J. Dairy Sci. 84:955–965

Characterizing Biosecurity, Health, and Culling During Dairy Herd Expansions[1,2]

M. A. Faust,* M. L. Kinsel,‡,[3] and M. A. Kirkpatrick†,[4]
*Department of Animal Science and
†Department of Veterinary Diagnostic and Production Animal Medicine,
Iowa State University, Ames 50011
‡Caine Veterinary Teaching Center, Department of Animal and Veterinary Science
University of Idaho, Caldwell 83605

ABSTRACT

Our objectives were to investigate strategies for biosecurity, expansion, and culling for expanding dairy herds in the Upper Midwest. Eighteen dairies in Iowa and Wisconsin were visited, and dairy managers and veterinarians were interviewed to characterize five biosecurity practices, herd culling practices, vaccines administered, and ensuing disease status for the herds. The majority of herds that were interviewed failed to employ comprehensive biosecurity programs for incoming cattle. Nearly 60% of herds obtained cattle from sources for which it was difficult to document genetic backgrounds and health histories, fewer than half required health testing for incoming cattle, and approximately 50% quarantined new cattle on arrival. Despite high rates of vaccination for bovine viral diarrhea, all herd owners and managers indicated that herd biosecurity was compromised as a result of expansion. Half of the interviewed herds indicated that bovine viral diarrhea and papillomatous digital dermatitis were notable disease problems. Herds that obtained cattle with unknown backgrounds and health status experienced the largest number of diseases. Before expansion, the most frequently cited reasons for culling were reproductively unsound; low milk production; mastitis, poor udder health, and high SCC; during expansion, the strategic decision to cull cows for low milk production was used less often. In addition, the stochastic simulation model, DairyORACLE, was used to evaluate economic outcomes for several expansion alternatives. Five model scenarios studied were: base scenario (herd size was maintained) and four expansion scenarios—all paired combinations of heifer quality (high, low) and voluntary culling (implemented, not implemented). Culling for low milk production yielded an additional $23.29 annually (6-yr annuity) per cow, but on the basis of purchased replacements, no voluntary culling was most profitable. Purchasing high versus low quality replacement heifers for expansions returned an additional $113.54 annually ($681.24 total net present value) per heifer purchased. Many opportunities exist to improve cattle-related factors for dairy herd expansions, including the use of comprehensive biosecurity programs, realistic planning and budgeting for cattle purchases, and cost effective purchase and culling practices.
(**Key words:** dairy, herd-expansion, biosecurity, culling)

Abbreviation key: BVD = bovine viral diarrhea, **IBR** = infectious bovine rhinotracheitis, **NAHMS** = National Animal Health Monitoring System, **PDD** = papillomatous digital dermatitis.

INTRODUCTION

Dairy farms in the Upper Midwest are undergoing significant changes in their size and structure (Bailey, et al., 1997; Smith, et al., 1997; Stahl, et al., 1999), and a proportion of herd owners are electing to undertake major herd expansion projects. To assist producers who are planning a herd expansion, considerable attention has been focused on guidelines for developing business and financial plans (Bailey, 1997), facilities (Smith, et al., 1997), and management plans (Bailey, 1997).

In practice, it is not unusual or unexpected for herd owners to devote more than 1 yr and several thousand dollars to complete the planning process for a herd expansion. For most situations, the majority of the planning phase is focused on facilities and equipment. Admittedly, investments in facilities, machinery, and

Received June 12, 2000.
Accepted November 13, 2000.
Corresponding author: M. A. Faust; e-mail: mafaust@iastate.edu.
[1]Journal Paper No. J-18923 of the Iowa Agriculture and Home Economics Experiment Station, Ames, Iowa, Project No. IOW03145, and supported by Hatch Act and State of Iowa funds.
[2]This research was completed as part of the Multistate Research Project, NC-119, Dairy Herd Management Strategies for Improved Decision Making and Profitability.
[3]Currently President and CEO of Agricultural Information Management, Inc.
[4]Currently employed by Pharmacia.

equipment for a new 500-cow dairy can approach $2 million, and, so, represent a substantial commitment by the owner for repayment. However, investments in cattle are 20 to 30% of total expansion investments including land (Bailey, et al., 1997), and, quite obviously, cattle must provide the income stream necessary to pay for the entire expansion project.

Inadequate attention to cattle during planning and expansion quickly can jeopardize the short- and long-term success for a dairy herd expansion. In fact, Stahl et al. (1997) reported that when owners of select Minnesota dairies were surveyed and asked to identify challenges to their expansions, “maintaining and improving herd health” was listed most frequently (34% of producers). However, results from several surveys indicated that relatively few dairy producers implement basic management practices to maintain herd biosecurity [National Animal Health Monitoring System (**NAHMS**), 1996; Rauff et al., 1996]. It is ironic that time devoted to planning and sourcing of cattle is a very small fraction of the total time spent planning for an expansion, and further that there are essentially no reports characterizing cow-related factors for dairy herd expansions.

The objectives of our study were to characterize and investigate biosecurity and herd culling practices used during herd expansions, herd management skills as assessed by herd veterinarians, and subsequent disease incidences for expanding dairy herds in the Upper Midwest.

