health program cows and 2.38, 86.82, and 140.07 for control cows.

Analysis of 388 breeding records by the least squares method was used by Shanks et al. (49) to study causes of variation in conception interval. Reproductive health was routinely checked at 30 ± 7 days postpartum. All open cows were assigned a conception interval of 308 days and they considered in the study. Good, fair, and poor involution scores were associated with reduced or increased days open of -31., -28, and 59 days, respectively. Uterine or ovarian treatment at 30 days postpartum was associated with an increase of 16 days to conception. Embryonic deaths, retained placentas, mechanical aid during calving, and third parity increased conception interval 27, 14, 27, and 22 days, respectively. They found that 26%

of the cows with no ovarian structure at 30 days did not conceive compared to 11% overall. Suboptimal reproductive health at 30 days postpartum increased intervals from calving to conception.

In one of the most extensive studies of fertility, Holtz and Lamb (31) studied 61,109 California DHI records to determine if the use of high Predicted Difference (PD) sires had any effect on the breeding efficiency of their daughters. The breeding practices of study herds had to be fairly uniform across the entire herd. Increased use of sterility programs and owner or hired man doing the insemination was noted during the study period. The first five lactations were used. Production levels that were looked at were: production the first four test periods and production for 305 day lactations. Milk, fat, and 3.5% fat-corrected milk were considered for each of these production variables. Breeding variables were: days from calving to first breeding, calving interval, and the number of breedings for conception. They looked at 900 correlation coefficients from the data. Production, independent of the measure, had no effect on the breeding efficiency of cows. They found no correlation between when a cow was first bred and the number of services per conception. Correlations between the days from calving to first breeding and the calving interval were positive (.34 to .38). They recommend early breeding (45 to 60 days postpartum) for the general population to reduce the calving intervals.

They also studied 247 sires, having at least 10 daughters in four or more herds and ranking from plus 1509 Predicted Difference -

Milk (PD) to a minus 1470 PDM, and found no relationship between PDM and reproductive efficiency of sire daughters. They concluded that daughters of high PDM bulls were no worse nor no better in the three reproductive variables they used than were daughters of average or minus PDM bulls. They did find a difference among individual bulls but it was not related to their PDM value.

MATERIALS AND METHODS

Source of experimental data

Herd removal data. Reasons for removal (sold or died) of 183 Holstein cows in the South Dakota State University dairy research herd were obtained from individual lifetime history records (Michigan Dairy Breeding and Health Record System). Cows removed from the herd after January 1, 1968 and before July 1, 1976, were considered, as records were available during these years. The reason or reasons for removal were recorded by the herd manager and more than one reason for removal were sometimes listed for each cow. When multiple reasons were given, equal weight was given for each reason given. Cows that died of unknown causes were posted at the South Dakota State University Veterinary Diagnostic Laboratory for a possible determination of cause or causes of death.

Reproductive problem data. Individual lactation records, including Dairy Herd Improvement Association (DHIA), Official Holstein-Friesian type scores, and Michigan Dairy Breeding and Health Record System records, were sources of reproductive data. All cows calving, after January 1, 1968 and completing a minimum of one record prior to July 1, 1976, in the South Dakota State University dairy research herd were considered for the reproductive data. After screening of all lactation records for completeness, there were 227 cows representing 535 lactations useable for this study. Complete records were those that had the following information recorded: lactation number, yield of 305-ME milk, yield of 305-ME fat, Official

Holstein-Friesian Association type score, difference from herdmates-milk, difference from herdmates-fat, percent Protein Lactose Minerals (PLM), yield of PLM, and breeding or insemination records. All breedings were by artificial insemination under the herdsman's supervision.

Clarification of terms

Yield of 305-ME milk and fat. The individual milk and fat records were standardized for length of lactations to 305 days, to twice-a-day milking, to mature equivalent basis and to an average month of freshening. Adjusted milk and fat records were taken from the monthly herd summary or the individual lifetime summary of lactations provided by the DHIA. Adjustment factors used by DHIA processing centers were developed by McDaniel et al. (36) which appropriate for each animal's breed, age, month of freshening, and area of the country to obtain mature equivalent records.

Type score. Cows were scored by official classifiers of the Holstein-Friesian Association of America with total herd Classification done every 15 months. Cows could have been classified more than once with each classification score matched to the nearest lactation(s). Type scores were adjusted for age (age at time of classification) using the factors developed by Cassell et al. (14).

