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I am submitting herewith a thesis written by Thomas H. Short entitled "The correlated response in health cost accompanying selection for milk yield in Jerseys." I have examined the final electronic copy of this thesis for form and content and recommend that it be accepted in partial fulfillment of the requirements for the degree of Master of Science, with a major in Animal Science.

Benny R. Bell, Major Professor

We have read this thesis and recommend its acceptance:

S.P. Oliver, F.M. Hopkins, R.G. O'Brien

Accepted for the Council:
Carolyn R. Hodges

Vice Provost and Dean of the Graduate School

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THE CORRELATED RESPONSE IN HEALTH COST ACCOMPANYING SELECTION FOR MILK YIELD IN JERSEYS

A Thesis
Presented for the
Master of Science
Degree
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ABSTRACT

Health data were recorded for 567 and 193 cows in selection and control herds, respectively. Health costs were expenses due to drugs, labor, and veterinary charges. Health expenses were grouped into one of six health functions: 1) mammary, 2) locomotion, 3) respiration, 4) reproduction, 5) digestion, and 6) other. Costs were summed across lactation and discounted to birth at rates of 0%, 3%, and 6%. Data were analyzed using a model that included year-season, parity, line, sire (line), and lactation length. Selection cows had significantly (P<.001) higher health costs at all three discount rates. Differences were mainly due to higher (P<.01) mammary costs. Differences between lines for other individual function costs were not significant, but were higher in selection cows. Parity, year-season, and stage of lactation were significant (P<.001) non-genetic sources of variation in health costs. Costs were greater for third and later parities and during the first 30 days of lactation. Results indicate that health costs are likely to increase with selection for milk yield; however, additional revenues from increased yield would offset added costs. Increased management in early lactation and later parities may decrease health expense.

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CHAPTER I

LITERATURE REVIEW

Introduction

Several aspects are reviewed to provide a basis for the present study. First, some concepts are presented on factors affecting the efficiency and profitability of dairy cattle. Second, methods of evaluating dairy cattle profitability using models are presented. The last section reviews information pertaining to dairy cattle health and its relationship with profitability. This section examines preventive herd health programs, the role of mastitis and infertility in overall dairy cattle worth, response of health costs to selection, and other studies relating to dairy cattle health.

Evaluation of Efficiency and Profit in Dairy Cattle

Determining overall worth of dairy cattle is a major objective of dairy cattle breeders. Yield is the major indicator of overall worth, however, other factors need to be considered. Legates (30) stated that "high milk yields are usually more efficient, but management and labor costs may dictate that the ultimate in production may not be desired for maximum profitability".

Efficiency of milk production has been examined (9,24,72, 73). Dickinson et al. (9) defined efficiency as the ratio of milk produced to feed consumed without consideration of additional inputs. Young (72) defined total efficiency as the ratio of the value of milk plus the value of progeny to the cost of feed, health care, and physical plant. Physical plant was the capital cost of providing and maintaining buildings, grounds and equipment needed in maintaining the dairy operation. He also stressed the need for records concerning individual cow care to effectively evaluate cows for efficiency with which they convert labor into milk.

Harris (24) discussed efficiency in livestock production. He stated that the primary goal of livestock producers is to "make money" and that the goal of genetic improvement in livestock should be one of the following: 1) profit (income minus expenses), 2) return on investment (income/expenses), or 3) cost per unit production (expenses/product). He suggested evaluating the potential amount of economic progress possible in a selection scheme relative to the cost of making that improvement. To do so, one needs to know the economic importance of the trait considered, the potential for genetic improvement, and the cost of measuring the trait.

Profit functions have been used to evaluate profitability in dairy cattle (1,4,18,19,47,63). The objectives of these studies were: 1) to evaluate income and expenses associated with milk production, 2) to determine relationships between various traits and profit, 3) to determine levels of certain variables that maximized returns, or 4) evaluate alternative selection strategies.

Pearson (46) discussed some general problems associated with the economic evaluation of dairy cows. He proposed that profit defined as income minus expenses was a better measure for economic evaluation than income divided by expenses because dairy producers are usually interested in improving profit rather than efficiency. Determination of items to be included should be based on their magnitude and variation among cows. He concluded that increased profit was not completely associated with increased production.

Gill and Allaire (18) studied relationships of breeding and management factors to economic return using lifetime records from 933 Holstein cows. Their profit function included milk production, body weight, reproductive performance, herdlife, and prices for feed, milk, calves, and salvage value. Information available on individual cows included milk yield for each lactation, weight at first calving and maturity, number of inseminations, and ages at calvings and disposal. Variable cost included cost of estimated net energy, breeding cost, and rearing costs. Other expenses, such as labor and veterinary costs, were considered fixed. Maximum profit per day of herdlife was obtained from cows calving for the first time at 25 months of age, being open 124 days and dry 42 days.

Andrus and McGiliard (1) used a regression equation to develop economic weights for milk production, mastitis, milk fat test, live freshenings, herdlife, body weight, and milking time to predict profit per year of herdlife. Standard partial regression coefficients of profit per year of herdlife on these traits were .64, -.38, .31, .22, .10, .09,and .03, respectively.These coefficients showed that milk was the most important factor in predicting profit per year of herdlife, followed by mastitis, milk fat, and live freshenings.

Gilmore (19) developed a model for annualized net income which incorporated health costs in addition to other costs. Other costs and revenues were similar to those used in previous studies (1,18). Dairy character, first lactation milk yield, and milk fat, accounted for 27% of the variation in annualized income. Annualized health costs were not associated with annualized income, however mastitis and reproduction costs were. Correlations between income and costs of mastitis and reproduction were .18 and -.31, respectively.

In another study, Dairy Herd Improvement variables were used to predict lifetime profitability (63). Two methods were used to predict lifetime total profit and profit per day. These were a relative net income function, calculated from lifetime milk and fat production, age at first calving, number of freshenings, and days of herdlife; and best fit regression models using one to four variables. The R^2 value for the relative net income function was .95, compared to .96 using the best fit regression equation with all four variables included in predicting total profit. The best fit regression model with these variables for predicting profit per day yielded an R^2 value of .86, compared to .85 for relative net income per day. The relative net income function was more successful in predicting total profit rather than profit per day.Value of milkand daysof herd-life were the most significant perdictors of total profit, followed by number of freshenings and age at first calving.

Bertrand et al. (4) developed a profit function that accounted for input and output costs associated with milk production. The profit function was used to evaluate daughters of high versus daughters of average Predicted Difference Milk (PDM) Holstein sires. Daughters of high PDM sires netted 18% more profit per day as well as 18% lifetime profit.

<u>Response in Health Cost to Selection for Milk Yield</u>

Over the past few years, intense selection for milk yield has occurred. The direct response has improved milk production, however, there may be some unfavorable correlated responses in other traits following single trait selection for milk. Among these are increased health costs. Young (72) stated that dairy prroducers believe selection for milk yield increased health disorders requiring individual attention, however supportive data was not available at that time. Recent studies (1,4,19,20) previously described have documented the effect of health costs on profitability and total economic merit.

A report by Gilmore and McDaniel (20) found a positive relationship between milk yield and frequency of treatment for disease. Cows with higher first lactation milk yield had a tendency to have higher annualized health costs. Mastitis and reproductive costs accounted for over 80% of the direct health costs.