MATERIALS AND METHODS

Characterizing Cow-Related Factors for Expansions

To characterize several herd management factors for herd culling decisions and incidences of selected diseases, seven specialized dairy veterinary practices in Iowa and Wisconsin were contacted during January 1998 as cooperators. The seven cooperating veterinarians were asked to identify several client herds that had completed dairy herd expansions, and could provide information for three distinct time periods: 1) before expansion, 2) during the expansion phase, and 3) following completion of the herd expansion. In total, 18 dairies were visited and interviewed; the majority of herds interviewed milked more than 300 cows. All herds had introduced additional cattle; however, two herds had increased herd size primarily by using internal growth. Interviews were conducted during farm visits, because it was felt that those interviewed would be more willing to openly discuss expansion issues and experiences with an independent interviewer on the farm. To standardize responses by veterinarians and their dairy herd owner clients to all portions of the interview, the primary author conducted all interviews.

During the interviews, dairy managers and their respective cooperating veterinarian(s) responded to a standard series of questions that were used to characterize five biosecurity practices, vaccines administered, ensuing disease status for the herd, and herd culling practices. In addition, herd veterinarians were asked to rate management skills in 16 areas for the cooperator herds using a 1 (superior) to 5 (needs improvement) scale. Biosecurity practices studied included identifying the primary advisor for herd biosecurity information, source of cattle used for the herd expansion, number of new sources for new cattle, age of new cattle, whether new cattle were quarantined, and where cattle were quarantined.

To characterize incidences for several economically important diseases, veterinarians and herd owner clients indicated diseases that in their opinions accounted for a notably larger percentage of treatments and(or) herd removals during the expansion phase. Diseases studied included bovine viral diarrhea (**BVD**), Johne’s, Salmonella, infectious bovine rhinotracheitis (**IBR**), clostridial disease, mastitis, shipping fever complex, and papillomatous digital dermatitis (**PDD**). Essentially, all assessments of disease incidence were confirmed by cooperating veterinarians; however, methods for reaching initial diagnoses were not requested during the interview.

Also, as part of the interview, herd managers ranked reasons for culling cows on their respective operations from the most to least frequently cited for the three phases of the expansion. Reasons for culling originally listed were typical for DHIA and included 1) low milk production; 2) mastitis, poor udder health, and(or) high SCC; 3) reproductively unsound; 4) disease, including metabolic disorders; 5) sold for dairy purposes; and 6) injury. In addition, herd managers were instructed to add reasons for culling or modify existing reasons to best describe farm culling decisions.

After collection, interview data were evaluated to determine associations of disease incidence and biosecurity practices by using the GENMOD procedure of SAS (1999). The response variable was an index computed as the sum of incidences for the eight studied diseases, and thus represented the cumulative disease effect experienced by the herd. For modeling purposes, the disease index was assumed to be distributed as Poisson, and the log link function was used. Independent variables included the five biosecurity practices studied, represented as binomial responses indicating whether the practice was or was not used by the herd. Probability values for independent effects were determined by difference of the –2 log likelihoods for full and individual

Table 1. Assumptions for DairyORACLE base scenario.

Parameter	Value used
Production, reproduction, and herd health	
Average daily milk yield for milking cows, kg[1]	36.4
Voluntary waiting period (min. interval calving to 1st breeding), d	60
Heat detection rate, %	50
Conception rate, %	45
Abortion rate, %	5.0
Dystocia, %[2]	5.0
Retained placenta rate, %	5.0
Calfhood mortality rate, %	5.0
Milk fever rate, %[3]	3.2
Ketosis rate, %[3]	1.7
Left displaced abomasum rate, %[3]	1.7
Metritis rate, %[3]	6.2
Cystic ovaries rate, %	6.1
Mastitis rate, %[3]	5.1
Lameness rate, %[3]	3.0
Hardware disease rate, %	0.8
Culling and replacement	
Initial rate for forced culling, %	20
Purchase price for springing heifers (purchased as needed only), $	1300
Salvage price for cull cows, $	400
Market price for calves sold, $	75
Other economic	
Milk price per 45.45 kg, $	12.00
Dry cow ration costs (daily per cow), $	1.75
Lactating cow ration costs (daily per cow), $	3.80
Interest rate for computing annuities, %	5.0

[1]Age-adjusted effect: 1st parity; 2nd parity; 3rd and greater parities. Kinsel, 1998.

[2]Age-adjusted effect: 1st parity; 2nd and greater parities. Kinsel, 1998.

[3]Age-adjusted effect: 1st and 2nd parities; 3rd and greater parities. Kinsel, 1998.

reduced models; differences were assumed to follow a chi-square distribution with 1 df. To study the effects of culling practices prior to the herd expansion for practices during expansion, Pearson Correlations were computed.

DairyORACLE Simulation

Many plans for dairy herd expansion include a projected herd replacement of 25%; however, replacement rates for United States dairy herds typically exceed 25% (NAHMS, 1997; Nieuwhof and Norman, 1989). Projected replacement rates greatly influence capital needs for cattle during herd expansion, consequently, accurate rates are necessary to ensure that lending requests are appropriate. To investigate in detail removal rates for dairy herds that were maintaining and expanding herd size, the DairyORACLE stochastic simulation model (Kinsel, 1998; Marsh et al., 1987) was modified to accommodate herd expansion, and two initial scenarios were defined—maintaining and expanding herd size. Basic assumptions for scenarios are in Table 1. Additional and alternative assumptions for herds that were increasing herd size during a single year to two times initial herd size were: forced culling was 10% and home-raised replacements when available or purchased springing heifers were brought into the milking herd when herd size was smaller than target size.

