PEER REVIEWED

Survey of Selected Risk Factors and Therapeutic Strategies for Parasitism on Milk Production Response of Lactating Dairy Cattle

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Abstract

A recent review of studies on the effect of parasite control programs on productivity of lactating dairy cattle has reported positive, but variable, results. A conjoint analysis survey was conducted, using dairy industry professionals and practicing veterinarians, to estimate the impact of various management strategies on the control of parasites on milk production in dairy herds. The results of the survey suggested positive associations of confinement housing systems, replacement heifer treatment programs and cow treatment programs with milk production. Spreading manure on pastures and not using a treatment program in heifers were determined to have the most important negative association with milk production. The survey responses also suggested that topical treatment for external parasites, and strategic use of endectocide products in the prepartum period, would have a positive effect on production. Areas of high priority for research on the association between parasites and productivity in dairy cattle would include the relative impact of whole herd versus strategic lactation cycle treatment programs.

Introduction and Review

Studies have indicated the presence of gastrointestinal nematodes in a high proportion of dairy cattle.[23,28] Yet, the impact of such infections on production has been difficult to quantify. In field trials using various anthelmintic treatments, a significant increase in milk production has been demonstrated in response to treatment.[4,5,19,25] On the other hand, similar trials have not resulted in a consistent and predictable change in production levels.[9,10,18,27] Many trials have found that milk production response to anthelmintic treatment is greatly variable between farms[10,19,23,24] as well as between stages of lactation.[23,27] The effect on production seems to be dependent on many other factors such as herd management, weather conditions, age of cow and risk factors for parasitism.[19,27] Currently, there is very little information available about the potential risk factors for parasitism in lactating dairy cows that would predict indications for anthelmintic use. In addition, a new generation broad-spectrum endectocide product, approved without a need for milk withholding, could make a considerable difference in this decision-making process.

A recent paper by Gross, Ryan, and Ploeger (1999) reviewed the effect of parasites and anthelmintic treatment on milk production.[12] Overall, the studies evaluated have shown that grazing cattle are likely to be affected with gastrointestinal nematode parasites, especially *Ostertagia ostertagi* and *Cooperia* spp. There is currently no reliable way to determine if a herd is subclinically infected with these parasites at a level that interferes with production. A total of 87 trials were reviewed, of which 70 (80%) had a positive response ($p<0.001$) in milk production following anthelmintic treatment. The median change in milk production was +1.39 lb (0.63 kg)/day. In studies that investigated milk fat yield, an increase was seen in 26 of 35 experiments ($p<0.01$).

The majority of experiments in which cows were dosed with infective larvae showed a negative effect of parasite infection on milk production. In experiments where naturally infected cows were treated with a variety of anthelmintics after the fourth week of lactation, an increase in milk production was seen in 15 of 19 experiments.[12] In trials investigating milk production after pre-calving or early lactation anthelmintic treatment, an increase in milk production was also seen in the majority of experiments. From these experiments, the reviewers suggested that older anthelmintics (coumaphos, thiabendazole, imidazothiazoles) had inferior efficacy compared to later benzimidazoles (albendazole, fenbendazole, oxfendazole), which were less effective than macrocyclic lactones (ivermectin, abamectin, moxidectin, doramectin, eprinomectin), especially against immature nematode parasites including *Ostertagia ostertagi*. The "modern" endectocide products resulted in more consistent positive responses in a greater proportion (97% vs. 74%) of cows. However, these findings may be confounded by improvements in management, genetic progress and other factors that have occurred over a similar time period.

The great variability in milk production response to anthelmintic treatment has created speculation about the factors that determine the milk production increase in a specific herd. The results of several studies would indicate that some of the most significant factors affecting response are the following:

Parasite Load. The level of infection has been suggested to be an important factor in determining milk production response.[23] However, this level is difficult to assess and to quantify. The fecal egg count technique has been traditionally used to assess parasite burden. However, having no fecal egg burden is considered to be a poor indication of infection in adult animals.[23] Studies have shown no quantitative correlation between egg shedding and degree of parasitism.[12] Furthermore, there is no evidence of a relationship between the mean fecal egg count of a herd and its response to treatment.[1,9,27] Egg shedding may vary seasonally or in relation to the gestation cycle. In addition, there may be a seasonal and/or a periparturient increase in fecal egg production, even though generally a low level of egg output is seen. Individual herds will show a wide variation in egg count.[12] Antibody titer to *Ostertagia* has been used as a measure of infection,[2,15,23] although differentiation between current and past infections may be difficult.[2] A positive correlation between the herd antibody titer and the mean treatment response has been demonstrated. However, the herd antibody titer was not high enough for predictive use.[23] Similarly, in another trial, the data were inconclusive with respect to the level of anti-ostertagia antibodies in the bulk milk sample and subsequent treatment response.[15] Even though it is possible to estimate parasite load, it is difficult to correlate these measures with the actual level of infection and subsequently with production losses.

Current Production of the Herd. High producing herds have shown better response to anthelmintic treatment than their lower producing counterparts.[24] In one study, there was a tendency for treated cows to produce increasingly more milk with increasing level of production.[19] Another trial showed a greater increase in milk fat production in first calf heifers in higher yielding herds compared to lower production herds.[24] Production responses have also tended to be greater when treatment is given in the early part of lactation;[27] although in a study where cattle were housed for the first part of their lactation, the increase was seen in later phases when the cattle were pastured.[12]

Replacement Heifer Parasite Control Program. The replacement heifer anthelmintic treatment protocol may be very important in determining milk production responses to anthelmintic treatment in the lactating herd. A greater response to treatment of mature cows has been seen in herds with a minimal calf parasite control program, and in herds that graze cattle on the same fields that calves have grazed.[3] In other words, there was a greater increase in milk production from treating herds that were exposed to infective larvae from calves. Nematode infections in the first 2 years of life can negatively influence future milk production through decrease in weight gain. Treatment of these calves results in increased growth which leads to increased first lactation milk yield.[22] A decreased weight gain during a replacement heifer's first grazing season can result in a permanent decrease in milk production potential. However, there is considerable debate about whether the parasite control should be at the minimum level required to prevent weight gain reductions, yet allow the animal to develop some immunity.[21] There appears to be a greater economic value to treating heifers during their first two years rather than treatment of cows at calving.[22]

In recent years, there has been a substantial improvement in our knowledge base concerning the epidemiology of parasites and their effects on performance. This research has been particularly conducted in the areas of beef cow-calf, beef feedlot and dairy replacement heifers. However, the knowledge base is still lacking many important details for lactating dairy cows. Dairy producers are looking for meaningful information on this topic. Recent articles in dairy industry publications have succinctly expressed the need for information such as the methods to determine which cows to treat, and the economic impact of treating dairy cattle for parasites.[6,7] Until such research has been published, the opinion of experts in the field is probably the best resource for effective decision making. However, individuals may vary widely in their opinions concerning the most important factors when choosing which herds and cows to treat, as well as the magnitude of the production response expected.

Two different epidemiological techniques have been used in other fields, where information has been lacking but individual scientists may have become knowledgeable and formulated specific opinions. The hypotheses generated from these methods can then be investigated with specific hypothesis-testing research. One of these methods is the **Delphi technique**[16] which involves the compilation of opinions of "experts" in a specific field. The experts are surveyed to obtain rankings for a series of **individual** factors. These rankings and comments are returned to the experts and the exercise repeated until a general consensus is obtained. The hypotheses generated are based on opinions and knowledge accepted by the majority of experts. Thus, the final theory is assumed to have scientific basis. However, the Delphi technique is a compositional method in which respondents rate each characteristic in isolation. When each characteristic is rated on its own there is some bias, as it is difficult to rate one factor and hold everything else equal.