Shanks et al. (54) studied the effect of selection for milk production on reproductive and general health in Holsteins. A base population of forty-three pairs of heifers of high versus average breeding values were mated to high PDM and average PDM Holstein sires, respectively. Milk yield was higher ($P<.001$) for the high breeding value group. Daughters of bulls selected for yield had 9% more digestive disorders, 5% more foot rot, 14% more skin or skeletal disorders, 11% more cases of udder edema, and 2% more lactations affected by mastitis than those of breed average sires. Health costs were $12.46 greater for the high breeding value group. Daughters of the high PDM sires produced more milk, had 8% fewer systemic uterine treatments, 3% fewer mammary cuts, more joint or leg injuries, 13% more skin or skeletal disorders, and 19% more cases of udder edema than did daughters of average sires.

In a study by Hansen et al. (22), health costs were estimated for high versus low breeding value groups. High breeding value cows yielded more milk, but had an increase in labor and expense for health care. Estimates of labor for the selection group were greater for mammary, locomotion and digestion categories, and for expense in mammary, respiration, first insemination, and later insemination categories. Total health costs including labor were $27.00 greater for the high breeding value group.

Wilk et al. (68) recorded health related disorders in the Randleigh Jersey herd to evaluate changes in health costs resulting from selection based on PDM. Comparisons between the high milk line and control line revealed that milk production, incidence of mastitis, treatment for improvement of breeding efficiency, metritis, edema, and total disorders increased as a result of selection. Significant increases were observed for total disorders, mastitis incidence, and treatment for breeding efficiency for each successive generation after four generations of selection.

A later report by Bertrand et al. (4) examined differences in health cost between daughters of sires selected for high and breed-average PDM. Daughters of high PDM sires produced 16% more milk, however they had 9% more respiratory costs, 6% more digestive costs, 8% more skin and skeleton costs, 26% more mammary costs, and 42% more discarded milk costs. Disregarding breeding costs, health costs were 21% higher for high PDM cows. Including breeding costs, total health costs were 32% higher.

Other evidence of association between increased milk yield and incidence of mastitis has abeen documented. O'Bleness et al. (43) found a genetic correlation of .44 between milk yield and incidence of clincial mastitis. Wilton et al. (69) reported genetic correlations of .30 between milk yield in first lactation and mastitis incidence in later lactations. Gilmore and McDaniel (20) found a positive correlation between first lactation yield and annualized health costs.

In contrast to other studies, Shanks et al. (56) found no significant relationship between level of milk production and health care costs when data from Iowa, Minnesota, and Beltsville were pooled and analyzed using production level in the model instead of genetic group. Health costs were higher for the highest producing group, but not significant.

In a study by Mahoney et al. (33), health care requirements were evaluated for cows selected for large versus small body size. Estimates of health costs were nearly twice as great for large cows. The difference of $5.50 between groups attributed largely to the $3.69 difference for digestive costs. Nearly all costs for digestive disorders were displaced abomasums. Apparently large cows were more predisposed to displaced abomasums which resulted in significantly greater health costs for large cows during first lactation.

While there may be some disagreement about the effect of selection for high yield on health costs, all studies were in agreement about the profitability of selection for increased production. Additional health costs incurred by daughters of high PDM sires were more than offset by increased milk revenues.

Factors Affecting Health Costs and Disorders

Genetic Effects

Genetic selection for reduced health costs is one potential method to increase profit and combat unfavorable correlated responses in health disorders. Selection for disease resistance would be effective if resistance is heritable, and accurate and economical measures of resistance could be found. Little information on heritabilities (h^2) of most health traits is available.

Many researchers have investigated the h^2 of mastitis. Estimates vary due to the measure of mastitis. Three studies (53,69,71) reported h^2 estimates for bacteriological tests. These studies involved repetitive bacteriologicalevaluation of all quarters for specific pathogens known to cause mastitis. Heritabilities from these studies averaged .11. Another direct measusre of mastitis is the recording of clincial cases. Estimates of h^2 for clinical cases in the literature (43,69,71) ranged from .00 to .50, and averaged .12. Heritability estimates of clinical infections tended to increase from first to later lactations (43,69,71).

Other potential measures of mastitis are indirect indicators, such as milk somatic cell count (SCC). Somatic cells are an indirect indicator of the presence of infection since the number of phagocytic cells in the udder increases in response to infection. Heritabilities for SCC found in the literature averaged .20, which is a substantial increase when compared to h^2 estimates from direct measures.

Miller (40) reviewed traits related to udder health and management to be considered in sire selection. Bacteriological evaluation of quarters helped identify infection, but was impractical on a large scale. Recording of clinical mastitis failed to indicate subclinical cases. Somatic cell counts are economical to obtain, but are highly variable, difficult to interpret, and are not sensitive indicators of subclinical infections. An apparent genetic antagonism exists between cell count and milk yield (r=.15). This unfavorable correlation and confusion about the role of elevated SCC as a defense mechanism suggested that selecting sires whose progeny have low cell counts should be considered carefully (40).

Enhancing an animals protective immune system is one method to combat disease. A report by Gaunt et al. (17) suggested selecting for lactoferrin as an aid in controlling mastitis. A moderate heritability (.44) plus considerable sire differences suggest genetic differences. If so, selection could be effective for a higher lactoferrin content. However, the cost of lactoferrin concentration measurement would have to be considered.

Dairy producers have attempted to decrease udder problems by selection for udder conformation traits. A study (39) comparing progeny from bulls selected for yield with those from bulls selected for yield and udder conformation failed to find differences in measures of clinical mastitis. Other studies (66,70) reported a relationship between udder height and mastitis. Cows with deep udders are more susceptible to injury and mastitis. Selection against deep udders appears warranted.

Few reports are available concerning genetic variation in other disorders in dairy cattle. Heritabilities of cystic ovaries range from .16 (7) to .43 (12). Erb et al. (12) estimated heritability of .38 for retained placenta. Philippson et al. (49) estimated heritabilities for the following dairy cattle disorders; ketosis (.07), milk fever (-.003), foot, leg or locomotive disease (.13). Van Vleck (64) reported a h^2 estimate of metabolic disease of approximately .25.

Reproductive problems are due to many various components including calving problems, cystic ovaries, and low conception rates. Heritabilities for calving difficulty are low, whether measured as a trait of the calf (direct effect) or as a trait of the dam (maternal effect). Thompson et al. (62) estimated heritabilities of direct effects for dystocia of .08 for heifers and .04 for cows. Heritabilities as a maternal effect were .03 for heifers and .01 for cows. Thompson et al. (61) found genetic correlations between dystocia and sires PDM, PD fat, PD%, and PD$, to range from -.04 to .03 for 423 Holstein sires. Little relationship was found between dystocia and production traits suggesting selection for milk yield would not increase dystocia. However, transmitting abilities of dystocia were negatively correlated with PD type and Total Performance Index. Correlation were from -.23 to -.29, respectively. Selection for type would be expected to slightly increase dystocia. Bulls currently are evaluated for dystocia in addition to production traits. Dairy producers can reduce calving difficulty and associated reproductive costs by not breeding heifers to bulls with high probabilities of difficult births.

Genetic relationships between yield and fertility have been reported from studies using field data and designed experiments. Laben et al. (29) found a small, but significant antagonistic association between yield and fertility after adjustment for herd-year-season and parity in DHI data. Berger et al. (3), using DHI data, reported that genetically higher-producing cows bred later, took longer to conceive, and required more services per conception. These results agree with Coleman et al. (8) and Spalding et al. (60). Others have also found genetic antagonism between yield and fertility (16,29). However, Laben et al. (29) reported that herds in California with highest yields also had best reproductive performance.

The association of yield and fertility has been examined in designed experiments. Herds at Iowa State University (54), the University of Minnesota (22), and the University of Wisconsin (32), were selected for milk production using high PDM sires. Contemporary groups were selected for either average production or were an unselected control population. Fertility was not significantly different between groups within any of the herds. Better reproductive management may have been the reason for lack of differences, as opposed to producer herds. In addition, only 16% of the genetic variance of fertility was associated with yield (16).

