A Simulation Model to Compare Strategies For Reducing the Effect of Cystic Ovarian Disease of Dairy Cattle on Herd Average Open Days

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Summary

A theoretical approach was taken to compare various ways of reducing the extended calving intervals that may result from cystic ovarian disease of dairy cattle. The question evaluated was which of the three following options would yield the greatest benefit in terms of reducing the herd's average number of open days: 1) reducing the cumulative incidence of cystic ovarian disease, 2) improving cystic ovary therapy effectiveness, or 3) improving heat detection and conception rate performance in general. A stochastic Markov Chain model was developed on a computerized spread sheet. This simulation model has the following alterable inputs: 1) cumulative incidence of ovarian cysts occurring before the first postpartum ovulation, 2) cumulative incidence of ovarian cysts occurring after the first postpartum ovulation, 3) probability of spontaneous resolution before or after first postpartum ovulation, 4) probability of responding to treatment, 5) probability of recurrence, 6) average days postpartum at first veterinary reproductive examination, 7) days postpartum of first allowable insemination, 8) days between routine veterinary reproductive examinations, 9) herd average services per conception, and 10) heat detection efficiency. The respective inputs were varied to simulate the expected improvement in herd average days open. Improving herd heat detection efficiency and service per conception were more effective at reducing herd average days open that were improvement of any of the cystic ovarian disease parameters.

Ein Simulations modell zum Vergleich verschiedener Strategien zur Reduktion des Effektes zystischer Ovarien auf die durchschnittliche Zwischenkalbezeit in Milchviehhaltungen

Vorgestellt wird hier ein theoretischer Vergleich verschiedener wege, die von zystischen Ovarien hervorgerufenen ausgedehnten Kalbeintervalle in Milchvieh zu reduzieren. Die Frage stellt dich, welche der drei folgeuden Möglichkeiten am effektivsten die durchschnittliche Zwischen kalbezeit verringert: 1. Die Summerder Fäille von zystischen Ovarien zu verringern. 2. Die Effektivität der Therapie zystiseher Ovarien zu verbesserm. 3. Generell die Brunsterkennung und Konzeptionsnaten zu verbesserm. Ein stochastisches Markov kettenmodell wurde mit dem Computer entwickelt. Das Modell hat die folgenden Variablen: 1. Summe der Fälle von Ovarzysten vor der ersten post partum Ovulation. 2. Summe der Fälle von Ovarzysten nach der ersten post partum Ovulation. 3. Wahrscheinlichkeit der spontanen Resolution vor oder nach der ersten post partum Ovulation. 4. Wahrscheinlichkeit des Therapieerfolges. 5. Wahrscheinlichkeit der Wiederkehr von Cysten. 6. Durchsehnittliche Zeitdauer zwischen Kalben und erster tierargtlicher Untersuchung. 7. Zeit zwischen Kalben und frühestmöglicher Besamung. 8. Zeitintervall zwischen routinemässigen tierärztlichen gynäkologischen Untersuchungen. 9. Durchschnittliche Zahl von Besamungen pre Befruchtung. 10. Effektivität der Brunsterkennung. Diese Faktoren wurden variiert um die entsprechenden Verbesserungen in durchschnittlicher Zwischenkalbezeit zu bestimmen. Verbesserung der Brunsterkennung und der Konceptionsraten pro Besamung waren effektiver in Reduktion der Zwischenkalbezeit als jegliche Verbesserung der Ovarzysten betreffenden Parameter.

Modelo para comparar las estrategias de reducir el efecto de Ovarios císticos en días abiertos en la ganadería de leche

Se diseño un modelo teórico con el fin de comparar los diferentes mecanismos usados para reducir