Conjoint analysis is another research method used to determine the importance or ranking of a **group** of characteristics or factors.[17] Conjoint analysis is useful to determine the impact of a factor when a decision-making process is multi-factorial in nature, or when the effect of one factor can be modified by the presence of other factors. Conjoint analysis is a decompositional method of analysis in which different subsets of the characteristics or factors being investigated are used to construct "profiles". The participants are then given a single opportunity to rank profiles in order of preference, and assign an actual value to the change in outcome. Each profile contains several key features, or "attributes", of the subject being studied. Within each attribute there are several possible choices or "levels". Profiles are generated by different combinations of one level for each attribute. The objective of the conjoint analysis is to determine the profile that contains the preferred level for each attribute. This can then be used to determine which factors are most important in the decision-making process. It is impossible to ask respondents to rank every possible combination of factors. Thus, a computer software program is used to create a representative number of combinations, which can then be used to extrapolate and weight the importance of each individual factor. The profiles are decomposed through the use of linear regression analysis with dummy variables to arrive at the relative importance of each factor. There are also excellent examples of the use of conjoint analysis in the human and animal health literature.[6,7,14,20]

The purpose of this study was to survey individuals from chosen groups of dairy professionals regarding the impact of estimated specific risk factors for parasitism and various approaches to therapy, on the performance of lactating dairy cattle. A conjoint analysis was conducted on the survey results. These outcomes of the conjoint analysis will be used to design the most beneficial prospective research on the risk factors and therapeutic strategies for parasite control in lactating dairy cattle.

Methods and Materials

A recent review of the published literature on factors affecting the impact of parasitism on milk production in lactating dairy cattle was obtained and evaluated.[12] From this review, three of the most important variables in the relationship between parasitism and performance were determined to be:

- the housing system and access to pasture
- the parasite control program for replacement heifers
- the type and timing of antiparasitic treatment of the lactating herd

These three variables or attributes were selected to form the basis of the farm profiles that selected dairy industry experts would be presented.

Each of the three variables were given a short profile name and divided into different levels. The profile term **Exercise/Pasture/Manure** referred to the level of access that the lactating cattle had to potentially contaminated sources of parasites. Cows were either confined to the barn or a concrete exercise yard; given access to the 10 acre field for 5 hours; grazed on three separate pasture fields on a rotating basis; or grazed on pasture, with manure treatment on the pasture fields in the late fall. The attribute term **Heifer Treatment** represented the anti-parasitic strategy for the replacement heifers. Older calves (>9 months), open yearlings, and bred heifers had access to pasture from mid-May until late October. Parasite control strategies for replacement heifers were evaluated based on their potential impact on future milk production. The options for internal and external parasite control were: no treatment for parasites; a broad-spectrum endectocide administered in early November after heifers are removed from pasture; a broad-spectrum endectocide administered via pour-on at 3 weeks and at 8 weeks after turn-out on pasture in the spring; or, an endectocide sustained release bolus administered at the time of turn-out on pasture in the spring. The profile term **Cow Treatment** represented the parasite control strategy used on the lactating cows.

The approaches to parasite treatment for cows were: no therapy for parasites; topical administration of a synthetic pyrethrin for treatment of mange and lice as needed; a pour-on endectocide administered once, during a period of one to three weeks prepartum, in all first-calvers and springing cows; a pour-on endectocide applied to all lactating and dry cows in early October.

Conjoint analysis was selected to evaluate the importance of the various levels of the three major attributes, since a large number of industry experts would be surveyed and its decompositional approach was desired for this multifactorial situation. A set of farm profiles was created using different combinations of factor levels within the three chosen variables. These profiles were constructed through the use of the Statistical Package for the Social Sciences (SPSS Inc., Chicago). The SPSS program selected a representative number of mutually orthogaral profiles in order to extrapolate the importance of individual factors and predict the outcome of other combinations of factors. Each farm profile was represented by a card which listed the specific management and risk factors for a fictitious farm. Respondents were asked to rank the cards based on their expectation of the impact the indicated pasture management strategy and therapeutic programs would have on milk production when compared to other profiles. Respondents were also asked to quantify the percentage of production lost or gained relative to the outlined baseline herd for each of the profiles.

The "baseline" dairy herd was defined explicitly for the participants. The herd was a 60 cow Holstein herd housed in a tie-stall barn, with a bi-weekly health management program. The herd had a 12-month rolling herd average production of 64 lb (29 kg) of milk per cow per day. There was moderate seasonality in their monthly milk production, with lower production in late summer and early fall. The baseline herd had a minimal parasite control and treatment program. The herd had no clinical evidence of a problem with internal parasites. There was a 5-8% prevalence of tail-head chorioptic mange, mostly during the late fall and winter in both lactating and dry cows. Lice were observed (rarely) in some mature cows. The basic herd management and parasite treatment strategy used in the baseline herd was as follows: lactating cows had access to the yard and 10 acre field all morning throughout the late spring and summer, and were in the yard only during fall and winter; a broad-spectrum endectocide was administered to all heifers in the fall; and topical pyrethrin was sprayed on the lesions of cows with clinical mange.