Interview results from this study suggested that few opportunities existed for unforced culling (culling for low milk production) during the expansion phase, and that a large difference exists for quality of purchased heifers and cows. Consequently, we designed additional DairyORACLE simulation scenarios to study the net economic returns to expanding herds for unforced culling and for purchasing heifers of different quality. Specific assumptions for these different model scenarios are in Table 1 or are listed: 1) high quality replacement heifers—purchased replacement heifers that were comparable to farm-raised heifers for milk production potential and rates of first-service conception and diseases; 2) low quality replacement heifers—milk production potential that was 90% of potential for high quality heifers, probability for dystocia and abortion of 10%, first-service conception rate of 35%, and rates for other diseases of ketosis (6.7%), metritis (11.2%), mastitis (10.1%), ovarian cysts (11.1%), and lameness (8.0%); 3) unforced culling—the cow (≥ 2nd parity) that had lowest milk production during the current week was culled voluntarily when herd size was at least 80% of target size; 4) no unforced culling—no culling based on milk production for cows. Thus, the additional five model scenarios were: a base scenario in which herd size was maintained, purchased heifers were of high quality, and unforced culling was practiced; and four expansion scenarios that included all paired combinations of heifer quality (high or low) and unforced culling (implemented or did not implement) alternatives.

For both sets of model scenarios, 30 replicates were simulated for each of the five different scenarios for a total of two 6-yr periods: the first period was intended to stabilize the model using all parameters for the base scenario (no data collected), and the second period was the experimental expansion period.

Data from DairyORACLE simulations were analyzed using mixed model procedures, where response variables were annual culling rates (yr 1, 2, and 3 to 6) or 6-yr annuities of net returns (per cow, per purchased heifer). Fixed independent variables were indicators for the simulation scenarios—heifer quality and culling strategy; replicate was included as a random independent effect. When the response variable was annual culling rate for yr 3 through 6, a random effect for year was included as an independent variable, also.

Table 2. Means, coefficients of variation, and maxima of herd management factors as assessed by herd veterinarians for interview herds.

Management factor	No. herds[3]	Scores assigned by herd veterinarian[1,2]		
		$\overline{X}$	CV, %	Maximum
Forages	15	2.3	48.3	4
Feed bunks	15	2.1	90.0	4
Cows	14	2.1	43.0	3
Consistency of feed, feeding	15	2.2	42.6	4
Cow grouping strategies and group management	13	2.5	50.0	5
Cow comfort	15	2.0	63.5	5
Udder health	15	2.5	57.6	5
Reproduction	15	2.5	49.6	4
Transition cows	15	2.7	43.7	5
Calving time	15	2.2	42.8	4
Calves	15	1.8	48.9	4
Replacement heifers	10	2.3	42.5	4
Culling decision making	15	2.7	48.9	5
Collection, use of production records for decisions	15	2.6	42.7	4
Use of financial records for decisions	15	2.1	53.3	4
Labor	13	2.2	46.8	4

[1]Scores assigned by herd veterinarians were 1 (superior management) to 5 (needs improvement).

[2]Minimum score assigned was 1 for all management factors.

[3]Scores reported only for herds and categories that veterinarians were able to assess. For instance, herds that did not raise replacements were not scored for this factor.

RESULTS AND DISCUSSION

Characterizing Cow-Related Factors for Expansions

Management assessment by herd veterinarians. Skill levels for management factors as assessed by herd veterinarians are in Table 2; herds were rated for pertinent parameters only, thus when replacement heifers were custom raised, no score was assigned for this management skill. Mean scores were 2.0 to 2.7 for all factors except management of calves, where the mean for study herds was 1.8. Scores may indicate that as a group, interviewed herds generally were above average for important management parameters; however, variability for skill level was great (Table 2).

Biosecurity and expansion practices. Practices that herd managers indicated were used during expansion of herds are in Table 3. Note that all herds had introduced some cattle, thus the sum of the three categories designated as "introduced . . . " is 100%. A small percentage of herds in our study increased herd size by using internal growth primarily. This finding disagrees with results from a Minnesota study (Stahl et al., 1999), but likely reflects differences in expansion objectives for the two sets of dairy herd owners. The average size after expansion for herds in the Minnesota study was 131 cows, whereas for our study, range for herd size was approximately 150 to 1200 cows, and nearly all interviewed herds exceeded 300 cows.

Nearly one-half of herd owners introduced heifers only and this agreed with results reported by others (Stahl et al., 1999). In our study, several herds expanded by introducing cows only, or by introducing heifers and cows. When heifers and cows were introduced,

Table 3. Practices used during herd expansion as indicated by herd owners and managers.[1]

Management Practice	Interview result	
	— % of herds[2] —	
Expansion strategy and ages of introduced cattle		
Primarily within herd	11.8	
Introduced heifers only	47.1	
Introduced cows only	17.7	
Introduced cows and heifers	35.3	
Source for introduced cattle		
Unknown—dealer, sale barn, etc.	58.8	
Known—private treaty, dispersal, etc.	41.2	
Health testing used[3]		
Mastitis, milk quality	47.1	
Other than mastitis, milk quality	47.1	
Primary advisor for biosecurity information		
Veterinarian	76.5	
Other, such as consultant	23.5	
Use of quarantine for introduced cattle[3]	47.1	
	$\overline{X}$	SD
For herds that used quarantine[3]		
Length of time quarantined, wk	2.9	1.43
Distance from milking herd, m	879	1573

[1]From Faust, 1999. Portions of table used with permission of MWPS, Ames, Iowa.

[2]Total of 18 herds interviewed.

[3]Management practice was used during all or part of the expansion process.

herd managers frequently noted that heifers were introduced during the initial phase of expansion and cows were introduced for subsequent phases. Prior to expansion, the initial presumption is that heifers present significantly fewer risks than cows for herd biosecurity.