Reproductive problems. Those lactations where cows had one of the following situations were considered as problems: four or more services per conception were required; there were more than 120 days from calving to conception; health records indicated that during that lactation a cow showed no estrus, irregular estrus (constant heat), or received some type of drug or hormone treatment that indicated a problem; and those cows removed from the herd because they were not pregnant. Cows that were sold open and considered a breeding problem had to have records that indicated that an effort was made to observe estrus or impregnate this cow.

Groups for analysis. Stepwise discriminant analysis was used to distinquish between lactations and/or cows with or without reproductive problems during a specific lactation or sometime during the study period based on the following set of discriminating variables: (1) lactation number, (2) yield in kg of 305-ME milk, (3) yield in kg of 305-ME milk fat, (4) age adjusted type score, (5) difference from herdmates-kg of milk, (6) difference from herdmates-kg of milk fat, (7) percent PLM, and (8) yield in kg of PLM. Analysis of four sample groups of cows and lactations were formed from the 227 cows representing 535 lactations for analysis of each group.

Sample group 1. Group 1 included all 535 lactations and used all eight discriminating variables of each specific lactation. Each cow was represented by only those lactations that she completed during the study period. A cow could have all her lactations in one or the other reproductive group or she could be represented by lactations in both groups.

Sample group 2. Group 2 included 172 first lactation records completed during the study period. Discriminating variables 2 through 8 measured during the first lactation were used. Each cow was assigned to one or the other reproductive group.

Sample group 3. Group 3 included 377 lactations from 131 cows that initiated their first lactation record during the study period and also before January 1, 1974. All eight of the discriminating variables of each specific lactation were used. Each cow had the opportunity to make three records. A cow could have all her lactations in one or the other reproductive group or she could be represented by lactations in both groups.

Sample group 4. Group 4 included the same 131 cows and 377 lactations of sample group 3. Cows were classified into those with or without reproductive problems during their lifetime using discriminating variables (2 through 8) that were measured during the first lactations. All cows had the opportunity to make three records or the averaged lifetime of dairy cows (2, 17, 22). Each cow was assigned to one or the other reproductive group.

Statistical analysis. Stepwise discriminant analysis was used in exploring the relationship between reproductive problems and all or just the last seven of the following set of variables: (1) lactation number, (2) yield of 305-ME milk, (3) yield of 305-ME milk fat, (4) age adjusted type score, (5) difference from herdmates-milk, (6) difference from herdmates-milk fat, (7) percent PLM, and (8) yield of PLM. Discriminant function was introduced by Fisher (21) as a statistical technique to facilitate the classification of things or persons. Li (33) stated that one of the many practical applications of discriminant function in animal and plant breeding is the construction of a selection index in breeding work.

Discriminant analysis begins with the desire to statistically distinguish between two or more groups of cases. To distinguish between the groups the researcher selects a collection of discriminating variables that measure characteristics on which the groups are expected to differ. It can also be used to test variables that have no past research work to show if they differ or not. Variables used in this study were also those variables that could be easily measured in the first lactation, and variables that are practical and economical to measure. By selecting variables easily measured in the first lactation, those (if any or all) variables found to be a good discriminator of breeding problems could be of practical use in the artificial inseminating young sire programs. This is because the initial proof of all young sires are predominately from first lactation records.

The maximum number of discriminant functions that can be derived is either one less than the number of groups or equal to the number of discriminating variables, whichever is smaller. Stepwise discriminant analysis is based on the assumptions (1) that residual variance of the variables within each stratum are normally and independently distributed with a mean of zero and common variance, (2) that the dependent and independent variables are measured without error, and (3) that the true relationship between the dependent and independent variables are linear.

The analysis consists of entering selected variables, one at a time, into a linear function based on improvement in discrimination.

By sequentially selecting the next best discriminator at each step, a reduced set of variables may be found which is almost as good as, or sometimes better than, the full set. Variables which maximize the variance between groups are entered successively until all variables are in the discriminant function. Some variables might not be selected if they don't provide a minimum level of improvement. This minimum level can be controlled by the use of inclusion levels. The use of the stepwise procedure results in an optimal set of variables being selected. The assumption is that this procedure is an efficient way of approximately locating the best set of discriminating variables as discussed by Klecka (32).

The merit of the reduced set of discriminating variables in distinguishing between groups is indicated by the number of lactations or cows correctly classified as having reproductive problems. These variables should also correctly classify a high number of lactations or cows without reproductive problems to combine to give a high number of lactations or cows correctly classified overall. High percentages of lactations or cows correctly classified as having reproductive problems and also those not having problems indicates that the discriminating variables give good separation of groups; conversely, low percentages indicate poor separation.