Each farm profile was represented by an individual card, with a numerical designation to differentiate the cards. Each card had a place for respondents to record a rank, and expected percent change in milk production relative to the reference herd. Respondents were reminded that all other herd management practices remain unchanged; only the parasite control and therapy program varied in each profile. A detailed explanation of the purpose of the study, definitions of the attributes, and instructions for completion of the survey were written for the participants in both English and French. The package was submitted to a selected group of dairy practitioners at the Ontario Veterinary College to ensure the instructions were clear and the task was feasible. After minor improvements, the survey package was sent by mail to the members of four different groups of dairy professionals. These individuals included bovine parasitologists in academic institutions, industry professionals involved in parasite control research and development, veterinarians specializing in dairy health management and key dairy extension people. The groups of participants were selected based on involvement in dairy health management practice, bovine parasitology, or dairy research and the animal health industry. In total, approximately 460 English versions of the survey, and 260 French versions were sent out. A pre-addressed, stamped envelope was provided for return of the information form and profile cards.

Statistical Methods

The profiles were decomposed via linear regression in order to estimate the effect of each level of each profile term using the regression coefficients. This was accomplished by creating dummy variables for each level of the attribute with the profile of the baseline herd serving as the reference. Potential confounding variables representing region, knowledge, academic training, year of graduation, and field of employment were also included in the modelling process. A linear regression using the generalized estimating equation (GEE) was utilized for the regression analysis to allow for the potential of overdispersion by a respondent. Thus, the random effects of respondent were controlled in the final regression analysis. The initial model was estimated for 16 out of the 20 profiles. To be specific, the 1 near regression model was of the form $y = \text{intercept} + B_1X_1 + B_2X_2 + \ldots$ Thus, the model was as follows:

% change in milk production = -0.588 + Pasture Level + Heifer Treatment + Cow Treatment + Employment Activity + Year of Graduation + Knowledge Level + Region

Four of the 20 profiles were designated as holdouts which were used to test the internal validity of the model. Based on the estimated model, predicted values were calculated for each of the respondents holdout cards. The difference between actual and predicted values was tested for significant difference ($p < 0.05$) from zero using a t-test. A non-significant t-test would indicate good internal validity for the model.

Results

Of the 720 surveys that were mailed out, a total of 102 were returned and used in the analysis. This represents a response rate of 13.4%. The majority of respondents (78.2%) were in veterinary practice, with a small proportion in the animal health industry (8.9%) and academic/government (12.9%). Further definition of professional activity revealed that the majority of respondents were either in general veterinary practice (42.6%), or dairy health management practice (40.6%). A further 9.9% of the respondents were parasitologists in academia or industry, and 5.0% were involved in extension education or industry. The respondents were asked to rate their knowledge of the current information on epidemiological risk factors, treatment options and control schemes for internal and external parasites of dairy cattle. For this question, 71.3%, 21.8%, and 6.9% of respondents felt their knowledge was moderate, extensive, and limited, respectively. The respondents were fairly evenly distributed with respect to completion of their most recent degree. A small number (7.0%) had graduated prior to 1970, 31.4% had graduated between 1970 and 1979, 38.2% between 1980 and 1989, and the remaining 22.5% had completed their schooling between 1990 and 1998. Geographically, 52.9% of respondents were from Ontario, 16.7% from Western Canada or the United States, and 30.7% from Quebec or Atlantic Canada.

The estimated percentage change in milk production was chosen as the dependent outcome variable. The mean estimated change in milk production for all risk factors considered collectively was 0.8%, the median was 1.0% and the range was -25% to +20%. The estimated percentage change in milk production variable was normally distributed. The results of the predictive linear regression model are presented in Table 1. The difference between the model predicted and participants estimate for percent change for the holdout profiles was not significantly different from zero. Thus, the regression model was deemed to have good internal validity.