Heritability estimates of measures of reproductive performance are low. Miller et al. (37) reported heritabilities of .04 for calving interval. Schaeffer and Henderson (52) estimated heritabilities for days open in first, second, and third lactations of .02, .04, .00, respectively. Berger et al. (3) obtained heritabilities of .04 for days to first breeding, .04 for days to last breeding, .02 for days open, and .01 for number of services per conception in first lactations. Current prospects of improving fertility via selection are dim due to negligible h^2 estimates for reproductive traits.

Environmental Sources of Variation in Health Cost

Health costs are more affected by non-genetic sources than genetic sources. Hansen et al. (23) examined non-genetic sources of variation in health disorders and costs. Stage of lactation was the greatest source of variation with costs in early stages quadruple that of later stages. Shanks et al. (55) found similar results. Increased health costs in earlier stages of lactation are due to disorders related to calving, such as dystocia, retained placentas, and milk fever. In addition, Smith et al. (58) reported that clinical cases of mastitis were highest during the first 76 days of lactation. Over one-half of these cases during this period were the result of infections originating in the dry period.

Health care costs increase with age of cow (23,55,68).

Hansen et al. (23) indicated that estimates multiplied threefold from first to fifth and later parities. Gilmore and McDaniel (20) reported a $9.00 increase in health cost per successive lactation. Shanks et al. (55) also found more total health, mammary and reproductive costs for cows in later lactations than first parity cows. Researchers (42,58,69) have reported increased rates of intramammary infections in later parities. Older cows have also increased risks of retained placenta, metritis, cystic follicles, and luteal cysts, whereas young cows have increased risks of dystocia (14). Parity also affects conception rates. Fertility was found to be higher in heifers than lactating cows and younger cows than older cows (8,16,29).

Calving year, season, and season and stage of lactation interaction were significant contributors to health costs (23,55,68). Shanks et al. (55) found a significant interaction between season and stage of lactation, indicating a late summer through early winter calving advantage in decreasing annual requirements of health care. Season affected rate of mastitis infection (58), with summer months showing maximum new infection rates. McDowell and McDaniel (35) found seasonal influences for mastitis incidence and severity in a crossbreeding study. In addition, Gwazdauskas (21) reported lower conception rates during extremely hot and cold periods. Erb and Martin (13) found seasonal effects on reproductive diseases. Cows calvings in the late fall and early winter had increased risk of dystocia. Lactations begun in late summer to early fall had increased risk of metritis. Retained placentas, cystic follicles, and luteal cysts diagnoses showed no seasonal patterns.

Lactation length has also been found to influence health cost. Hansen et al. (23) found a covariable to adjust for length of lactation to be significant ($P<.001$). Shanks et al. (56) reported lactations of greater lengths to be associated with higher health cost. They also found greater health costs in terminal lactations.

Results of research to date indicate that management during the dry period and during the month following parturition are critically important. It is also important to observe older cows closely and avoid calving in certain seasons of the year. Concentrated efforts to improve management during these periods would reduce health costs.

Preventative Medicine Programs

Barfoot et al. (2) appraised the economic value of a preventative medicine program for dairy herds utilizing different levels of veterinary service. The control group was subjected to emergency veterinary service only and each of the remaining four groups represented increasing levels of veterinary service. Five specific variables relating directly to herd health were studied and analyzed in each of the five systems. They were: 1) milk production, 2) calving probability and days open, 3) calf mortality, 4) cow mortality, and 5) culling rate. Average services and supplies per cow were $8.00, $20.00, $25.00, $30.00, $35.00 for the control group and the four preventative programs, respectively. Average days open, cow mortality, calf mortality, culling rate, and milk production level for the control group were 138.5, 2.5%, 11.8%, 13.5% and 11,830 lbs., respectively. The first four categories decreased and the last category increased as veterinary service increased. For the most intense level of veterinary service the corresponding values were 123.6, 1.9%, 7.5%, 8.1%, and 13,020 lbs. In an analysis of income over health costs, the percent return ranged from 32.9% under the least intensive control program at the lowest level of milk production to 502.2% for the most intense level of health care at the highest possible level of milk production.

In another study, McCauley (34) reported the average value of marginal product for veterinary service for a group of southern Minnesota farms was $2.96, indicating income would increase an average of $2.96 for each additional $1.00 spent for veterinary service. Analysis also showed that as the intensity of veterinary service increased, the contribution of veterinary service to income approached diminishing returns.

Blosser (5) estimated losses of $1.294 billion to the

US dairy industry in 1976, as a result of mastitis. Preventative measures could reduce these losses by 50% or more (26). Dry cow therapy and teat dipping are the two most recommended procedures in controlling mastitis. Many studies have indicated that dry cow therapy and teat dipping reduced mastitis (10,27,41,50,51,65). Most indicate that these procedures used in conjunction with a sanitary hygiene program can successfully reduce or eliminate Streptococcus agalactiae or Staphlococcus aureus infections. However, postmilking teat dipping is less effective or ineffective in reducing rate of new infection by environmental pathogens (11).

Smith et al.(58) evaluated environmental effects on mastitis and described two approaches as probable control methods. The first approach was to decrease exposure of teat ends to environmental pathogens. This method would reduce the frequency of these pathogens in the environment of the cow, and decrease exposure of teat ends ends to environmental pathogens. The second approach involved increasing resistance of cows to infection through immunization, use of intramammary devices, or altering diets of dairy cattle by increasing vitamin A, vitamin E and selenium contents. They concluded that further research is needed if control of mastitis caused by environmental pathogens is to be achieved.

Reproductive failure causes economic loss directly to the dairy industry as a result of its affect on yearly milk producton and surplus calves for sale, and indirectly because the potential selection differential is reduced with fewer replacements (31). Surveys of dairy cattle enrolled in DHIA showed that sterility is the second most frequent cause of culling (44). Pelissier (48) estimated losses of nearly $1.3 billion due to reproductive and infertility problems.

Oltenacu et al. (45) used simulation studies to determine effects from improvements in rates of detection of estrus and conception. When conception rate was held constant (.5), a 20% improvement in heat detection resulted in an additional return of $60/cow/year. When heat detection rate was held constant (.55), changing conception from .42 to .58 resulted in a loss of $7/cow/year. These results indicated a point of diminishing returns is reached soon beyond a heat detection rate of .6 and a conception rate of .5.

In a review of the relationship of reproductive performance and economic returns, Britt (6) concluded that benefits will most likely result from day to day management of dairy cattle. He emphasized that the modern dairy cow "requires high management to produce large amounts of milk and to reproduce at a satisfactory rate simultaneously, and that greater financial losses due to infertility may be incurred if this fact is not recognized".

CHAPTER II

MATERIALS AND METHODS

Experimental Population and Sire Selection

In 1967, the herd at the Dairy Experiment Station (DES), Lewisburg, Tennessee was divided into two breeding groups. Cowswere assigned randomly within sire groups on a 3:1 ratio to selection or control lines, respectively. The selection line of 120 cows and associated young stock was bred to Artificial Insemination (AI) sires available with the highest Predicted Difference (PD) for milk. Sires were required to have at least 60% repeatability. Once selected, sires were used for four consecutive years with a new bull added to the group each year. Exceptions were three of the initial sires and certain bulls with limited availability. The 17 sires used in the selection line are shown in Table 1. Culling of females in the selection line aside from involuntary reasons was based on milk yield.

The control line of 40 cows and associated young stock were mated to 20 young sires which were selected randomly from AIsampling programs at the timethe project was initiated. Inaddition, four young sires bred at the DES with similar pedigree indices were used. The 24 sires used in the control group are presented in Table 2. Culling of females in the control line beyond involuntary losses was at

Table 1. Selection Group Sires at the Dairy Experiment Station.