All statistical analyses were conducted using the electronic computer located at the Computing Center, South Dakota State University. Stepwise discriminant analyses were carried out using the subprogram BMDO7M from the Biomedical Computer Programs by Dixon (15).

RESULTS AND DISCUSSION

Cow removal rate

During the study period, 183 cows were removed from the herd and 235 reasons for removal recorded. Cows averaged 3.2 lactations. One-fourth of the cows were removed for more than one reason: 137 were removed for one reason, 44 for two reasons, and two for three reasons. Other studies (25, 39) involving larger numbers of cows and with a similar method of recording reasons for removal, reported that 18.5 to 20.8% of the cows were removed for more than one reason.

The four major reasons for cow removal accounted for 87.2% of the total reasons. Major reasons included: reproductive problems, 46.8%; type related problems, 14.9%; mastitis, 14.5%; and low milk production, 11.1% (Table 3). Gaunt (25) reported the same major reasons for culling of Massachusetts DHIA cows, but with more importance for culling for low production, 24.9%; reproductive problems, 22.8%, type, 9.9%; and mastitis, 9.0%. A survey (39) of New York DHIA herds showed the following main reasons: low producing, 25%; sterility, 15.4%; type, 14.3%; dairy purposes, 11.8%; and mastitis, 8.6%.

Reproductive problems

Poor reproduction was the main reason for removal and accounted for 46.8% of the total reasons (Table 3). This is more than twice the levels reported by O'Bleness and Van Vleck (39), and Gaunt (25) reporting values of 15.4% and 22.8%, respectively. A high percentage (68.2) of cows removed with reproductive problems had it as the sole reason for removal. Lactations per cow averaged 3.0 for the 110 cows

TABLE 3. Reasons why Holstein cows were removed from the South Dakota State University dairy research herd[a].

Individual reasons	Cases reported per reason for removal	% of total reasons	% as sole reason[b]	Average lactations when removed
Reproductive problems	110	46.8	68.2	3.0
Type related	35	14.9	25.7	3.9
Mastitis	34	14.5	41.2	4.0
Low production	26	11.1	46.2	2.7
Injuries	8	3.4	100.0	3.3
Died, unknown cause	7	3.0	85.7	4.0
Milk fever	4	1.7	100.0	4.5
Sold[c]	2	.8	100.0	1
Feed trial related	2	.8	50.0	5
Misc. reasons	5	2.1	80.0	3.8
Managament problems[d]	2	.8	00.0	1.0
Totals	235	99.9		

[a]Reasons for 183 cows removed from Jan. 1, 1968 to June 30, 1976.

[b]Percentage of each individual reason for removal when reported as the sole reason for removal.

[c]Sold - not noted sick or reason of removal.

[d]Cows that due to management traits were removed (such as temperament).

(60.1% of the total cows removed) removed with reproductive problems as the sole reason or as one of the reasons for removal. Culling data from research herds (1, 17, 29, 42) had reproductive problems as the main reason for removal with 23.5 to 41.3% of the cows removed because of reproductive problems. Studies involving DHIA herds (3, 37, 39, 46, 53, 56, 57) complicate this by reporting that reproductive problems was the second most important cause of cow removal and second only to low production. DHIA data showed a range of 7.3 to 27.0% of the cows are removed for reproductive problems. This suggests that there may be a difference in the pressure for culling for low production between research and DHIA herds.

Type related problems

Type related problems accounted for 14.9% of the reasons for removal (Table 3) which was slightly higher than the value (9.9%) reported by Gaunt (25). O'Bleness and Van Vleck (39) reported that 38.4% of the type related reasons for removal were not the primary reason for removal. Approximately 75% of the cows removed in this study with a type related problem, had one or more other reason(s) recorded along with it. In this study, cows removed for type related reasons were usually removed with another reason associated with the cause of removal. The records in this study did not identify which of the multiple reasons was the primary cause of removal. Thirty-five cows were removed with type related problems as the sole reason or as one of the reasons for removal. These cows averaged 3.9 lactations which is similar to another report (54).

Type related problems were further broken down into three areas: poor type, feet and legs, and poor udders (Table 4). Cows removed because of poor type accounted for 57.1% of the type related reasons. This is over twice the value (24.1%) reported by O'Bleness and Van Vleck (39) and over three times greater than another study value of 16.8% (25). Records of cows removed for poor type did not indicate a specific area of type problem. Atkeson et al. (5) reported that classifiers generally weighed general appearance and mammary system excessively in making final scores. This suggests that high quality and low quality of mammary system or general appearance may play a large part in the poor type breakdown.