The survey respondents felt that dairy cattle confined to a barn, with or without access to a concrete yard, would have increased production when compared to the baseline herd, which had lactating cows turned out on a 10 acre pasture or exercise field throughout the spring and summer. The production increase was predicted to be approximately 3.15% ($p<0.05$). Allowing the herd to graze three separate pasture fields on a rotating basis

Table 1. Estimates of percent change in milk production for various levels of management intervention derived from a multiple linear regression model controlling for respondent characteristics.

Variable	Estimated percent change in milk production	Standard Error	95% Confidence Interval
Exercise/Pasture/Manure			
Field⁺	0.00		
Confined+/- Yard	+3.15*	0.397	(+2.37, +3.93)
Pasture	-0.89*	0.429	(-1.73, -0.051)
Pasture and Manure	-1.94*	0.397	(-2.72, -1.16)
Heifer Treatment			
Fall Heifer Treatment⁺	0.00		
No Heifer Treatment	-4.92*	0.384	(-5.67, -4.17)
Spring Heifer Treatment	+1.01*	0.308	(+0.41, +1.61)
Full-Season Heifer Treatment	+3.31*	0.259	(+2.81, +3.81)
Cow Treatment			
Topical Cow Treatment⁺	0.00		
No Cow Treatment	-1.62*	0.213	(-2.04, -1.20)
Prepartum Cow Treatment	+3.15*	0.288	(+2.59, +3.71)
Fall Cow Treatment	+2.53*	0.295	(+1.95, +3.11)

*significant at $p<0.05$
⁺selected baseline variables

was predicted to decrease the production by 0.89% ($p<0.05$). Adding manure treatment to the pasture fields was predicted to decrease the production further, resulting in a loss of 1.23 lb (0.56 kg)/cow/day ($p<0.05$).

The individuals surveyed felt the baseline treatment for heifers, which was broad spectrum endectocide applied in the fall, was preferable to no heifer parasite control program. No heifer treatment was predicted to result in a milk production loss of 4.92% ($p<0.05$). Spring heifer treatment (use of a broad spectrum endectocide treatment at 3 and 8 weeks after pasture turnout) was predicted to increase production by 1.01% ($p<0.05$) compared to fall treatment. Full season treatment through the use of endectocide via a sustained release endectocide bolus was considered to be most effective by increasing production 3.31% ($p<0.05$).

The baseline cow treatment was topical pyrethrin sprayed on cows with clinical evidence of mange. As compared to this baseline, the use of no parasite treatment for cows was predicted to decrease milk production by 1.62% ($p<0.05$); indicating that the respondents attributed production loss associated with clinical mange that would be alleviated with pyrethrin therapy. Prepartum cow treatment (a pour on endectocide administered at 1 to 3 weeks prepartum to all first calvers and springing cows) was predicted to cause a 3.15% ($p<0.05$) increase in milk production or the equivalent of 2.00 lb (0.91 kg)/cow/day compared to topical treatment. Fall cow treatment (a pour on endectocide administered to all cows in early October) was expected to increase milk production by 2.53% ($p<0.05$) or 1.61 lb (0.73 kg)/cow/day.

There was no significant difference in estimated percent change in milk production between groups of respondents (Table 2). It is noteworthy that a substantial, but not statistically significant difference was found in the responses of those that considered themselves to have "limited knowledge". This group, which represented 6.9% of the respondents, tended to predict milk production changes of 1.46% higher when compared to the "extensive knowledge" group ($p<0.1$). Other respondent characteristics such as region, year of graduation, and employment type did not affect the estimated milk production change with changing management conditions.

Discussion

The response rate of 13.4% may have been due to several factors. The timing of distribution of the survey

Table 2. Estimates of percent change in milk production for various levels of respondent characteristics derived from a multiple linear regression model controlling for management intervention