Sire	DOB	Latest (PD82) Predicted Difference[b]				
		Rpt.	Milk	%	BF	$
Brigham Confident Infred	12-52	91	-228	-.05	-16	-42
Sybil Royal Predictor	3-56	95	-188	+.11	+ 3	- 7
Sybil Carletta's Finalist	5-57	97	+ 20	-.12	+15	+27
Nobleman's Lotus Designer	11-58	99	- 41	+.03	+ 1	- 1
Observer Signal Revival	12-56	96	+ 4	-.10	-11	-19
Observer Chocolate Soldier	4-72	98	+535	-.06	+18	+62
Milestones Generator	9-64	99	+176	-.23	-19	-21
Secret Baronet	9-64	99	-212	+.15	+ 7	- 2
SS Quicksilver of Fallneva	8-60	99	- 10	+.27	+31	+52
Vaucluse Sleeping Surville	1-66	99	-289	+.10	- 3	-24
Milkboy Happy Hill Abe	10-68	98	-164	+.07	+15	+38
Supreme Virginian	4-70	98	+258	-.11	- 1	+15
Glen Meadows Jeweled Mark	11-65	98	-160	-.03	-11	-29
Briarcliff Bold Torono	5-70	98	+524	-.30	-11	+15
Starn General	2-72	98	+850	-.21	+14	+78
Favorite Saint	1-74	98	+624	-.24	+ 1	+42
Briarcliff Soldier Boy	1-72	95	+913	-.09	+32	+113

[a] DOB= Date of birth

[b] Rpt.= Repeatability, Milk= lbs. milk, %= Percent butterfat, BF= lbs. butterfat, $= Dollars.

Table 2. Control Group Sires at the Dairy Experiment Station.

Sire	DOB	Latest (PD82) Predicted Difference[a] Rpt.	Milk	%	BF	$
Sables Sybil Ira	11-64	64	- 560	.00	-27	- 82
Milestones Bellringer	5-64	89	-1156	+.28	-26	-119
Secret Baronet	9-64	99	- 212	+.15	+ 7	- 2
Headspring Sparkle	11-64	66	-1130	+.18	-35	-132
Jester Infred Scotty	12-64	81	- 474	+.06	-16	- 58
UK Cherry Kelvin	4-65	59	- 129	+.17	+13	+ 14
Confident Jeweler	2-65	79	- 458	+.08	-13	- 52
Stardust Itaska Designer A	4-65	91	-1003	-.11	-60	-167
Marlu Stylist Beacon	4-65	--	-1382	+.09	-57	-186
Headspring Sleeping Goliath	3-65	82	- 812	+.09	-29	-102
Pixys Fancy Voyageur	1-65	80	- 705	+.05	-28	- 93
Jestermans Standard Basil	3-65	95	- 700	+.25	- 6	- 55
Marlu Tempo	8-65	94	- 965	.00	-46	-141
Patience Supreme	3-65	70	-1088	-.07	-59	-171
Beauty's Advancer	8-65	45	-1174	+.02	-54	-168
Borgs B. Etta Preceptor	6-65	57	-1364	+.05	-60	-190
Vaucluse Dazzling Rosemont	11-65	85	-1746	+.24	-60	-215
Cherry Secret Noble	8-65	81	-1010	+.12	-36	-126
Tymor Gipsy Snoball	9-66	75	-1434	+.21	-47	-172
Confident Infred Basil	10-65	66	-1214	+.06	-52	-167
Tenn. Confident IEB Lad	5-70	92	+ 561	-.14	+10	+ 53
L23[b]	N/A	N/A	N/A	N/A	N/A	N/A
L157[b]	N/A	N/A	N/A	N/A	N/A	N/A
L213[b]	N/A	N/A	N/A	N/A	N/A	N/A

[a]DOB= Date of birth, Rpt.= Repeatability, Milk= Lbs. milk, %= Percent butterfat, BF= Lbs. butterfat, $= Dollars.

[b]Information not available.

random. No mating was made in either herd which would result in an inbreeding coefficient of $\geq$6.25%.

Animals culled randomly from the control herd which had production merit to remain in the herd entered a miscellaneous herd. Their records after the time they moved into the miscellaneous group were not included in the analyses. Offspring born to these cows entered the selection group as foundation animals.

Animals were culled as nonbreeders from both herds if they were not pregnant by 305 days or six services. In addition, animals were culled for involuntary reasons such as health problems. First lactation animals were required to milk at least 90 days before removal in both the control and selection herd.

Both herds were housed in a free stall, loose housing barn. They were milked in a double-two walk-through parlor in which they received an 18% grain supplement in quantities relative to individual production. Otherwise, cows were fed and managed the same.

Data Collection and Description

Number of lactations of cows in each line and generation are shown in Table 3. Foundation animals were not included. There were 567 and 193 cows in the selection and control lines, respectively.

Incomplete lactations were included since the lactation

Table 3. Numbers of Lactations of Cows in each Generation[a].

Generation	Selection	Control
1	600	172
2	474	152
3	287	113
4	127	66
5	38	23
6	1	1
Total	1527	527

[a]Foundation animals not included.

may have been terminated by a health disorder.However, only lactations of 15 days or greater were used in the analysis. Lactation length was defined as the period of time from parturition to the next parturition. Mean lactation length was 315.1 days. Number of lactations initiated in each season are shown in Table 4. There were 2036 lactations of 760 cows calving between 1970 and 1984 in the data set. Due to smaller subclasses of later lactations, third and later lactations were pooled. Also, fourth and later generations were pooled .

All health disorders and treatments were recorded for animals from birth until the date of disposal. However, only health disorders encountered after first parturition were used in the analysis.

Health costs included costs of drugs, medication, and labor, or charges by a veterinarian to compensate for labor, drug expense, and use of equipment. Costs of medication were obtained from veterinarians who provided services to the herd, and the University of Tennessee College of Veterinary Medicine. Drug costs used in the study were based on 1985 prices.

Labor was time expended to care for health disorders. The length of time to treat the disorder was entered for each disorder. Labor was entered at a minimum rate of 15 minutes. Length of treatment time depended upon the nature ofthe treatment required.Cost of labor was calculated by

Table 4. Number of Lactations initiated by Line and Season.

Season	Selection	Control
January 1 - March 31	322	97
April 1 - June 30	105	32
July 1 - September 30	559	188
October 1 - December 31	531	519

multiplying an average hourly wage by the time required to treat the disorder. The hourly wage used to calculate labor cost was $8.00, which is representative of a typical herdsmens' wage. Veterinarian labor cost were included in veterinary charges.

Health disorders were grouped into functions suggested by Young (72). These categories were comprised of related health problems or preventative measures. The six functions and examples of each are:

1) Reproduction - retained placenta, metritis, cystic ovaries,
2) Digestion - bloat, hardware, displaced abomasum,
3) Locomotion - foot rot, joint injury,
4) Respiration - pneumonia, shipping fever,
5) Mammary - masitits, edema, dry treatment,
6) Other - milk fever, ketosis, pinkeye.

Total health cost was the cost of treatment, both medication andlabor, of each cow for each lactation. Analyzing data using a lactational format seemed appropriate since most inferences concerning dairy cattle production are presented on a lactation basis.