Most herds relied on veterinarians as the primary source for biosecurity information (76.5%), and this result was very similar to findings reported by others (NAHMS, 1996; Rauff et al., 1996). For herds in our study, fewer than half required health testing for incoming cattle, and approximately 50% of herd owners reported that new cattle were quarantined (Table 3). As reported by NAHMS (1996) only 6% of incoming cows and 15.3% of incoming bred dairy heifers were quarantined. Similarly, Rauff et al. (1996) reported that 12% of surveyed dairy producers in Pennsylvania isolated purchased replacement cattle on arrival. Thus for the expanding herds that we interviewed, a larger percentage of incoming cattle were quarantined; however, for nearly all of the interviewed herds, the definition of "quarantine" was an area adjacent to the existing herd. In fact, several herd owners reported "quarantining" cattle in different pens of the barn in which was housed the existing herd. Thus, location of quarantine area was extremely variable (Table 3). For herds with 200 and more cows, 57.5% of herds surveyed by NAHMS (1996) required no health testing prior to introducing cattle onto the dairy operation, and this result was similar to our own.

Nearly 60% of interviewed herds obtained cattle from sources for which it was difficult to document genetic backgrounds and health history, such as cattle dealers and sale barns (Table 3). Workers who surveyed Pennsylvania dairy producers reported that slightly fewer than one-half of respondents knew that purchased replacements were obtained from vaccinated herds (Rauff et al., 1996). Admittedly, sources for cattle with known health and genetic backgrounds are limited; however, it is not clear whether the value of records and genetic merit are fully documented and realized.

Table 4 shows the percentages of herds reporting vaccines that were administered to incoming cattle and cattle in the existing herd prior to introduction of new cattle. Nearly all herds that we interviewed vaccinated existing and incoming cattle for BVD. However for incoming cattle, modified live vaccine products were used by only slightly more than 30% of herds. More than half of herds vaccinated all cattle for IBR (Table 4). Other vaccine products were used relatively infrequently, and no herds reported vaccinating cattle for Johne's, PDD, Salmonella, and mastitis.

To assess the importance of herd management factors and biosecurity practices for several economically important diseases, veterinarians and herd owner clients indicated diseases that in their opinions accounted for a notably larger percentage of treatments and(or) herd removals during the expansion phase. Diseases studied included BVD, Johne's, Salmonella, IBR, clostridial disease, mastitis, shipping fever, and PDD. All herd owners and managers indicated that herd biosecurity was compromised noticeably as a result of herd expansion. Half of the expansion herds that were interviewed indicated that BVD and PDD were notable disease problems during the expansion phase, and nearly 20% of herds had experienced losses from IBR and clostridial disease (Table 5).

Rauff et al. (1996) reported similarly high rates of vaccination for BVD (82.2%). However, when techniques for administering vaccines were studied, these workers concluded that 72% of surveyed herds in Pennsylvania were inadequately vaccinated. We did not study vaccination techniques, but relatively high incidences of BVD related losses for these expanding herds may suggest that several of the interviewed herds were inadequately vaccinated. In addition, relatively low implementation rates for recommended biosecurity practices by herds that knowingly were compromising biosecurity for their herds seem to indicate that many herd owners were unable or unwilling to execute aggressive

Table 4. Vaccines reported as administered to incoming cattle and cattle in the existing herd prior to introducing new cattle.

Vaccine administered	Incoming cattle	Existing cattle
	— % of herds[1] —	
Bovine viral diarrhea, killed product	59.4	59.4
Bovine viral diarrhea, modified live product	31.2	50.0
Infectious bovine rhinotracheitis	53.1	62.5
Clostridial disease	12.5	21.9
J5[2]	6.2	18.8
Johne's	0.0	0.0
Papillomatous digital dermatitis	0.0	0.0
Salmonella	0.0	0.0
Mastitis	0.0	0.0

[1]Some or all cattle received specified vaccine.

[2]Pharmacia, North Peapack, NJ.

Table 5. Percentages of herds interviewed indicating a notably larger proportion of treatments and(or) removals of cows during expansion for several diseases.

Disease	% of herds
Bovine viral diarrhea	50.0
Papillomatous digital dermatitis	50.0
Johne's	31.2
Clostridial disease	18.8
Infectious bovine rhinotracheitis	18.8
Mastitis	18.8
Salmonella	12.5
Shipping fever complex	12.5

and integrated biosecurity programs for their herd expansions.

Least squares means and the importance of biosecurity practices implemented for number of different diseases experienced by herds are in Table 6. Least squares means in this table represent back transformations (e^x) of the originally computed least squares means. As a result of the limited number of expanding herds that were interviewed, differences for their respective vaccination and biosecurity programs, varied experience level with expansions, and exposure to specific diseases for interviewed herds, it was difficult to identify statistically important associations with diseases. However, findings for this study generally corroborate the effectiveness of biosecurity practices recommended commonly in the dairy industry.

Background information and health status for introduced cattle was associated with cumulative disease index (Table 6). There was a trend ($P = 0.10$) for herds that introduced cattle from sources with unknown backgrounds and health statuses to experience the largest number of different diseases during expansions (2.40 diseases). This result is not unexpected, and in fact, may be an important first step for documenting the value to dairy herds for genetic merit, records, and health, disease, and vaccination information. Although the effect was not important, slightly fewer diseases were experienced by herds that quarantined some or all introduced cattle (1.56 diseases) compared with herds that did not quarantine cattle (1.94 diseases). This finding may indicate that "quarantine" practices used by many herd owners in this study were ineffective (e.g., quarantined new cattle in pens adjacent to the existing herd), or may reflect the that fact that some herds quarantined only a portion of incoming cattle.