In this study feet and legs accounted for 28.6% of the type related reasons for removal (Table 4). This is similar to the level reported for Massachusetts DHIA herds (25). O'Bleness and Van Vleck (39) reported a lower level with feet and leg problems accounting for 22.1% of the type related reasons. Other studies (12, 29) that indicated type problems for feet and legs showed that approximately 3.0% of the cows were removed because of feet and leg problems.

Type related problems due to poor udders accounted for 14.3% of the type related reasons (Table 4). Only five cows were removed due to poor udders and three of those cows had one or more reason(s) for removal recorded with the type reason. Other workers (25, 39) reported a much higher level of poor udder problems and showed that it accounted for approximately 54% of the type related problems. The difference may be due to the small numbers of animals removed in this

TABLE 4. Breakdown of type related reasons of removal.

	Times recorded as reason for removal	% of type related reasons
Poor type[a]	20	57.1
Feet and legs	10	28.6
Udder	5	14.3
Totals	35	100.0

[a]Cows removed for poor type but no specific problem area recorded.

study and because cows that were removed for poor type did not show the specific problem. Other studies (12, 29, 57) showed that a range of 3.1 to 13.5% of cows culled were removed with poor udders as the cause for removal.

Mastitis problems

Mastitis was recorded for 34 cows as a reason for cow removal and accounted for 14.5% of the total reasons for removal (Table 3). Cows removed with mastitis listed as the sole reason or with it as one of the reasons recorded for removal averaged 4.0 lactations. Approximately 41% of the cows listed as culled for mastitis had it as the sole reason for culling. Other workers (25, 39) reported that mastitis accounted for approximately 9.0% of the total reasons for removal. Other studies (1, 29, 37, 46, 53, 57) showed that 4.9 to 13.0% of the cows culled were removed because of mastitis. Some workers (3, 17, 42, 56) combined mastitis and poor udders together and the individual level of each could not be separated.

Low production

Low production accounted for 26 of the total reasons for removal of 11.1% of the total reasons (Table 3). Other workers (25, 39) reported over twice this level. Some 46.2% of the cows removed in this study for low production had it as the sole reason for removal. Research herds (1, 17, 29) show a range of 17.1 to 23.4% of the cows were removed because of low production. Testing association herds (3, 12, 37, 39, 46, 53, 56, 57) reported a range of 15.5 to 54.8% with most studies over the 30% level. This suggests that the level of culling for low production in this study was at a low level.

Other problems

Only 12.8% of the total reasons for removal were accounted for by the remaining reason for removal (Table 3). The remaining reasons for removal and the percent of the total reasons for removal were the following: injuries, 3.4; died unknown cause, 3.0; miscellaneous, 2.1; milk fever, 1.7; sold, .85; feeding trial related, .85; and management problems, .85.

Cows that died of an unknown cause were those cows that were posted but no cause of death was found. Miscellaneous reasons included cows sold or died because of hardware, pneumonia, or ketosis. Cows that were listed as sold had records that did not indicate if the cow was sick or did not give the reason for removal. Cows removed because of feed trial related problems became sick during a trial and never recovered. Management problems included a cow with bad temperament and one that would not use the free stalls.

Sample group 1

Reproductive problems were recorded for 151 of the 535 lactations when all cows and all lactations were studied. Stepwise discriminant analysis differentiated between lactations with no reproductive problems and those lactations with reproductive problems based on the best set of discriminator variables, which correctly classified only 62.2% of the lactations with no problems and 55.6% of the lactations with reproductive problems (Table 5). Variables that made up the best set, in order of inclusion into the stepwise analysis, were as follows: lactation number, type score, yield of PLM, yield of milk, difference from herdmate-milk, yield of milk fat, and difference from herdmates-milk fat (Table 5). Overall there were still approximately 40% of the lactations that were misclassified as having a reproductive problem when in actuality there was no problem or classified as having no problem when in actuality there was a reproductive problem.

Lactation number was the best discriminator variable and by itself correctly classified 60.2% of the lactations with no reproductive problems and 52.3% of the lactations with reproductive problems (Table 5). Only a small improvement in accuracy of classification was shown with the addition of the six other discriminator variables that made up the best set. The selected variables indicated some ability to separate lactations with no problems and those with reproductive problems but not with a high enough degree of accuracy to be reliable.