Variable	Estimated percent change in milk production	Standard Error	95% Confidence Interval
Professional Activity			
General Veterinary Practice+	0.000		
Dairy Health Management Practice	-0.276	0.534	(-1.32, 0.77)
Government	-0.212	0.645	(-1.48, 1.05)
Industry	-0.492	0.551	(-1.57, 0.59)
Year of Graduation			
Graduation Year 1990-1998+	0.000		
Graduation Year 1980-1989	+0.686	0.830	(-0.94, 2.31)
Graduation Year 1970-1979	+0.525	0.766	(-0.98, 2.03)
Graduation Year <1970	+0.868	1.549	(-2.17, 3.90)
Extent of Knowledge			
Extensive Knowledge+	0.000		
Moderate Knowledge	-0.127	0.773	(-1.39, 1.64)
Limited Knowledge	+1.458	0.763	(-0.04, 2.95)
Geographic Region			
Ontario+	0.000		
United States and Western Canada	-0.084	0.989	(-2.02, 1.85)
Quebec and Atlantic Canada	+0.447	0.586	(-0.70, 1.59)

+selected baseline variables

could have played a role in the low response. It arrived at a busy time for most dairy practitioners. Furthermore, completion of the survey was probably much more time consuming than was anticipated. Participants were not offered a direct incentive for completion of the survey. Thus, the time required to complete the ranking exercise was likely a deterrent. The only incentive offered for completion was a copy of the report when finished. Participants were not required to include their names with their returned surveys. Thus, respondents were anonymous, and it was not possible to follow up on unreturned surveys. The respondent names were selected from several general mailing lists. It is possible that there was inadequate screening done prior to mailing. Some of the selected participants may not have had any interest in parasite control programs for dairy herds. Others may not have considered themselves to be suitable candidates to answer this questionnaire. Although the instructions for the study were presumably explained in a clear manner, it is possible that some potential participants did not fully understand how to complete the ranking of farm profiles, or the predicted milk production change. Some individuals may have had difficulties with the definition of the baseline herd or with the terms used in the survey, even though the instructions indicated several methods for contacting members of the research team should questions arise.

Respondents that did return the survey completed both exercises appropriately. There were no questions from the participants. There is no reason to suspect that the sample population is biased; although this was impossible to assess. The major effect of limited response rate was to reduce the statistical power to detect any differences in the opinions of respondents of different geographical region, years of graduation or type of employment.

Conjoint analysis was a good method for determining "expert" opinion with respect to parasitism in lactating dairy herds. The predictions from the model which was generated closely mirror the results from the Gross et. al. (1999) literature review in terms of milk production increases in treated animals.

Within the pasture management attribute, the greatest predicted risk factor for parasitism was the pasturing of cattle, on a rotating basis, on fields which had been treated with manure. Pasturing cattle in three separate fields on a rotating basis was predicted as the next greatest risk factor, followed by turnout for 5 hours per day in a 10 acre field. The lowest predicted risk was in animals that were confined, or turned out into a concrete exercise yard. These predictions are consistent with literature which suggests that grazing cattle are at a much higher risk for gastrointestinal nematode parasites. The likelihood of ingesting infective larvae increases when cattle graze in limited pasture fields, especially where there is a chance of a high parasite burden in the field. When cattle are given access to larger fields, it is expected that their exposure to infective larvae will be decreased. Confinement, or prevention of access to grass, greatly decreases the chance of exposure to parasite larvae. The infective larvae are ingested with the herbage, and prevention of access to grass will drastically decrease the chance of parasite ingestion.

Predictions suggested that choosing to use no treatment for heifers resulted in the greatest loss of milk production. Fall treatment was predicted to have the next greatest loss of milk production. Spring treatment was preferable to these two options, and full season treatment with a sustained release endectocide bolus was predicted to result in the largest increase in milk production. Replacement heifer parasite control has been shown to be important in ensuring adequate growth which results in increased first lactation yield. Some studies have shown that heifer treatment in the first 2 years is more beneficial than treatment of cows at calving.[22] Treatment of the replacement heifers is also important as a strategy for management of parasites in the lactating herd. If heifers are grazed with lactating cattle, or even on the same field at different times during the pasture season, they will contribute to the parasite contamination of the environment. The respondents predicted the highest milk production responses when heifers were treated either full season, or twice in the spring, when the pasture infectivity is likely to be the highest.