Many researchers have indicated the need to adjust for costs or revenues that are incurred at different times in an animal's lifetime, as well as account for differences in the value of money over time (15,38,57). Since health expenditures occur at different times in animal's life, discounting was used to adjust for the timing of expenses and the time value of money to provide a more accurate economic appraisal. Total lactation health costs were discounted back to the year of birth for each animal using the following formula:

$$DC = \frac{E}{(1 + r)^t}$$

where:

DC = discounted cost

E = value of lactation health cost to be discounted

r = discount rate

t = time period over which the cost was discounted

The real interest rate was used as the discounting rate in this study. Real interest rate, or effective annual interest rate, is equal to the nominal rate minus the inflation rate. Smith (57) first suggested use of the effective annual interest rate to evaluate alternative genetic programs. The typical real interest rate paid by dairy producers is about 3%. However, todays real interest rate approaches or slightly exceeds 6%. This is an historically high value and most likely will not continue. The value has also approached zero, therefore, discount rates of 0, 3, and 6% were examined to determine effects of increased real interest rates. Discounting was used to evaluate total health costs and individual categories and was not used to examine stage of lactation effects.

Method of Analysis

To investigate genetic and non-genetic effects in health cost Model 1 was used:

Model 1

$$Y_{ijkl} = u + R_i + L_j + N_k + S(L)_{l(j)} + bD_{ijkl} + e_{ijkl}$$

where:

Y_{ijkl} = labor and/or expense accumulated for a function or lactation or stage of lactation period from a cow calving in the i^{th} year-season from the j^{th} line in the k^{th} lactation from the l^{th} sire within the j^{th} line

u = overall mean

R_i = effect of the i^{th} year-season of calving

L_j = effect of the j^{th} genetic line

N_k = effect of the k^{th} lactation number

$S(L)_{l(j)}$ = effect of the l^{th} sire within the j^{th} line

b = partial regression coefficient of Y_{ijkl} on D_{ijkl}

D_{ijkl} = length of lactation in days

e_{ijkl} = residual

The linear partial regression coefficient (b) on the number of days in lactation (D) was used to adjust for different lactation lengths. This covariate was used only to evaluate total health costs and was not used in analysis of individual categories or stage-of-lactation effects. Several derivations of the above model were evaluated. Generation within line was originally added to the model but was removed due to nonsignificance and confounding with lactation number in estimating least squares means.

To examine the effect of a line by year-season interaction, Model 2 was used. Model 2 was identical to the previous model. However, a line by year-season term was added.

To more closely examine the line by year-season interaction, year-season was divided into year fresh and season fresh. Model 3 included interactions of line with year fresh and season fresh and is shown below:

<u>Model 3</u>

$$Y_{ijklm} = u + R_i + E_j + L_k + N_l + S(L)_{m(k)} + RL_{ik} + EL_{jk} + bD_{ijklm} + e_{ijklm}$$

where:

Y_{ijklm} = labor and/or expense accumulated for a function or lactation or stage of lactation period of a cow calving in the i^{th} year and j^{th} season from the k^{th} line in the l^{th} lactation from the m^{th} sire within the k^{th} line

u = overall mean

R_i = effect of the i^{th} year fresh

E_j = effect of the j^{th} season fresh

L_k = effect of the k^{th} genetic line

N_l = effect of the l^{th} lactation number

$S(L)_{m(k)}$ = effect of the m^{th} sire within the k^{th} line

RL_{ik} = interaction of the $k^{\underline{th}}$ line and $i^{\underline{th}}$ year fresh

EL_{jk} = interaction of the $k^{\underline{th}}$ line and $j^{\underline{th}}$ season fresh

b = partial regression coefficient of Y_{ijklm} on D_{ijklm}

D_{ijklm} = length of lactation in days

e_{ijklm} = residual

A line by lactation number interaction was included in Model 3, but was found to be non-significant and was removed.

CHAPTER III

RESULTS AND DISCUSSION

Direct Response to Selection

Response to selection for milk yield has been an important aspect of the Regional Dairy Cattle Improvement Project entitled "S-49". Direct response to selection based on increased milk yield has been reported in the S-49 project (25,47,67). Cattle selected for increased milk yield were compared to daughters of control sires (25,67) in Jersey herds, and to daughters of sires selected for net genetic merit in Holstein herds (47). Least squares means of production traits for first lactation cows at the DES are shown in Table 5. Selection females produced more mature equivalent (ME) milk and fat, and fat-corrected (FC) milk (P<.01). However, butterfat percentage decreased significantly (P<.05). Wilk and McDaniel (67) found similar results in Randleigh Jerseys.

Genetic Effects on Total Health Cost

The data set analyzed included health cost of 2036 lactations of 760 cows. F-values of genetic effects using Model 1 are shown in Table 6. All main effects were significant (P<.001), including the covariable (P<.05). Least squares means of health costs by line are shown in Table 7. Health costs decreased geometrically as the

Table 5. Least Squares Means of Production Traits by Line in First Lactation Cows at the Dairy Experiment Station[a].

	n	ME Milk(kg)	ME Fat(kg)	FCM (kg)	Fat %
Selection	446	6329±145	294±6	6936±143	4.68
Control	180	5754±138	277±5	6457±136	4.83
Difference		575**	17**	479**	-.15*

[a]Source: Hollon et al. (25)

*P<.05

**P<.01

Table 6. F-values and Residual Mean Squares for Discounted Health Costs using Model 1.

		Discount Rate (%)		
Main Effect	DF	0	3	6
Year-Season	56	2.24***	2.13***	2.05***
Lactation Number	2	15.72***	10.74***	6.84***
Line	1	11.20***	12.17***	13.05***
Sire(line)	40	1.81***	1.90***	1.99***
Lactation Length	1	5.35*	5.64*	5.62*
Error M.S.	1935	951.46	740.94	588.34

*P<.05

***P<.001

Table 7. Least Squares Means of Discounted Costs by Line using Model 1.

	Discount Rate (%)					
	0		3		6	
	Mean	SE	Mean	SE	Mean	SE
	$					
Selection	28.15	±1.88	25.21	±1.66	22.69	±1.48
Control	19.98	±1.85	17.69	±1.63	15.75	±1.45
Difference	8.17***		7.52***		6.94***	

***P<.001

discount rate increased, indicating that higher real interest rates had a smaller effect on discounted values. Costswere greatest for the 0% discount rate since differences in the value of money over time were not included. Differences in health costs between selection and control groups were \$6.94, \$7.52, and \$8.17 for 6%, 3%, and 0% discount rates, respectively. These differences are in general agreement with other studies involving Holsteins (22,54). Shanks et al. (54) reported that health costs were \$12.46 higher in first lactation for high pedigree cows compared to low pedigree cows and \$9.69 higher for daughters of high PDM sires compared to average PDM sires. Line differences indicate that selection for milk yield can be expected to increase health costs.

Others have reported differences in sire groups for occurrence of health disorders. Solbu (59) found significant differences between sires for teat injuries, locomotive diseases, and total veterinary treatments in a Norwegian study. Philipsson et al. (49) found significant differences between sires for teat injuries, locomotive diseases, and total veterinary treatments in two breeds of Swedish dairy cattle.

Genetic Effects on Labor Requirements and Cost

The total cost of a health disorder included the cost of drugs or veterinary expense plus the cost of labor. The cost of labor was the amount of time spent to treat a disorder multiplied by a hourly wage. Genetic effects on labor were evaluated using Model 1. F-values for the genetic effects on labor are shown in Table 8. Both genetic line and sire within line were highly significant (P<.001) contributors to labor required. Least squares means of labor by line are shownin Table 9.The 1.79 of hours labor required for selection cows was higher (P<.001) than 1.26 hours for controls. These requirements equate to labor cost of $14.30 for selection animals, compared to $10.08 for controls and represented 50% of total health costs for each line. Hansen et al. (22) reported annual labor requirements of 2.24 hours for selection cows versus 1.66 hours in Holstein cows in the Minnesota experiment. At an hourly wage of $8.00, these values correspond to cost of $17.92 and $13.28 for selection and control cows, respectively. These costs were $4.00 higher in both lines than results of the present study. Since labor costs were about 50% of total health costs, differences in overall health costs would indicate differences in labor costs.