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el intervalo entre cría debido a problemas con ovarios císticos en la ganadería de leche. La pregunta fue que cual de los siguientes parámetros resultaría en el mayor beneficio en cuanto a reducir el promedio de días abiertos: 1) Reducir la incidencia acumulativa de ovarios císticos, 2) Mejorar la eficiencia de la terapia de ovarios císticos o, 3) Mejorar la detección de calores y el porcentaje de concepción en general. Un modelo computarizado de la cadena de Markow fue creado en una hoja electrónica. Este modelo tenía las siguientes variables. 1) Incidencia acumulativa de ovarios císticos ocurridos antes de la primera ovulación pos parto, 2) Incidencia acumulativa de ovarios císticos ocurridos después de la primera ovulación pos parto, 3) Probabilidad de resolución espontanea antes o después de la primera ovulación pos parto 4) Probabilidad de respuesta a tratamiento, 5) Probabilidad de reocurrencia, 6) Promedio de días pos parto para el primer examen veterinario del aparato reproductivo, 7) Días pos parto para el primer posible servicio, 8) Promedio de días entre un examen y el siguiente examen veterinario del aparato reproductivo, 9) Promedio de servicios por concepción y 10) Eficacia en detección de calores. Las diferentes variables fueron seleccionadas y modificadas para imitar el esperado rendimiento en reducir los días abiertos. Mejorar la eficiencia en detección de calores y reducir los servicios por concepción fueron mas efectivos en reducir el promedio de días abiertos comparados con pretender mejorar cualquiera de los otros parámetros relacionados con problemas de ovarios císticos.

Introduction

Cystic ovarian disease (COD) of dairy cattle is a common cause of subfertility in dairy cattle.[1] The disease is economically important due both to direct veterinary costs and indirect costs associated with extended calving intervals.[2,3] Extended calving intervals are a result of acyclicity during COD and subsequent delayed conception. A convenient measurement of delayed conception on a herd-wide basis is the herd average calving-to-conception interval or days open (DO).

Much of the pathophysiology of bovine COD has been described.[4] But as of yet, factors that influence the risk of COD incidence or the success rate of therapy are not well enough described to be of practical use. It would be attractive to have the ability to manipulate known risk factors in a manner that would reduce the incidence of COD or improve the effectiveness of therapy.

When considering potential options for reducing the effect of COD on herd average DO, a practical question is what approaches are likely to benefit a dairy herd the most in terms of herd average DO? While preventing COD may be a viable management option in the near future, how much of a difference would it make in herd average DO in comparison to merely improving heat detection and services per conception? Similarly, how much of a benefit in herd average DO could actually be realized if the response to COD therapy could be markedly improved?

The purpose of this research was to assess the comparative effectiveness of reducing herd average DO by improving the COD situation or by simply improving certain aspects of reproductive management. A randomized simulation model created on an electronic spreadsheet and run on a personal computer was used to generate herd average DO under various management and COD conditions.

Materials and Methods

Simulation Model

A model was constructed to simulate the principal events that occur between parturition and conception. A Forrester flow diagram was built to schematically lay out the important events and the possible pathways between events (Figure 1). Briefly, referring to Figure 1, notice that a fresh cow would be introduced into the model and one of three events would occur: 1) an ovarian cyst occurs before the first post partum ovulation, or 2) after the first post partum ovulation, or 3) no ovarian cysts occur during that lactation. A cow with either a pre- or post-first-ovulation ovarian cyst is treated and either responds to

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treatment or fails to respond, and so forth.

The computerized simulation model was made up of the events displayed in the flow diagram and was created on an electronic spreadsheet[a]. The model was a Markov Chain type model and simulated one animal at a time. During a simulation an animal would enter the model as a fresh cow and move from one event to another in a sequential or chain-like fashion until she either conceived or until a maximum of eight events had occurred. The pathway of events that each simulation followed was determined stochastically, or with an element of chance, so that two separate simulations run under identical conditions would usually produce non-identical results.

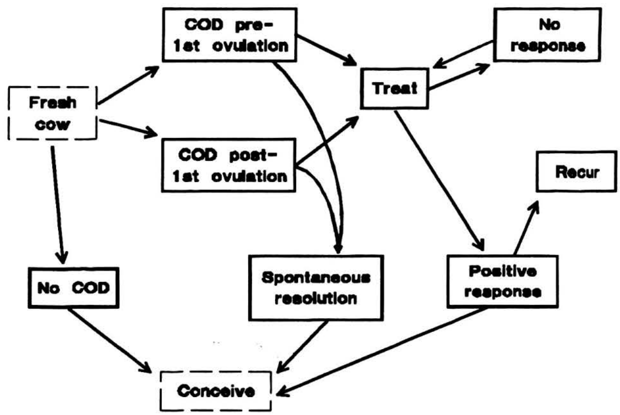

Figure 1. Forrester flow diagram of reproductive events pertinent to simulations of bovine cystic ovarian disease.