Within the category of cow treatment, herds that received no treatment for parasitism were predicted to have the lowest production. Topical treatment was the next greatest predicted risk factor. In comparison, fall treatment reduced the predicted parasitism risk, as did prepartum cow treatment. The current literature on parasitism in lactating dairy cattle is limited. However these predictions seem logical based on extrapolation from other research. It is expected that without treatment, all cows will have some baseline level of parasitism. The effect that this level of infestation will have on milk production is not completely clear. Yet, it is logical that treatment for this parasitism could increase production. Parasitized animals may be in a generally lower state of health compared to non-parasitized animals. Topical treatment for external parasites may decrease the skin irritation associated with external parasite infestation, especially with the lesions of chorioptic mange. It is plausible that prolonged intense pruritis would cause reduced dry matter intake in early lactation. However, a more broad spectrum endectocide that will also decrease the gastrointestinal worm burden would likely show a more significant response with respect to milk production. Timing of this broad spectrum endectocide would likely change the effect on milk production, but further research must be done to investigate results at different stages of lactation and gestation.

It is important to recognize that this survey did not specifically address the economic impact of the factors examined. Although a specific treatment or prevention strategy may provide additional milk production it may require a drastic increase in labor input or other financial expenditures which might negate the benefit of increases in production. Also, some management strategies examined here are not possible for all establishments. For example, pasture management strategies are useful where there is an opportunity to change. In many cases, the manager will be unable to implement changes. If replacement heifers or lactating cows are purchased into the lactating herd, it is difficult to select those that have identical parasite control programs.

Parasite control strategies are one of the many management factors that affect milk production. Factors such as mastitis control, nutrition, disease control, reproductive management and cow comfort also greatly affect the milk production of a herd. Therefore, it is important to recognize that an improvement in parasite control will have limited impact on milk production if other management factors are inadequate.

Conclusions

The purpose of this study was to identify what veterinarians and researchers believe are the most important risk factors and treatment strategies for parasitism in lactating dairy cattle, and use this information to design further investigations in this area. The results of this survey suggest that the risk factors affecting milk production the most would include the housing system and access to pasture, the importance of strategic endectocide treatment, the impact of external parasite control and the carry-over impact of replacement heifer parasite control on the lactating herd. Although the opinions of experts are based on extensive education and experience, this does not imply that "real life" results will follow their predictions. Many individuals were surveyed and although their opinions were similar, there is still very little concrete evidence to support the assumptions we use when advising producers, and designing parasite control strategies.

Producers should be aware of the potential increased risk for parasitism in animals that graze potentially infected pasture, particularly when the heifers and cows are not treated for parasites. Treatment programs that target both internal and external parasites are likely to produce an increase in milk production. Those animals that are treated strategically at higher risk times, such as after spring pasture turnout, during the periparturient period, and during growth of pastured heifers, should have the best response. Each farm must be considered individually, and a program tailored to their specific needs and available resources. Treatment of growing heifers should influence their future milk production, as well as impact on the lactating herd if the two groups are housed or pastured together. The lactating herd, especially those with high production and good management, may also show production increases from treatment in the prepartum period, or fall, with a broad spectrum endectocide product.