Group 1 variable means and standard deviations show little difference between the lactation groups with no problems and those with reproductive problems (Appendix Table 1). The largest difference appeared to be between the group means for difference from herdmates-milk, yet it did not enter into the stepwise analysis until Step 5. Within groups correlation matrix values are listed in Appendix Table 2.

TABLE 5. Summary of stepwise discriminant analysis for sample group 1[a].

Step number	Variable entered	F value to enter or remove	% lactations correctly classified overall	% of lactations correctly classified with no problems[b]	% of lactations correctly classified with problems[b]
1	Lactation number	7.5083	57.9	60.16	52.32
2	Type score	1.1493	57.4	61.20	47.68
3	PLM, yield	0.2607	57.9	62.24	47.02
4	Milk, yield	0.8493	59.4	64.84	45.70
5	Diff. herd[c]-milk	1.3587	60.6	65.36	48.34
6	Milk fat, yield	0.5854	60.4	64.06	50.99
7	Diff. herd[c]-fat	1.9722	60.4	62.24	55.63

[a]Included all cows (227) represented by 535 lactations.

[b]Lactations with no reproductive problems or those with reproductive problems.

[c]Abbreviation for difference from herdmates - milk or fat.

Sample group 2

Reproductive problems were recorded for 40 of the 172 cows that completed first lactation records. Six variables correctly classified 72.5% of the cows that had reproductive problems during the first lactation (Table 6). This set of variables was only able to correctly classify 58.3% of the cows that did not have reproductive problems. Overall there were still 38.4% of the cows misclassified as having reproductive problems when in actuality they had none or classified as not having problems when they actually had reproductive problems.

Age adjusted type score was the best discrimination variable, but by itself it only identified 50.0% of the cows with no reproductive problems and 62.5% of the cows with reproductive problems recorded in the first lactation (Table 6). The best set of discriminating variables are listed in Table 6. There was a 10% increase in the lactations or cows correctly identified as having reproductive problems over the level showed by the best set of variables in group 1. But overall accuracy was equal between the sample groups.

Means and standard deviations of Sample group 2 variables are listed in Appendix Table 3. There is some indication that cows that had reproductive problems had a higher adjusted type score. Small difference is noted in the other group variables. Within groups correlation matrix values for first lactation records are listed in Appendix Table 4.

TABLE 6. Summary of stepwise discriminant analysis of sample group 2[a].

Step number	Variable entered	F value to enter or remove	% lactations correctly classified overall	% of lactations correctly classified with no problem[b]	% of lactations correctly classified with problems[b]
1	Type score	6.3684	52.9	50.00	62.50
2	PLM, yield	1.3263	58.7	56.82	65.00
3	Milk, yield	3.4760	59.9	57.58	67.50
4	PLM %	0.0392	60.5	59.09	65.00
5	Milk fat, yield	0.0636	59.3	58.33	62.50
6	Diff. herd[c]-fat	0.1580	61.6	58.33	72.50

[a]Includes all cows (172) first lactation records initiated during study period.

[b]Cows or first lactations with no reproductive problems or those with reproductive problems.

[c]Abbreviation for difference from herdmates-fat.

Sample group 3

There were 131 cows represented by 377 lactations in this group. Reproductive problems were recorded in 105 lactations. No reduced set of discriminating variables was found. All eight variables formed the set of discrimination variables that gave the most correctly classified lactations (Table 7). Only 60.7% of the lactations with no reproductive problems and 61.0% of the lactations with reproductive problems were correctly identified (Table 7). Again, only 60.7% of the lactations were correctly classified overall.

Lactation number was the first discriminating variable selected in the analysis, but it was more accurate in classifying lactations without reproductive problems than classifying lactations with reproductive problems. Steps 6 and 8 were equal in the degree of accuracy in classifying lactations with reproductive problems (Table 7). Variables in step 8 showed a slight advantage in classifying lactations without reproductive problems and also a slight increase of the percent correctly classified overall. The best set of variables still didn't identify with a high enough degree of accuracy.

Group 3 variable means and standard deviations are listed in Appendix Table 5. No large differences were noted between those lactations with or without reproductive problems. Within group correlations matrix are listed in Appendix Table 6.

TABLE 7. Summary of stepwise discriminant analysis for sample group 3[a].