Genetic Effects on Individual Functions

Total health costs were divided into categories of similar disorders to examine the contribution of each to overall costs. The groups categorized one through six were

Table 8. F-values and Residual Mean Square for Labor using Model 1.

Main Effect	DF	Labor
Year-season	56	1.97***
Lactation number	2	14.98***
Line	1	14.27***
Sire(Line)	40	2.49***
Lactation length	1	0.36
Error M.S.	1935	3.10

***P<.001

Table 9. Least Squares Means for Labor by Line using Model 1.

	Mean	SE
	-----minutes-----	
Selection	107.22	6.42
Control	75.66	6.30
Difference	31.56***	

***P<.001

reproduction, digestion, locomotion, respiration, mammary, and other, respectively. Using Model 1, each group was analyzed individually. F-values for the genetic effects on individual functions are shown in Table 10.

Least squares means for function costs are shown in Table 11. Mammary costs accounted for 68% of total health cost in each line. Mammary costs were the most critical of the six different categories representing 48% of total health costs for each line. Costs included in the mammary function were only costs of drugs and labor, and did not include losses attributed to discarded milk. Had discarded milk costs been included, these costs would have been much higher. Line and sire within line were both significant sources of variation (P<.01) for mammary costs. Mammary costs were the only individual category with a significant difference (P<.01) between lines. Mammary costs totaled $13.43 in selection cows, compared to $9.63 in controls. Hansen et al. (22) reported a difference of $6.00 between lines for mammary costs which represented about two-thirds of the total difference in health costs. Shanks et al. (54) reported a $2.01 higher mammary cost in high pedigree foundation animals compared to low pedigree cows.

Reproduction costs of $5.63 and $4.13, respectively for selection and control cows, were not significantly different. Hansen et al. (22) found no significant differ-

Table 10. F-values and Residual Mean Squares for Cost of Individual Functions using Model 1.

Dependent Variables	YR-SEAS (DF=56)	LAC-NO (DF=2)	Main Effect[a] LINE (DF=1)	S(LINE) (DF=40)	ERROR M.S. (DF=1976)
			0%		
Reproduction	1.84***	2.08	2.11	1.13	171.77
Digestion	1.16	2.88*	1.88	0.77	174.80
Locomotion	1.93***	6.38***	0.89	0.93	65.55
Respiration	2.01***	1.59	0.14	0.53	0.03
Mammary	1.50**	0.75	6.08**	2.51***	384.04
Other	1.81***	66.31***	0.22	1.57**	31.38
			3%		
Reproduction	1.80***	1.36	2.25	1.12	137.35
Digestion	1.15	2.04	2.03	0.81	135.77
Locomotion	1.89***	5.55**	0.98	0.98	47.78
Respiration	2.01***	1.59	0.14	0.53	0.03
Mammary	1.43*	0.27	6.69**	2.61***	306.85
Other	1.68***	64.05***	0.28	1.59**	23.24
			6%		
Reproduction	1.77***	0.81	2.38	1.11	111.40
Digestion	1.14	1.38	2.17	0.84	107.36
Locomotion	1.84***	4.76**	1.06	1.03	35.67
Respiration	2.01***	1.59	0.14	0.53	0.02
Mammary	1.38**	0.41	7.26**	2.71***	249.26
Other	1.57**	61.39***	0.35	1.62**	17.53

[a]YR-SEAS=Year-season, LAC-NO=Lactation Number, LINE=Genetic Line, S(LINE)=Sire within Line, ERROR M.S.=Residual Mean Squares

*P<.05

**P<.01

***P<.001

Table 11. Least Squares Means by Line for Individual Functions using Model 1.

	Selection		Control		Difference
	Mean	SE	Mean	SE	
	---$---				
Function					
	---0%---				
Reproduction	5.63	.80	4.13	.78	1.50
Digestion	4.57	.80	3.15	.78	1.42
Locomotion	2.00	.49	1.40	.48	.60
Respiration	.01	.01	.00	.01	.01
Mammary	13.43	1.19	9.63	1.16	3.80**
Other	2.23	.34	2.03	.33	.20
Total	27.87		20.34		7.53
	---3%---				
Reproduction	5.04	.71	3.66	.69	1.38
Digestion	4.07	.71	2.77	.69	1.30
Locomotion	1.76	.42	1.23	.41	.53
Respiration	.01	.01	.00	.01	.01
Mammary	12.14	1.06	8.58	1.04	3.56**
Other	1.94	.29	1.74	.29	.20
Total	24.96		17.98		6.98
	---6%---				
Reproduction	4.54	.64	3.26	.63	1.28
Digestion	3.65	.63	2.45	.61	1.20
Locomotion	1.57	.36	1.08	.35	.49
Respiration	.00	.01	.00	.01	.00
Mammary	11.03	.96	7.68	.93	3.35**
Other	1.70	.25	1.50	.25	.20
Total	22.49		15.97		6.52

*P<.01

ence between genetic lines for reproductive costs when breeding costs were not included. Shanks et al. (54) found higher reproductive cost to be a direct result of higher semen cost of higher PDM bulls. Breeding costs were not included in this study. Reproductive cost accounted for 20% of total health cost for each line.

Digestive costs were not different (P<.05) between lines. The difference of $1.42 in digestive cost accounted for 19% of the total difference between lines. Hansen et al. (22) reported digestive cost of $1.56 and $.69 for selection and control cows, respectively in their Holstein selection experiment. Mahoney et al. (33) reported a $3.69 difference in digestive cost between cows selected for large versus small body size. In that study, the difference in digestive costs represented 67% of the difference between groups for total cost. Since nearly all digestive costs were for displaced abomasums, they concluded that larger cows were apparently more predisposed to displaced abomasums.

Values of $2.00 and $1.40 were found for locomotion costs of selection and control cows. The difference of $.60 was not significant between lines. Shanks et al. (54) reported 5% more cases of foot rot in higher pedigree cows, but gave no value for overall locomotion costs. Hansen et al. (22) reported higher (P<.10) locomotion cost in control cows. In that study, locomotion cost represented 4% of total cost in control cows compared to 1% in selection cows. In the present experiment, locomotion costs represented 7% of total health cost for both lines.

Respiratory costs were approximately zero for both lines. Shanks et al. (54) obtained similar results in foundation animals in the Iowa study. However, a difference of \$.48 was reported in subsequent generations. Hansen et al. (22) reported respiration costs of \$1.88 for selection cows and \$.44 for control cows. Both studies showed that respiratory costs were only a small portion of total health cost. Respiration cost in the current study represented less than 1% of total health cost, suggesting their importance is of lesser consequence.

The function referred to as other costs, which included disorders such as milk fever, ketosis, and allergic reactions, were not different between lines ($P<.10$). The values of \$2.23 and \$2.03, for selection and control animals, respectively were three times less than those reported by Hansen et al. (22). Shanks et al. (54) found more cases of milk fever in high pedigree foundation animals than low pedigree cows.

<u>Non-genetic Effects on Total Health Cost</u>

Three non-genetic factors were found to be significant sources of variation in health cost ($P<.001$). F-values for non-genetic effects using Model 1 are shown in Table 6 and include parity and year-season fresh. The covariable used to adjust for different lactation lengths was also significant (P<.05). Stage of lactation effects were also examined.