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References

1. Barger LA, Gibbs HC: Milk production of cows infected experimentally with Trichostrongylid parasites. Vet Parasit 9: 69-73, 1981.
2. Berghen P, Hilderson H, Vercruysse J, Dorny P: Evaluation of pepsinogen, gastrin and antibody response in diagnosing ostertagiasis. Vet Parasit 46:175-195, 1993.
3. Bisset SA, Marshall ED, Morrison L: Economics of a dry-cow anthelmintic drenching programme for dairy cows in New Zealand. Part 2. Influence of management factors and other herd characteristics on the level of response. Vet Parasit 26: 119-129, 1987.
4. Block E, Gadbois P: Efficacy of morantel tartrate on milk production of dairy cows: a field study. J Dairy Sci 69:1135-1140, 1986.
5. Block E, McDonald WA, Jackson BA: Efficacy of Levasol on milk production of dairy cows: a field study. J Dairy Sci 70:1080-1085, 1987.
6. Bocher LW: Consider these factors when treating for parasites. 1998. Hoard's Dairyman 143:182, 1998.
7. Bocher LW: Take a Closer Look at Parasites. Hoard's Dairyman 143:146, 1998.
8. Dewey CE, Martin SW, Friendship RM, Kennedy B: A Delphi exercise used to identify potential causes of variation in litter size of Ontario swine. Can Vet J 33:40-45, 1992.
9. Fetrow J, Johnstone C, Bartholomew R: Production responses of lactating dairy cows and heifers given thiabendazole at parturition. Am J Vet Res 46:48-52, 1985.
10. Frechette JL, Lamothe P: Milk production effect of morantel tartrate treatment at calving in dairy cows with subclinical parasitism. Can Vet J 22:252-254, 1981.
11. Green PE, Srinvasan V: Conjoint analysis in marketing: New developments with implications for research and practice. Journal of Marketing 54: 3-19, 1990.
12. Gross SJ, Ryan WG, Ploeger HW: Anthelmintic treatment of dairy cows and its effect on milk production. Vet Rec 144:581-587, 1999.
13. Horst HS, Huirne RBM, Dijkhuizen AA: Eliciting the relative importance of risk factors concerning contagious animal diseases using conjoint analysis: A preliminary survey report. Prev Vet Med 27:183-195, 1996.
14. Hovingh E: Predicting pasture dry matter for large scale observational studies. Chapter 4 in "Seasonal variation of milk production in Prince Edward Island" PhD Thesis, 1998.
15. Kloosterman A, Ploeger HW, Pieke EJ, Lam TJGM, Verhoeff J: The value of bulk milk ELISA *Ostertagia* antibody titres as indicators of milk production response to anthelmintic treatment in the dry period. Vet Parasitol 64:197-205, 1996.
16. Linstone HA, Turoff M, eds: The Delphi Method, Techniques and

Applications. Reading Massachusetts: Addison-Wellesley Publishing, 1975.
17. Maas A, Stalpers L: Assessing utilities by means of conjoint measurement: An application in medical decision analysis. Medical Decision Making 12:288-297, 1992.
18. Michel JF, Richards M, Altman JFB, Mulholland JR, Gould CM, Armour J: Effect of anthelmintic treatment on the milk yield of dairy cows in England, Scotland and Wales. Vet Rec 111:546-550, 1982.
19. Ploeger HW, Kloosterman A, Bargeman G, Wuijckhuise L, Van Den Brink R: Milk yield increase after anthelmintic treatment of dairy cattle related to some parameters estimating helminth infection. Vet Parasitol 35:103-116, 1990.
20. Ploeger HW, Kloosterman A, Rietveld FW, Berghen P, Hilderson H, Hollanders W: Quantitative estimation of the level of exposure to gastrointestinal nematode infection in first-year calves. Vet Parasitol 55:287-315, 1994.
21. Ploeger HW, Kloosterman A, Rietveld FW, Hilderson H, Berghen P, Pieke EJ: Production of dairy replacement stock in relation to level of exposure to gastrointestinal nematode infection in the first grazing season: second-year calves and heifers. Vet Parasit 65: 99-115, 1996.
22. Ploeger HW, Kloosterman, Borgsteede FHM: Effect of anthelmintic treatment of cattle on growth perfomance during winter housing and first lactation yield. Vet Parasit 36: 311-323, 1990.
23. Ploeger HW, Schoenmaker GJW, Kloosterman A, Borgsteede FHM: Effect of anthelmintic treatment of dairy cattle on milk production related to some parameters estimating nematode infection. Vet Parasitol 34:239-253, 1989.
24. Thomas GW, Barton NJ, McGowan AA, Mickan FJ, Miller G, James RE: Effect of whole herd anthelmintic treatment on milk production of dairy cows. Res Vet Sci 36: 266-269, 1984.
25. Todd AC, Bliss DH, Grisi L, Crowley JW: Milk production by dairy cattle in Pennsylvania and North Carolina after deworming (treatment at freshening and systematically over the first three months of the lactation). VM/SAC 73:614-619, 1978.
26. Turnwald GH, Friske JS, Banks WJ, Gedon CA: Identification of concerns in veterinary medical education: A delphi study. J Vet Med Ed 18:38-42, 1991.
27. Walsh TA, Younis PJ, Morton JM: The effect of ivermectin treatment of late pregnant dairy cows in south-west Victoria on subsequent milk production and reproductive performance. Aust Vet J 72:201-207, 1995.
28. Yazwinski TA, Gibbs HC: Survey of helminth infections in Maine dairy cattle. Am J Vet Res 36:1677-1682, 1975.