Step number	Variable entered	F value to enter or remove	% lactations correctly classified overall	% of lactations correctly classified with no problems[b]	% of lactations correctly classified with problems[b]
1	Lactation number	4.6976	60.7	66.5	45.7
2	Diff. herd[c]-fat	0.6615	57.3	59.2	52.4
3	Milk yield	0.4713	56.8	57.7	54.3
4	Diff. herd[c]-milk	1.3040	58.9	59.9	56.2
5	Milk fat, yield	1.6780	58.4	58.5	58.1
6	PLM yield	0.4608	59.4	58.8	61.0
7	PLM %	0.1377	59.2	58.8	60.0
8	Type score	0.0322	60.7	60.7	61.0

[a]Included 131 cows represented by 377 lactations and each cow had opportunity to make three lactation records.

[b]Lactations with no reproductive problems or those with reproductive problems.

[c]Abbreviation for difference from herdmates-milk or fat.

Sample group 4

Reproductive problems were recorded for 75 of the 131 cows in this group. Stepwise discriminant analysis differentiated between cows with no reproductive problems during their lifetime and those cows with reproductive problems during their lifetime based on seven variables measured during the first lactation. No best set of discriminator variables was found. All seven variables were used to correctly classify only 60.7% of the cows with no problems and 56.0% of the cows with reproductive problems (Table 8). Overall only 58.0% of the cows were correctly classified.

The percent PLM was the first discriminator variable selected in the stepwise analysis. Alone it had comparable power to discriminate cows with reproductive problems during their lifetime based on first lactation variables than the full set of variables. The full set increased the ability to identify cows with no reproductive problems and percent of cows correctly classified. No set of variables showed a high degree of power to separate no problem and problem cows.

Variable means and standard deviations for this group show little differences between groups (Appendix Table 7). Within group correlation matrix values are included in Appendix Table 8.

TABLE 8. Summary of stepwise discriminant analysis for sample group 4[a].

Step number	Variable entered	F value to enter or remove	% lactations correctly classified overall	% lactations correctly classified with no problems[b]	% lactations correctly classified with problems[b]
1	PLM %	0.2802	52.7	46.4	57.3
2	Milk, yield	0.1790	52.7	50.0	54.7
3	Diff. herd[c]-fat	1.1484	51.1	48.2	53.3
4	Diff. herd[c]-milk	0.3946	54.2	55.4	53.3
5	Milk fat, yield	0.6197	51.1	50.0	52.0
6	Type score	0.2990	57.3	58.9	56.0
7	PLM, yield	0.2624	58.0	60.7	56.0

[a] Includes 131 cows and using first lactation variables to predict reproductive problems during lifetime.

[b] Cows with no reproductive problems or those with reproductive problems.

[c] Abbreviation for difference from herdmates-milk or fat.

SUMMARY

A two part study was conducted. First, a study was made to determine the reasons why cows were removed from the South Dakota State University dairy research herd. Experimental animals were those cows removed during the period of time starting January 1, 1968 and ending July 1, 1976.

The four major reasons for cow removal (reproductive problems, type related problems, mastitis, and low production) accounted for the major portion of the reasons why cows were removed. A number of cows were removed for more than one reason. The average lactations per lifetime was considered to be average.

Reproductive problems was the major reason why cows were removed and this level was considered to be higher than what is expected. Type related problems, mastitis, and low production had similar levels of reasons for removal. But, type related problems had it recorded as the sole reason for removal a lower percentage of the time. The level of removal for low production was lower than expected. The remaining reasons for removal accounted for only a small portion of the total reasons.

Results of this part of the study indicated that culling for reproductive problems was a major problem area in the study herd. The high level of involuntary removal for reproductive problems may have reduced the opportunity to select for production in the milking herd. The lower than expected level of selection for production in the milking herd may also have been influenced by the fact that in

research herds there is less of a chance to cull for low production.

In the second part of the study, stepwise discriminant analysis was used to differentiate between lactations and/or cows with or without based on the following discriminating variables: lactation number, yield of 305-ME milk, yield of 305-ME milk fat, age adjusted type score, difference from herdmates-milk, difference from herdmates-milk fat, percent PLM, and yield of PLM. Four sample groups of lactations and/or cows were formed and discriminant analysis run on each group. Experimental animals were those cows that calved after January 1, 1968 and completed a minimum of one record prior to July 1, 1976.

Group 1 was formed with all the lactations (535) and represented 227 cows. All eight discriminator variables were considered for the analysis to identify those lactations with or without reproductive problems. Variables were measured from each specific lactation.

Group 2 consisted of only the first lactation (172) records of cows. Variable 2 through 8 were considered for the analysis to identify those cows with or without reproductive problems during the first lactation. The variables were measured from the first lactation records.