Health costs by parity are shown in Table 12. Costs of first and second parities were not significantly different, however, health costs of third and greater parities differed from the first two lactations (P<.001). Health costs increased approximately $9.00 from second to third and later lactations. Gilmore and McDaniel (20) reported a $9.00 increase in health cost per successive lactation. Hansen et al. (23) reported increases of health cost of threefold from first to fifth lactation. Wilk et al. (68) found an upward trend in total health disorders with advancing age. Health disorders appear to be more prevalent in older, higher-producing cows. Table 13 shows least squares of health costs by parity and function.

Lactational health costs of each cow were divided into ten-thirty day periods starting at time of parturition to examine the effect of stage of lactation on total costs. Model 1 was used to analyze each of the ten stages seperately, with stage-of- lactation cost being the dependent variable. Least squares means of health costs by line for each stage are shown in Table 14. Health costs were greatest for both lines during the first stage, and were significantly different between lines (P<.001). Hansen et

Table 12. Least Squares Means of Health Costs by Parity using Model 1.

Parity	0%		3%		6%	
	Mean	SE	Mean	SE	Mean	SE
	----------		$		----------	
1	20.40	1.67	18.87	1.48	17.52	1.31
2	20.44	1.84	18.48	1.62	17.77	1.45
≥3	29.62[a]	1.83	25.39[a]	1.62	21.89[a]	1.44

[a]Difference between parity 3 and parities 1 and 2 significant (P<.001).

Table 13. P-values and Least Squares Means of Health Costs by Parity and Function using Model 1.

		Parity					
		1		2		>3	
		Mean	SE	Mean	SE	Mean	SE
Function	P	$					
		0%					
Reproduction	.12	4.05	.70	4.65	.78	5.63	.77
Digestion	*	3.29	.71	3.11	.78	4.87	.77
Locomotion	***	1.37	.44	.95	.48	2.64	.47
Respiration	.20	.01	.01	.00	.01	.00	.01
Mammary	.47	11.03	1.05	10.67	1.16	12.08	1.15
Other	***	.83	.30	1.15	.33	4.36	.33
		3%					
Reproduction	.26	3.71	.63	4.19	.69	4.86	.69
Digestion	.13	3.03	.63	2.80	.69	4.15	.68
Locomotion	**	1.27	.37	.87	.41	2.24	.41
Respiration	.20	.01	.01	.00	.01	.00	.01
Mammary	.76	10.27	.94	9.66	1.04	10.39	1.03
Other	***	.72	.26	1.03	.29	3.72	.29
		6%					
Reproduction	.44	3.42	.57	3.79	.63	4.22	.62
Digestion	.25	2.81	.56	2.53	.61	3.55	.61
Locomotion	**	1.17	.32	.80	.35	1.91	.35
Respiration	.20	.01	.01	.00	.01	.00	.01
Mammary	.66	9.59	.85	8.77	.94	8.99	.93
Other	***	.63	.23	.93	.25	3.19	.25

*P<.05

**P<.01

***P<.001

Table 14. Least Squares Means of Health Costs by Stage of Lactation using Model 1[a].

Stage (days)	Selection Mean	Selection SE	Control Mean	Control SE	Difference[b]
	------------------		$		------------------
0-30	14.08	1.41	8.58	1.23	5.50***
31-60	2.20	1.07	2.67	.82	.47
61-90	2.51	.72	2.61	.56	-.10
91-120	.87	.71	1.16	.54	.29
121-150	1.59	.62	1.02	.47	.57
151-180	2.45	.50	2.34	.46	.11
181-210	.59	.58	.59	.49	.10
211-240	.81	.34	.71	.26	.10
241-271	.84	.53	1.05	.34	-.21
>270	6.70	1.21	4.86	.79	1.84
Total	32.66		25.59		8.67

[a]0% discount rate.

[b]Selection minus control.

***P<.001

al. (23) reported health cost to be greatest during the first 100 days of lactation in the Minnesota study. Most of the health cost in this and other studies were due to mastitis costs. It is reasonable that health costs are higher in early lactation since clinical cases of mastitis are highest during the first 76 days of lactation (58). Costs declined steadily as lactation progressed, until the last stage, where health costs increased for both lines.

Health costs for each stage by parity are shown in Table 15. Again, costs were greatest for all parities during the first stage and decreased throughout lactation. Third and greater parities had higher cost during the first, third, and tenth stage ($P<.05$).

Various reports showed significant variation in health costs attributed to season of calving (23,49,68). Wilk et al. (68) found calving year significant in total health disorders as well as some individual disorders. Model 2 was used to examine seasonal effects on health costs. Model 2 included a line by year-season interaction, which was found to be highly significant ($P<.001$). To more closely examine the line by year-season interaction, Model 3 was used, where year-season fresh was divided into year and season-fresh. Mean health costs by line and season-fresh are shown in Table 16. Lactational health costs of control cows were highest when cows freshened in October to December and lowest for cows calving in January to March. Selection cows

Table 15. Least Squares Means by Stage-of-Lactation and Parity using Model 1[a].

		Parity					
		1		2		>3	
Stage (days)	P	Mean	SE	Mean	SE	Mean	SE
		$					
0-31	***	9.95	1.10	8.24	1.23	14.62	1.22
31-60	+	1.86	.75	2.25	.83	3.30	.82
61-90	*	2.25	.51	2.21	.57	3.24	.56
92-120	.50	1.27	.49	.73	.55	1.10	.54
121-150	.97	1.29	.43	1.29	.48	1.21	.47
151-180	.16	2.41	.39	2.00	.43	2.76	.43
181-210	+	.49	.44	.20	.48	1.08	.48
211-240	.94	.80	.24	.74	.27	.72	.27
241-270	.56	.77	.35	.94	.39	1.17	.38
>270	**	4.39	.81	5.78	.89	6.82	.88

[a]0% discount rate.

+P<.10

*P<.05

**P<.01

***P<.001

Table 16. Least Squares Means of Health Costs[a] by Line and Season Fresh using Model 3.

Season-Fresh	Selection	Control	Difference
		$	
January 1 - March 31	30.49	14.84	15.65*
April 1 - June 30	26.59	17.40	9.19*
July 1 - September 30	23.28	17.67	5.61
October 1 - December 31	22.20	18.81	3.39

[a]0% Discount Rate

*P<.05

did not follow the same trend and were highest for cows freshening in January to March. Findings do not agree with previous studies (23,68) reporting higher health costs for cows calving in the summer months. Health costs by line and year fresh obtained using Model 3 are shown in Table 17. Health costs of control cows remained fairly constant from 1970 to 1984 as opposed to selection cows, which showed a positive increase in health cost over the same period.

Non-genetic Effects on Labor Requirements

Non-genetic effects also were found to contribute to labor costs. Year-season fresh and parity were both highly significant ($P<.001$) sources of variation in overall labor requirements using Model 1. F-values for non-genetic effects on labor requirements are presented in Table 8, page 38. Hansen et al. (23) found greatest labor requirements ($P<.05$) in summer months, and lowest during winter months (January through March). In addition, they reported year to be significant ($P<.001$) in total labor required.

Labor requirements by parity are shown in Table 18. Greater labor requirements were detected for older cows. Labor requirements were 1.83 hours for cows in third and greater parities, compared to 1.35 hours for first lactation heifers. Hansen et al. (23) reported labor requirements increased significantly with successive lactations. They

Table 17. Health Costs by Line and Year-fresh using Model 3.

Year-fresh	Selection	Control	Difference[a]
	$		
1970	15.88	15.92	-.04
1971	19.19	15.83	3.36
1972	23.88	20.86	3.02
1973	15.18	17.76	-2.58
1974	21.06	33.95	-12.89
1975	19.24	17.42	1.82
1976	24.80	17.96	6.84
1977	23.74	15.25	8.49
1978	27.31	18.03	9.28
1979	37.40	19.04	18.36
1980	36.72	15.59	21.13
1981	36.62	15.72	20.90
1982	29.59	11.25	18.34
1983	38.14	20.76	17.38

[a]Selection minus control.