Intuitively, one may rationalize advantages to herd biosecurity for introducing heifers only during herd expansions; however, the effect of introducing cows for disease index was not important ($P = 0.43$). Furthermore, our original response variable for diseases included results for mastitis. Admittedly, introduced heifers can introduce mastitis problems into dairy herds; however, introduced cows likely would introduce considerably greater mastitis risks for herds. Thus, the effects of introducing cows for cumulative disease index was reevaluated when mastitis incidences were eliminated from the response variable, and this effect remained unimportant ($P = 0.25$). Our findings suggest that no clear biosecurity advantage was realized when herds expanded by introducing heifers only, but that herds may have benefited when backgrounds and health status of introduced cattle were known.

Culling practices. Also as part of the interview, herd managers ranked standard DHIA reasons for culling cows from the most to least frequently cited reason for the three time periods and were instructed to add reasons for culling or modify existing reasons to best describe farm culling decisions. Added or modified reasons included unsound feet and legs, dystocia, died, and stray voltage. Stray voltage is not a typical reason for culling, and some may disagree with its inclusion as a reason in this study. However, all reasons for culling except for "died" are subjective assessments of cow re-

Table 6. Least squares means of number of different diseases (cumulative disease index) encountered during herd expansion for biosecurity practices used by interview herds.

Biosecurity practice used	Cumulative Disease Index LS Means[1]	*P*-value[2]
Source for introduced cattle		0.10
Known backgrounds and health status	1.26	
Unknown backgrounds and health status	2.40	
No. of herd sources for introduced cattle		0.54
Single herd source	1.48	
Combined several herds of cattle from different sources	2.05	
Primary advisor for herd biosecurity information		0.31
Veterinarian	1.45	
Other than veterinarian	2.09	
Ages of introduced cattle		0.43
Heifers only	1.40	
Cows or heifers and cows	1.71	
Use of quarantine for introduced cattle		0.50
No quarantine used	1.94	
Quarantine used for some or all introduced cattle	1.56	

[1]LS Means represent back transformations (e^x) of the original model estimates.

[2]*P*-values determined using the difference between –2 log likelihoods for residuals of full and reduced models.

Table 7. Means and SEM of owner-designated scores for culling reasons of cows during three phases of herd expansions.[1]

Culling reason	Prior to expansion[2]		During expansion[3]		After expansion[4]	
	Mean	SEM	Mean	SEM	Mean	SEM
Mastitis, poor udder health, high SCC	2.75	0.512	3.15	0.564	2.64	0.452
Reproductivity unsound	2.44	0.273	3.00	0.519	2.83	0.441
Disease, including metabolic disorders	4.62	0.626	3.28	0.518	3.77	0.303
Low milk production	2.69	0.435	4.46	0.418	2.92	0.486
Sold for dairy purposes	6.42	0.313	6.00	0.0	7.00	0.0
Injury	3.47	0.506	3.23	0.521	3.33	0.527

[1]Lower scores indicated the culling reason was usd more frequently by individual herds.

[2]Additional reason cited: unsound feet and legs.

[3]Additional reasons cited: unsound feet and legs, stray voltage, dystocia, and died.

[4]Additional reasons cited: unsound feet and legs and stray voltage.

movals, and in this context, it is appropriate to include a producer-cited reason such as stray voltage.

Means and standard errors of rankings for reasons for culling are in Table 7. Originally, it was intended that actual culling data for cows would also be obtained and evaluated. Several herd owners indicated that, for various reasons, they were not confident with the accuracy of their DHIA data for herd removals, and for other herds, data were not available. Thus, results in this study represent relative importance of reasons for culling as cited by herd owners only.

Before expansion, the most frequently cited reasons (lowest mean rankings; Table 7) for removing cows from the herd were reproductively unsound (mean = 2.44); low milk production (mean = 2.69); and mastitis, poor udder health, and(or) high SCC (mean = 2.75). Least frequently cited reasons for culling prior to expansion were: sold for dairy purposes (mean = 6.42) and disease, including metabolic disorders (mean = 4.62). During the expansion phase (Table 7), a large percentage of herds indicated that low milk production was a relatively unimportant reason for culling during the expansion period (mean = 4.46), and was again cited frequently as a removal reason following the expansion period (mean = 2.92). Rankings for reasons for culling before and after expansion were similar to rankings reported by NAHMS (1996), but differed numerically from rankings during the expansion phase for our study.

These findings are noteworthy, because numerous studies have reported that the largest financial net returns are associated with low rates of forced culling and optimum unforced (primarily, low milk production) rates. Sol and Renkema (1984) estimated losses associated with disease-related culling are $180 to $500 per cow culled and others have reported that dairy herds could realize 20% larger annual net returns per cow by eliminating forced culling (Renkema and Stelwagen, 1979; Rogers et al, 1988). Herd owners and managers who were interviewed indicated that financial constraints severely restricted their ability to make seemingly optimal culling decisions, and this is evidenced in part by changes of culling patterns for expanding herds (Table 7). During the expansion phase and after initial purchases of cattle were completed, most herd owners were unable to obtain supplementary capital to purchase herd replacements. However, most managers and their lenders felt that it was imperative for timely loan repayment to “keep all stalls filled,” and as a result, less profitable and unprofitable cows remained in herds. Profitabilities for culling strategies reported to date by researchers are for herds maintaining herd size (Renkema and Stelwagen, 1979; Rogers et al, 1988; Sol and Renkema, 1984); researchers have not reported profitabilities for using different culling strategies during dairy herd expansions.