The simulation model user supplied two sets of inputs that could be altered in order to simulate different conditions. First, probabilities were supplied for each of the potential pathways between events. Second, farm conditions were specified. A separate random number generator was incorporated into the model for each set of alternative pathways. The pathway taken from a given event on one cycle of the simulation was determined by the result of a comparison of a randomly generated number to the probability assigned by the user.

The duration of a simulation was limited to either a conception or to when eight state transitions had taken place, whichever came first. When a simulation ended, the accumulated DO were obtained and represented the total DO for the simulated animal. An average DO value for a herd of a given size could be modeled by running the simulation one time for each cow and taking the average of the respective individual cow results.

The simulation model assigned DO to a cow during a simulation according to the following rules. The number of DO assessed at occurrence of any of the first three initial events was the number of days postpartum at which reproductive examinations were routinely performed. The DO assessed for SPONTANEOUS RESOLUTION and for the first TREAT was the difference between the postpartum day at which the reproductive examinations were made and the postpartum day after which insemination was allowed. It was assumed that ovarian cysts were routinely not treated unless they were present at postpartum day 60 or later. In addition, the number of days between routine veterinary reproduction examinations was added to DO when the TREAT event occurred, assuming that time will elapse between occurrence of an ovarian cyst and veterinary examination. For the POS RESPONSE to treatment, NO RESPONSE to treatment and RECUR states, the number of DO assessed was equal to the 21 day reproductive cycle length plus the number of days between routine veterinary reproduction examinations. When the conception state is reached, the number of DO assessed is calculated based on the random

[a] Supercalc 4.0, version 1.0, copyrighted 1986. Computer Associates International, Inc.

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assignment of individual services per conception and the random assignment of the percent of the individual's heats detected. The random assignments of services per conception and percent of heats observed were drawn from Poisson distributions of these events centered on means equal, respectively, to the herd average services per conception and average heat detection efficiency.

Simulations

The simulation model was used to evaluate the success of various interventions at reducing herd average DO in dairy herds. Six treatment groups, corresponding to six interventions, were simulated. A control or baseline group was also simulated. The treatment and baseline groups each consisted of 31 farms. Each farm consisted of 99 cows.

Of the six different interventions, three interventions focused on controlling COD itself: reducing the probability of post-therapy recurrence, reducing the incidence of COD, and increasing the probability of a positive response to therapy. The remaining three interventions focused on dairy farm reproductive management in general: improving heat detection efficiency, reducing the average number of services per conception, and increasing the frequency of veterinary reproductive examinations. The herd average DO under a given intervention strategy was simulated by changing the appropriate inputs to the simulation model with respect to the baseline inputs. The baseline inputs (group 1 in Table 1) were used for simulation of the control group. The baseline probabilities (Table 1) were drawn from Roberts' review of the literature.[1] The baseline management conditions (Table 1) were defined by the investigator to represent a reasonable situation that could be encountered on a dairy farm. The simulation model input alterations made for each of the treatment groups are also displayed in Table 1.

Table 1. Inputs to a stochastic simulation model of individual cow days open, used to compare six interventions to a baseline simulation.

	Intervention groups						
Intervention	1	2	3	4	5	6	7
Average services per conception	2.8	2.2	2.8	2.8	2.8	2.8	2.8
Heat detection efficiency (%)	60	60	80	60	60	60	60
Reproduction exam interval (days)	14	14	14	7	14	14	14
Cystic ovarian disease incidence	.105	.105	.105	.105	.05	.105	.105
Probability of recurrence	.45	.45	.45	.45	.45	.25	.45
Probability of response to treatment	.70	.70	.70	.70	.70	.70	.85

Herd average DO was compared between simulated treatment groups by One-Way Analysis of Variance (ANOVA). The difference between individual group means were tested by means of Tukey's HSD multiple range test.[6] All analyses were performed using Statgraphics[b].