Group 3 consisted of lactations (377) from 131 cows that initiated a first lactation after January 1, 1968 and prior to January 1, 1974. All eight variables were considered to identify those lactations with or without reproductive problems and they were measured from each specific lactation.

Group 4 consisted of the same cows and lactations found in group 3. Variables 2 through 8 were used to identify those cows with or without reproductive problems during their lifetime. Variables were measured during the first lactation.

Groups 1 and 2 were the only groups where a reduced set of discriminator variables were found. The reduced set of variables of group 2 had the highest percentage of lactations and/or cows that were correctly classified with reproductive problems. Group 3 had the next highest level and groups 1 and 4 had similar levels. Results from all groups were variable but all indicated that the selected variables have some ability to identify lactations and/or cows with reproductive problems.

The best set of variables found for group 1 had the highest percentage of lactations and/or cows that were identified correctly without reproductive problems. Groups 3 and 4 showed slightly lower levels and group 2 had the lowest level. Results from all groups were not as variable in identifying lactations and/or cows without problems as compared to the results of identifying lactations and/or cows with reproductive problems. Results of all groups indicated that the selected variables have some ability to identify lactations and/or cows without reproductive problems.

All groups gave similar levels of lactation and/or cows correctly classified overall. Group 2 results gave the highest level of accuracy but only slightly higher than group 4, which had the lowest level. Again the results suggest that the selected variables have some ability to identify lactations and/or cows into those with or without reproductive problems.

Results of this part of the experiment suggests that stepwise discriminant analysis using the selected discriminator variables has some ability to identify lactations and/or cows into those with or without reproductive problems. Identification of reproductive problems in the first lactation appear to be the most promising for further investigation. But the accuracy is not high enough to be reliable. This suggests that there may be some missing variable(s) that may increase the accuracy of identification, or that there are no variables easily measured that could increase accuracy, or this may be the highest level of accuracy that can be obtained. It may also mean that there may be other factors that cannot be measured that might play a part in causing reproductive problems.

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APPENDIX

APPENDIX TABLE 1. Group[a] means, standard deviations, and grand means for 8 variables in sample group 1[b]

Variables	No problem group		Reproductive problem group		Grand
	$\overline{x}$	SD	$\overline{x}$	SD	$\overline{x}$
1 Lactation number	2.42	1.46	2.81	1.63	2.53
2 Milk, kg	6877.38	1366.27	6853.40	1286.01	6870.61
3 Milk fat, kg	238.15	48.75	236.17	47.07	237.59
4 Type score	78.31	4.93	78.89	5.16	78.47
5 Diff. herd[c]-milk, kg	327.49	1349.93	250.22	1332.12	305.68
6 Diff. herd[c]-fat, kg	9.89	47.39	7.77	45.02	9.29
7 PLM %	8.999	.33	8.995	.29	8.998
8 PLM, kg	551.57	119.84	553.45	122.33	552.10

[a]Each lactation separated into groups having no problems or having reproductive problems.

[b]Include all cows (227) represented by 535 lactations.

[c]Abbreviation for difference from herdmates-milk or fat.

APPENDIX TABLE 2. Within groups correlation matrix for sample group 1.

Variables	1	2	3	4	5	6	7	8
1 Lactation number	1.00							
2 Milk, yield	-0.10	1.00						
3 Milk fat, yield	-0.02	0.83	1.00					
4 Type score	0.05	0.06	0.05	1.00				
5 Diff. herd[a]-milk	-0.14	0.96	0.79	0.05	1.00			
6 Diff. herd[a]-fat	-0.06	0.81	0.94	0.05	0.84	1.00		
7 PLM %	-.09	0.01	0.12	0.12	0.01	0.16	1.00	
8 PLM, yield	0.20	0.82	0.70	0.11	0.77	0.69	0.13	1.00

[a]Abbreviation for difference from herdmates-milk or fat.

APPENDIX TABLE 3. Group[a] means, standard deviations, and grand means for 7 variables in sample group 2[b].

Variables	No reproductive problem group		Reproductive problem group		Grand
	$\bar{x}$	SD	$\bar{x}$	SD	$\bar{x}$
1 Milk, kg	7115.98	1278.39	7109.20	1121.21	7114.40
2 Milk fat, kg	245.65	42.50	242.61	37.12	244.94
3 Type score	77.86	5.33	80.17	4.14	78.40
4 Diff. Herd[c]-milk, kg	598.45	1318.26	575.23	1180.69	593.05
5 Diff. Herd[c]-fat, kg	18.07	43.53	16.49	36.87	17.70
6 PLM %	9.05	0.31	9.04	0.29	9.05
7 PLM, kg	517.41	89.80	503.11	88.25	514.09

[a]Cows first lactations separated into groups having no problems or having reproductive problems.