Associations between culling decisions made during different periods of the expansion are in Table 8. Interview responses suggested that culling decisions prior to expansion influenced culling decisions during the expansion phase. Herd managers who indicated that more cows were culled during expansion for mastitis, reproductive unsoundness, and injury indicated that more cows were culled for these respective factors before expansion. In addition, greater culling for mastitis was associated with removing more cows for disease (Table 8). Results suggest that for many herds, new facilities and equipment alone are insufficient to overcome high levels of culling for management-related reasons for culling, such as mastitis, reproductive unsoundness, and injury.

In addition to the factors studied, individual herd owners reported other factors that they associated with culling decisions made during the expansion phase. These included, new concrete (foot and leg problems), lame cows; timing of foot trimming prior to moving cows to new facility; stray voltage; poor design and construction of new free stalls; inadequate reproductive perfor-

Table 8. Pearson correlations of importance of cull reasons prior to expansion for reasons during expansion.

Culling reason during expansion phase	Culling reason prior to expansion				
	Mastitis, poor udder health, high SCC	Reproductivity unsound	Disease, including metabolic disorders	Low milk production	Injury
Mastitis, poor udder health, high SCC	0.80**	–0.04	0.24	–0.41	–0.45
Disease, including metabolic disorders	0.77**	–0.12	0.11	0.04	–0.37
Reproductively unsound	0.36	0.63*	0.29	–0.25	–0.36
Low milk production	–0.36	–0.01	–0.24	0.45	–0.08
Injury	–0.40	–0.23	–0.09	0.05	0.68**

*$P < 0.05$, where H_o: r = 0.
**$P \leq 0.01$, where H_o: r = 0.

mance in the existing herd that occurred when herd owner attention was devoted to construction of new facilities; worker stress and insufficient labor supplies during initial months when freshening large numbers of heifers; and calving problems that occurred for introduced heifers with unknown service sires and due dates. This list is not inclusive, but is provided to represent the broad range of factors that may influence culling and its associated financial impact during dairy herd expansions.

DairyORACLE Simulation

Average annual rates of culling for the initial two scenarios, herds that were maintaining and increasing herd size, are shown in Figure 1 and Table 9. Resulting culling rates for the steady state simulation scenario ranged from 28.8 to 59.4% and were comparable to rates for United States herds (NAHMS, 1997; Nieuwhof and Norman, 1989), suggesting that model parameters are representative of culling decisions in dairy herds (Figure 1 and Table 9). For the expansion scenario, average culling rates during yr 1 were 20.2%; simulation starting values for forced rates were 10%; thus, overall rates indicated that approximately 10% unforced culling was practiced during the expansion year (Table 9). In fact, for this study, expanding herds attained culling levels that were similar to control herds relatively quickly, namely by the second year of the simulation. Note that many expansion planning budgets are based on maintaining annual culling rates of 25%, but despite using a starting value in the model for forced culling rates of 10% (one-half of steady-state rates), expansion herds were unable to maintain overall culling rates of 25% during subsequent years.

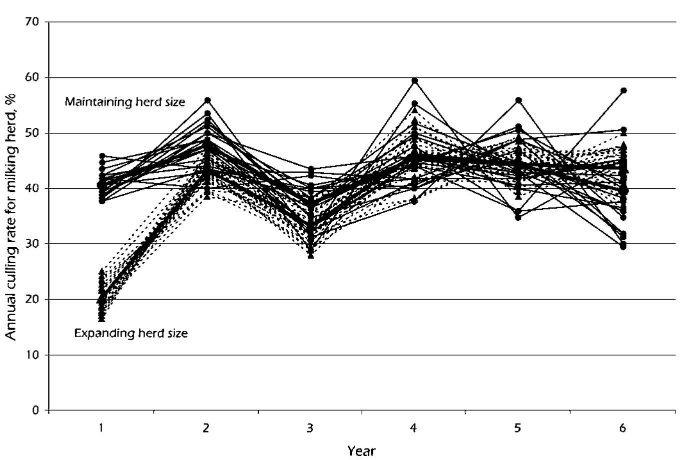

Figure 1. Annual culling rates of cows for 30 replicates of 2 herd expansion scenarios from DairyORACLE. (From Faust, 1999. Figure used with permission of MWPS, Ames, IA 50011.)

It is improbable that dairy herds routinely and profitably maintain forced culling rates of 10% (model starting value for expansion herds). Findings from several studies indicate high risk of early culling for disease events that likely occur with relatively high frequency during herd expansions, such as abortion, mastitis contracted during the dry period, abomasal displacement, ketosis, uterine infections, and ovarian cysts (Beaudeau et al., 1995; Kinsel, 1998). In addition, the majority of United States dairy herd removals are forced removals as opposed to unforced or strategic removals, and findings reported from data collected by the NAHMS 1996 Dairy Study (1997) indicate that disease-related removals account for nearly 80% of cows that were sold for slaughter. Several herd owners who have completed large expansion projects suggest using culling rates of 35 to 40% for expansion planning, and simulation results support these values suggested by herd owners. In addition, for expansion projects it is advisable to use sensitivity analyses to evaluate the effect of different herd culling rates on financial outcomes for expansion projects, and results shown in Table 9 can provide necessary guidelines. Projects that are less risky will remain profitable when high rates of culling are budgeted; however, profitability for highly risky expansion projects will be very sensitive to cull rates used.