Table 18. Least Squares Means for Labor by Parity using Model 1.

Parity	Mean	SE
	----minutes----	
1	81.12	5.70
2	76.80	6.24
$\geq$3	109.62[a]	6.24

[a]Parities 3 and greater significantly different from parities 1 and 2 (P<.001).

also found labor requirements of third and later parities to be twice that of first lactation cows. Labor differences were not as prominent in this study.

Non-genetic Effects on Individual Function

Factors such as parity, year-season fresh, and stage of lactation were significant non-genetic contributors to health costs of individual functions. F-values of the non-genetic effects on individual functions are shown in Table 10. With health costs of individual functions being the dependent variable, Model 1 was used to determine effects of non-genetic factors on health costs of individual functions. Least squares means of health costs of each function by parity are shown in Table 13, page 47.

Mammary costs were higher for third and later parities compared to first and second parities, although not significant (P<.05). Costs of $11.03, $10.67, and $12.08, for first, second and third and later parities, respectively, were found for the mammary categories. Hansen et al. (23) found similar first lactation mammary costs, however, values obtained for second and later lactations were twice as great. Smith et al. (58) reported rate of intramammary infections increased 5 times from first lactation to lactations six and greater. Wilk et al. (68) also reported increased incidence of mastitis with older cows.

Various reports indicated stage of lactation to have a significant effect on mammary cost (23,58). Hansen et al. (23) reported highest mammary cost in the first 100 days of lactation. In the present study, mammary costs decreased progressively throughout lactation. These results agree with those of Smith et al. (58) who found greatest rate of intra-mammary infection in the first 76 days of lactation. Health costs of individual functions were not analyzed by stage of lactation. However, analysis of total health costs revealed that total costs increased in the last stage (>270 days) of lactation. This increase reflected dry cow therapy costs. These costs were higher for selection cows ($6.70 versus $4.86), however, not significant. There was a difference (P<.01) between parity groups for health costs in the tenth stage of lactation. Costs incurred in the last stageof lactation increased with each successive parity. General policy at DES was to dry treat cows that had been treated for clinical mastitis during that lactation. However, only quarter(s) that were treated for mastitis received dry cow therapy.

Year-seasonfresh was also a significant contributor to mammary cost. Other studies document year-season effects (23,49, 58) on mastitis. Hansen et al. (23) and Philipsson et al. (49) found cows calving in the spring to have higher cost during the summer months. Smith et al. (58) reported rates of coliform and streptococcal infections to be highest during the summer season. They found increased coliform rates in the summer to be associated with elevated levels of coliform bacteria in bedding materials. Greater coliform rates of mastitis in summer months were mostly associated with multiparous cows.

Of the non-genetic factors evaluated, only year-season had an effect on reproductive costs (P<.001). This is most likely attributedto a variety of weather and temperature conditions found in the middle Tennessee area. Gwazdauskas (21) reported that extremes in climate can adversely affect reproduction and stated that seasonal variation in temperature alters estrous activity as well as duration of estrus.

Reproductive costs increased with parity, however, were not different between parity groups (P<.10) . Hansen et al. (23) found reproductive cost at least 2.5 times greater in cows in third and later lactations than first lactaton heifers. Parity was the only non-genetic factor to affect digestive costs (P<.05). Digestive costs were not different between parities one and two, however, third and greater parities differed from the first two. Values of $3.29, $3.11, and $4.86 were found for first, second, and later parities, respectively. Greater digestive cost in older cows is probably attributed to more cases of displaced abomasums. Wilk et al. (68) found an upward trend in displaced abomasums with advancing age in the Randleigh herd.

Year-season and parity were significant contributors to locomotion costs (P<.001). Year-season effects could have been attributed to several factors. Wet, rainy seasons cause more foot rot, which was the primary health cost in this category. In addition, confinement housing increases the chances of cows slipping on wet or icy concrete. Cows were allowed on pasture when possible, however, the majority of time they were on concrete surfaces. Philipsson et al. (49) reported a peak in foot and leg problems in Swedish Friesians calving in spring and summer. Feet problems became more prevalent in older cows housed in confinement for long periods of time. Locomotion costs of third and greater parities were $2.64, which was twice the value found for first and second parities. Hansen et al. (23) found highest locomotion costs in fifth and later parity cows, however, not significantly higher.

Of the non-genetic factors, only year-season had a significant effect on respiration costs (P<.001). Hansen et al. (23) reported an effect of year on respiration cost (P<.10). They also found a season effect on respiratory cost (P<.001). Apparently, climate and temperature have varied effects on respiratory disorders. Cows were vaccinated for IBR and no occurrence of this disorder was reported at the DES.

In the category referred to as other costs, two non-genetic effects were found to be significant ($P<.001$). Parity had the greatest effect on this group of disorders with the $4.36 value for third and later parities being 4 times the value for these costs in either of the first two parities. Another report indicated the same trend in Holsteins (23). Ketosis and milk fever were the major constituents of this category. Year-season was also highly significant in other costs ($P<.001$). Hansen et al. (23) reported differences in seasonal and yearly costs, however, they were not significant.

CHAPTER IV

SUMMARY AND CONCLUSIONS

Health cost data were collected on two genetic lines of Jerseys at the Dairy Experment Station. A selection line, consisting of cows selected for milk yield, was compared to an unselected control line to determine if differences in health costs accompanied selection for increased milk yield.

Costs were summed on a lactation basis since this method seemed to be an appropriate method of comparing health related costs. Different lactation lengths were incurred, therefore, length of lactation was used as a covariate to adjust for these differences. Discounting methods were used to adjust for costs that occurred at different times in an animals lifetime. The effect of genetic and non-genetic factors were examined to determine their contribution to total health costs.

Genetic factors considered were line and sire within line. Health costs were higher for selection cows at all three discount rates. Significant sire within line differences were observed. Labor requirements were higher for selection cows and differences were detected for labor requirements for sires within each line. Costs decreased geometrically for both lines as the discount rate increased.

Parity, year-season fresh, and stage-of-lactation were non-genetic contributors to total health costs. Total health costs were greater for third and later parities. Likewise, labor requirements were greatest for older cows. Examining stage of lactation differences showed that health costs were greatest during the first 30 days of lactation. Costs decreased gradually as lactation progressed, until the last stage, where cost increased due to dry cow therapy costs.

Sub-division of total health costs into functions of related disorders revealed that mammary costs accounted for the majority of health costs, followed by reproductive and digestive costs. Respiration, locomotion, and other costs were the least costly of all the functions examined.

Health related costs deserve attention in economic comparisons of dairy cattle. Today, production strategies of many dairy producers is to maximize profit. If health costs are significant in overall profitability of the dairy cow, omitting them allows inaccurate measures of profit.

Health costs have been shown to be greater in higher producing cows. However, other studies have shown that additional revenue from yield of selection cows would offset additional health costs. It is paramount to include losses of revenue due to discarded milk, since this may be a substantial amount of income that is not realized. Increased management is potentially useful in decreasing health costs. Closer attention should be paid to cows in early lactation, as well as cows in later lactations.

Evaluation of correlated responses to selection for milk yield are extremely important. If single trait selection continues, detrimental effects may be incurred in traits such as mastitis and reproduction. Studies such as this provide dairymen with valuable information with economic implications of genetic improvement for yield. Including secondary traits such as health costs in economic comparisons of alternative selection decisions should more accurately identify selection policies that would improve profit.

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