[b]Included all cows (172) having first lactation during study period.

[c]Abbreviation for difference from herdmates-milk or fat.

APPENDIX TABLE 4. Within groups correlation matrix for Sample group 2.

Variables	1	2	3	4	5	6	7
1 Milk, yield	1.00						
2 Milk fat, yield	0.83	1.00					
3 Type score	0.05	-0.003	1.00				
4 Diff. herd[a]-milk	0.96	0.79	0.04	1.00			
5 Diff. herd[a]-fat	0.78	0.91	0.01	0.83	1.00		
6 PLM %	-0.11	0.07	0.18	-0.11	0.10	1.00	
7 PLM, yield	0.89	0.76	0.11	0.85	0.73	0.08	1.00

[a]Abbreviation for difference from herdmates-milk or fat.

APPENDIX TABLE 5. Group[a] means, standard deviations, and grand means for 8 variables in sample group 3[b].

Variables	No problem group		Reproductive problem group		Grand
	$\bar{x}$	SD	$\bar{x}$	SD	$\bar{x}$
1 Lactation number	2.18	1.24	2.50	1.34	2.27
2 Milk, kg	6941.81	1371.18	6890.43	1338.85	6927.50
3 Milk fat, kg	239.42	47.58	236.11	45.88	238.50
4 Type score	78.05	5.39	78.12	5.40	78.07
5 Diff. herd[c]-milk, kg	394.02	1364.52	266.26	1407.76	358.44
6 Diff. herd[c]-fat, kg	12.87	46.55	8.3	44.32	11.60
7 PLM %	9.07	0.35	8.99	0.30	9.01
8 PLM, kg	553.92	120.46	554.40	130.74	554.05

[a]Each lactations separated into groups having no problems or having reproductive problems.

[b]Includes 131 cows represented by 377 lactations.

[c]Abbreviations for difference from herdmates-milk or fat.

APPENDIX TABLE 6. Within groups correlation matrix for sample group 3.

Variables	1	2	3	4	5	6	7	8
1 Lactation number	1.00							
2 Milk, yield	-0.04	1.00						
3 Milk fat, yield	0.06	0.81	1.00					
4 Type score	0.03	0.07	0.05	1.00				
5 Diff. herd[a]-milk	-0.09	0.97	0.77	0.07	1.00			
6 Diff. herd[a]-fat	-0.02	0.80	0.93	0.07	0.83	1.00		
7 PLM %	-0.10	-0.03	0.10	0.12	-0.003	0.16	1.00	
8 PLM, yield	0.22	0.82	0.69	0.13	0.78	0.68	0.12	1.00

[a]Abbreviations for difference from herdmates-milk or fat.

APPENDIX TABLE 7. Group[a] means, standard deviations, and grand means for 7 variables in sample group 4[b].

Variables	No problem group		Reproductive problem group		Grand
	$\bar{x}$	SD	$\bar{x}$	SD	$\bar{x}$
1 Milk, kg	7093.75	1280.77	6989.64	1180.03	7034.14
2 Milk fat, kg	242.48	42.55	243.68	36.48	243.16
3 Type score	77.78	5.91	78.20	5.25	78.02
4 Diff. herd[c]-milk, kg	582.61	1302.99	546.20	1261.47	561.77
5 Diff. herd[c]-fat, kg	17.75	40.05	20.30	40.02	19.21
6 PLM %	9.05	0.36	9.08	0.31	9.06
7 PLM, kg	513.95	94.99	512.53	84.40	513.13

[a]Each cow separated into groups with or without reproductive problems during lifetime.

[b]Includes 131 cows and using first lactation variables to predict reproductive problems.

[c]Abbreviation for difference from herdmates-milk or fat.

APPENDIX TABLE 8. Within group correlation matrix for sample group 4.

Variables	1	2	3	4	5	6	7
1 Milk, yield	1.00						
2 Milk fat, yield	0.81	1.00					
3 Type score	0.03	-0.05	1.00				
4 Diff. herd[a]-milk	0.96	0.76	0.04	1.00			
5 Diff. herd[a]-fat	0.78	0.89	0.001	0.82	1.00		
6 PLM %	-0.11	0.05	0.18	-0.10	0.08	1.00	
7 PLM, yield	0.86	0.72	0.08	0.83	0.69	0.09	1.00

[a]Abbreviation for difference from herdmates-milk or fat.