Table 9. Means, minima, and maxima for annual rates of herd removal from 30 replicates of two simulation scenarios—herds maintaining herd size and expanding during yr 1 to two times original herd size.[1]

Year	Maintaining herd size			1 yr Expansion[2]		
	$\overline{X}$	Minimum	Maximum	$\overline{X}$	Minimum	Maximum
	%			%		
1	40.6	37.6	45.9	20.2	16.5	25.0
2	47.9	40.0	55.9	43.4	38.5	47.4
3	37.3	28.8	43.5	33.3	27.9	38.5
4	45.5	37.6	59.4	46.2	37.9	54.1
5	44.3	34.7	55.9	44.4	38.5	49.4
6	39.5	29.4	57.6	43.7	36.2	50.0

[1]From Faust, 1999. Portions of table used with permission of MWPS, Ames, Iowa.

[2]Expansion to two times original herd size.

Another common concern voiced by herd owners who completed expansion projects was inadequate long-term budgeting and planning with lenders for subsequent purchases of replacement cows or heifers. Herd owners have indicated that it was necessary to cull a large number of purchased animals that had completed a single lactation only; a similar outcome was indicated by results for simulated expansion herds. Rates of culling during yr 2 were more than two times rates of yr 1 for simulated expansion herds (Table 9 and Figure 1). In addition, findings from the DairyORACLE simulation for yr 1 through 3 indicated that expanding herds replaced a smaller percentage of cows than herds that were maintaining herd size (Table 9); however, it was necessary for expanding herds to purchase more herd replacements during yr 1 through 3 of the study (Table 10). Moreover, all expanding herds required purchasing additional replacements during yr 2. These findings can be used to provide information for planning cash needs for cattle purchases; for example, results in Table 10 can be used to budget annual purchase of replacements for representative 300-cow herds and for 600-cow herds that are expanding from 300 cows. Number of replacements purchased by typical 300-cow herds that are expanding to 600 cows are projected to be 319, 70, and <1 heifers during yr 1 through 3, respectively. Few herd owners and lenders would anticipate a need to purchase additional herd replacements during yr 2 and 3, following a major herd expansion during yr 1.

Results for five different DairyORACLE simulation scenarios designed to study the net economic returns to expanding herds for unforced culling and for purchasing heifers of different quality are in Table 11. Thirty replicates were simulated for the 6-yr experimental period for each of the five different model scenarios. For all scenarios, charges for purchased replacement heifers were $1,300, thus values in Table 11 represent economic value above their purchase price. Simulation results indicate that culling rates during the expansion year (yr 1) were slightly larger (1.35%) for the scenarios that included purchasing high quality replacement heifers (Table 11). For subsequent cull rates (years 2 through 6), heifer quality had essentially no influence for rates. Implementing unforced culling for expanding herds was associated with significantly larger culling rates during yr 2 of the simulation, but reduced annual

Table 10. Means, minima, and maxima for annual replacement heifer purchases as a percentage of target herd size from 30 replicates for two simulation scenarios—herds maintaining herd size and expanding during yr 1 to two times original herd size.[1]

Year	Maintaining herd size[3]	1 yr Expansion[2]		
		$\overline{X}$	Minimum	Maximum
	$\overline{X}$, % of target size	% of target size		
1	0.0	53.2	50.0	57.9
2	0.0	11.7	4.7	15.9
3	0.0	0.06	0.0	1.8
4	0.0	0.0	0.0	0.0
5	0.0	0.0	0.0	0.0
6	0.0	0.0	0.0	0.0

[1]From Faust, 1999. Table used with permission of MWPS, Ames, Iowa.

[2]Expansion to two times original herd size.

[3]Herds that were maintaining herd size required no purchase of additional replacement animals.

Table 11. Mixed model solutions for culling rate and annuities for simulated net returns from four alternative expansion scenarios and one scenario to maintain herd size.[1]

	Effect for high quality heifers	Effect for unforced culling	
	Mixed model solution	Mixed model solution	SE
Culling rate			
year 1, %	1.35*	0.034	0.539
year 2, %	–0.80†	24.8**	0.459
year 3 to 6, %	–0.11	–3.73**	0.385
Annuity for net returns			
Per purchased heifer, $	113.54**	–250.62**	16.73
Per cow, $	66.37**	23.29**	6.82

[1]30 replicates were simulated for each scenario.
*$P < 0.05$, where H_o: Solution = 0.
**$P < 0.01$, where H_o: Solution = 0.
†$P < 0.10$, where H_o: Solution = 0.

herd replacement rates for 3 of 4 yr (average of 3.7% reduction) during yr 3 through 6 (Table 11). This latter result was unexpected, but likely indicates that when unforced culling was practiced during the expansion phase, herds were able to eliminate a significant portion of low producing heifers after a single lactation (cull rate during yr 2 was 24.8% higher for unforced culling scenarios). Culling of these low producing heifers was delayed when unforced culling was not practiced.

Interestingly, no culling for low milk production was more profitable than practicing unforced culling ($–250.62 6-yr annuity) when evaluated on the basis of purchased replacements (Table 11). However, when the profit measure used was an annuity for net returns per cow, culling for low milk production yielded an additional $23.29 annually (6-yr annuity) when compared to profitability for no unforced culling. This result may occur because a measure such as annualized profit per purchased replacement heifer likely is more sensitive to profit effects that arise due to the difference between cost for purchased replacement heifers and sale value for cull cows. On the other hand, the latter profit measure is based on a fixed target herd size annually. This profit measure based on an annuity per cow is expected to more sensitively detect differences in profit that are associated with milk sold per stall and better indicate the overall profitability to the farm for practicing unforced culling during herd expansions.