Results

The mean and standard deviation of the simulation-model-generated herd average DO values are

[b] Statgraphics. Statistical Graphics System by Statistical Graphics Corporation.

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summarized in Table 2. Table 2 also summarizes the results of the ANOVA and Tukeys' HSD test. Decreasing herd average services per conception and increasing heat detection efficiency (treatment groups 2 and 3, respectively) resulted in statistically significant reductions in herd average DO relative to the control group. Herd average DO was more markedly reduced by improving services per conception than it was by improving heat detection efficiency. In addition, increasing the frequency of veterinary reproduction farm visits, reducing the herd incidence rate of COD, and improving the probability of treatment effectiveness (treatment groups 4, 5 and 7, respectively) also resulted in significant differences in mean herd average DO in comparison to the control group. The mean herd average DO of these latter three treatments were not significantly different from each other, however.

The only manipulation that did not result in a statistically significantly reduction of mean herd average DO was reducing the probability of recurrence of COD from .45 to .25. Although treatment groups 4, 5, and 7 were statistically significantly different from the control group, the practical difference was small. Groups 2 and 3, on the other hand, showed a marked decline in mean average DO relative to group 1 as well as relative to groups 4 through 7.

Table 2. The mean of the average days open of 31 simulated dairy herds by intervetion group.

Intervention group	Mean	Standard deviation	95% Confidence interval	Tukey's HSD*
1	169.8	7.65	(167.3, 172.5)	a
2	151.5	7.04	(154.8, 160.0)	b
3	157.4	7.46	(148.8, 169.1)	c
4	166.4	8.10	(163.8, 169.1)	d
5	167.2	7.03	(162.7, 167.9)	d
6	165.3	6.73	(164.5, 169.8)	a,d
7	166.9	7.61	(164.3, 169.5)	d

* Groups with different letters were significantly different (α=0.05) by Tukey's HSD test of differences between individual group means.

Discussion

The simulations performed in this investigation indicate that improving heat detection and services per conception on a dairy may be more effective at improving herd average DO than improving parameters directly related to COD. Notwithstanding the superior benefit gained from improving heat detection efficiency and services per conception, a herd-wide benefit in average DO was realized, both when the incidence of COD was reduced from .105 to .05 and when the probability of response to therapy was increased from .70 to .85.

It is admittedly theoretical to reduce the incidence of COD in a dairy herd, or increase the response to therapy or decrease the rate of recurrence. At the present time, our ability to alter these parameters is limited. But on the other hand, one can argue that based on the foregoing theoretical simulations, there may not be a real need to improve the ability to alter the incidence, resolution and occurrence of COD. When COD is considered strictly in terms of its' effect on herd average DO, practitioners may be justified in recommending to clients that they focus their attention on improving heat detection efficiency and on improving services per conception and not be concerned about an inability to directly improve the COD situation on their farm.

All of the mean average DO were quite large. The simulation model apparently over estimates average

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DO. This larger average DO may be explained in part by the fact that some of the individual animals for which DO were recorded by the simulation did not end in a conception. This resulted in a larger representative of high DO values in each simulated herd than if cows that didn't conceive had been excluded from the calculations. More realistic DO values might also have resulted if fewer days were assessed at each event in the simulation model.

The model used in this simulation may come under criticism on two other points. The first is that reproductive performance and COD parameters were treated as averages across the herd. However, a herd is heterogeneous, consisting of cows of different parities, different metabolic states, different milk production levels, different disease histories, and so forth. Because the inputs were treated as herd averages, it is not likely that the qualitative results of the simulations would have been different if the simulation model had incorporated these additional details. Reproductive management would probably have still come out to be a superior method for reducing the DO in a dairy herd. The actual average DO values obtained for each herd might have been different though, had these other factors been considered.

An additional criticism could be that the various different reproductive management parameters and COD parameters were manipulated independently from one another. In reality these different parameters do not represent completely isolated and independent phenomenon and a change in one is likely to be associated with a change in some of the others. It will be the task of future developments of dairy health simulation methodology to improve upon this model and to address these criticisms.

In summary, the results of the reported modelling and simulation procedure indicate that in terms of DO, the most strategic control measures should focus attention on improving herd reproductive performance by improving services per conception and heat detection efficiency.

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