For the parameters used in these simulation scenarios, profitability as indicated by an annuity for net returns per purchased replacement heifer was largest for expansion scenarios that included high quality heifers (Table 11). Per purchased replacement heifer, purchasing high versus low quality replacement heifers for expansions returned an additional $113.54 annuity (6-yr) for net returns or a total net present value of $681.24. Per cow, this advantage was an additional $398.22 ($66.37 6-yr annuity). This finding is noteworthy, because it is difficult in practice to attribute real economic value to factors such as future health status and genetic potential for heifers, and results in Table 11 may be useful for defining this value. Moreover, this economic incentive for high quality heifers from simulation results likely is smaller than may occur in practice for dairy herds. For example, compared with quality parameters used for our simulation, several herd owners have reported higher incidence rates for abortion, dystocia, calfhood mortality, and ensuing culling when low quality heifers are introduced.

CONCLUSIONS

Results from this study imply that many opportunities exist to improve decision making of cattle related factors for dairy herd expansion projects. Fewer than half of dairies that were interviewed employed basic biosecurity practices for incoming cattle such as disease testing, adequate quarantine, and obtaining cattle with known genetic and health histories. However, all herds reported notable increases in disease related problems for BVD, PDD, IBR, and(or) clostridial disease following herd expansions, and our findings indicated that herds experienced the greatest number of different diseases when adequate biosecurity was not employed.

Additionally, results from this study suggest that assumptions for culling and replacement used commonly for expansion planning may be invalid. Interview participants and simulation results suggest that commonly assumed rates may be too low and that cull rates used for expansion planning should be more consistent with preexpansion rates. In addition, the simulation model results suggest that dairy managers should: 1) anticipate a need for purchase of replacements during yr 2 and 3 of the expansion, 2) be willing to pay a premium for replacement heifers with adequate to good genetic and health backgrounds, and 3) consider implementing unforced culling during the expansion phase.

ACKNOWLEDGMENTS

We extend sincere gratitude to the dairy herd practitioners and their clients who contributed their time, data, and experiences to this study. Contributing veterinarians were Ed Kreykes, DVM, Sanborn, Iowa; Jack Hansen, DVM, Seymour, Wisconsin; John Baldwin, DVM, West Union, Iowa; Ken Weston, DVM, Postville, Iowa; Don Niles, DVM, Casco, Wisconsin; David Rhoda, DVM, Evansville, Wisconsin, and David Weber, DVM, Manchester, Iowa. Also, we wish to recognize the generosity of Pharmacia (North Peapack, NJ) in covering the publication charges for this manuscript.

REFERENCES

Bailey, K. 1997. Blueprint for a successful dairy expansion. J. Dairy Sci. 80:2760–2765.

Bailey, K., D. Hardin, J. Spain, J. Garrett, J. Hoehne, R. Randle, R. Ricketts, B. Steevens, and J. Zulovich. 1997. An economic simulation study of large-scale dairy units in the Midwest. J. Dairy Sci. 80:205–214.

Beaudeau, F., V. Ducrocq, C. Fourichon, and H. Seegers. 1995. Effect of disease on length of productive life of French Holstein dairy cows assessed by survival analysis. J. Dairy Sci. 78:103–117.

Faust, M. A. 1999. Stocking the dairy herd expansion. Pages 35–43 *in* Positioning for the Future: Expanding Dairy Profitability through Strategic Growth. MWPS-4SD4. MidWest Plan Service. Ames, IA.

Kinsel, M. L. 1998. An economic decision tool for dairy cow culling and replacement. Ph.D. Diss. Department of Clinical and Population Sciences. University of Minnesota, St. Paul.

Marsh, W. E., Dijkhuizen, A. A., and Morris, R. S. 1987. An economic comparison of four culling decision rules for reproductive failure in United States dairy herds using DairyORACLE. J. Dairy Sci. 70:1274–1280.

National Animal Health Monitoring System. 1996. Reference of 1996 Dairy Management Practices. USDA. Animal and Plant Health Inspection Service. Veterinary Services. Fort Collins, CO.

National Animal Health Monitoring System. 1997. Dairy ’96. USDA. Animal and Plant Health Inspection Service. Veterinary Services. Fort Collins, CO.

Nieuwhof, G. H., and H. D. Norman. 1989. Phenotypic trends in herd life of dairy cows in the United States. J. Dairy Sci. 72:726–736.

Rauff, Y., D. A. Moore, and W. M. Sischo. 1996. Evaluation of the results of a survey of dairy producers on dairy herd biosecurity and vaccination against bovine viral diarrhea. J. Am. Vet. Med. Assoc. 209:1618–1622.

Renkema, J. A., and J. Stelwagen. 1979. Economic evaluation of replacement rates in dairy herds. I. Reduction of replacement rates through improved health. Livest. Prod. Sci. 6:15–37.

Rogers, G. W., J. A. M. Van Arendonk, and B. T. McDaniel. 1988. Influence of production and prices on optimum culling rates and annualized net revenue. J. Dairy Sci. 71:3453–3462.

SAS. 1999. SAS/STAT Users Guide. Ver. 8. SAS Institute Inc. Cary, NC.

Smith, J. F., D. V. Armstrong, M. J. Gamroth, and J. G. Martin. 1997. Planning the milking center in expanding dairies. J. Dairy Sci. 80:1866–1871.

Sol, J., and J. A. Renkema. 1984. A three-year herd health and management program on thirty Dutch dairy farms. Vet. Q. J. Vet. Sci. 6:141–148.

Stahl, T. J., B. J. Conlin, A. J. Seykora, and G. R. Steuernagel. 1999. Characteristics of Minnesota dairy farms that significantly increased milk production from 1989–1993. J. Dairy Sci. 82:45–51.