April 2018
Volume 56
Number 2
Article # 2RIB4
Research In Brief

Repro Money: An Extension Program to Improve Dairy Farm Reproductive Performance

Abstract

A farmer-directed, team-based Extension program (Repro Money) was developed and executed by the University of Wisconsin–Madison Department of Dairy Science in collaboration with University of Wisconsin–Extension. The goal of the Repro Money program was to help Wisconsin dairy farmers increase reproductive performance and profitability through identification of areas for improvement and implementation of action plans. For the 40 Wisconsin dairy farms that completed the Repro Money program, mean 21-day pregnancy rate increased by 2 percentage points, which was estimated to result in an economic net gain of $31 per cow per year. Extension professionals can apply similar team-based programs to tackle multifaceted, interrelated problems that may be only partially addressed by other, more traditional programming.

Keywords: reproduction, Extension, management team, pregnancy rate, service rate

Maria C. Cordoba
Outreach Specialist
ccordoba@crinet.com

Pamela L. Ruegg
Professor
plruegg@wisc.edu

Randy D. Shaver
Professor
rdshaver@wisc.edu

Kent A. Weigel
Professor and Chair
kent.weigel@wisc.edu

Paulo D. Carvalho
Graduate Research Assistant
pcarvalho@wisc.edu

Paul M. Fricke
Professor
pmfricke@wisc.edu

Victor E. Cabrera
Associate Professor
vcabrera@wisc.edu

Department of Dairy Science
University of Wisconsin–Madison
Madison, Wisconsin

Introduction

Reproductive performance of dairy herds is recognized as a major contributor to the overall profitability of dairy operations (Galvão, Federico, De Vries, & Schuenemann, 2013; Giordano, Kalantari, Fricke, Wiltbank, & Cabrera, 2012; McCullock, Parsons, & Roman-Muniz, 2012). Cows that fail to conceive in a timely manner spend more time in late lactation, producing less, and are culled (Overton, 2010a, 2010b). The most widely used measurement for evaluating reproductive performance on dairy farms is the 21-day pregnancy rate (PR) (Niles, Eicker, & Stewart, 2001). An increase of 5 percentage points in the PR results in an economic benefit of about $75 per cow per year (Cabrera, 2014).

Many interacting factors affect PR; therefore, it is difficult for only one consultant (i.e., veterinarian, artificial insemination [AI] technician, county Extension agent) to provide the expertise and resources required for an in-depth evaluation of herd reproductive performance (O'Connor, Baldwin, Adams, & Hutchinson, 1985). Increasing reproductive performance and profitability requires an interdisciplinary approach (Bitsch & Thornsbury, 2010). Extension management teams have been used successfully as a tool for enhancing relationships and management capabilities of farmers (Hohmann & Ruegg, 2012; Rodrigues, Caraviello, & Ruegg, 2005; Derks, van de Ven, van Werven, Kremer, & Hogeveen, 2012).

Working as members of a collaborative effort by the University of Wisconsin–Madison Department of Dairy Science and University of Wisconsin–Extension, we applied the management team model to Repro Money, a farmer-directed, team-based Extension program. The objective of the study we report here was twofold: (a) describe the Repro Money program, and (b) determine whether Repro Money could be used to increase reproductive efficiency and profitability on Wisconsin dairy farms.

Materials and Methods

Farm Enrollment, Program Description, and Data Collection

Program enrollment and formation of Repro Money teams occurred between fall 2010 and summer 2014 through statewide recruitment efforts led by Extension professionals. Each farm that enrolled in the Repro Money program agreed to form a reproductive performance team and committed to conducting a minimum of four meetings during a 4- to 16-month period. During these meetings, reproduction goals were set via consensus of the team after an initial assessment of the farm. Upon enrollment, farm owners selected team members (e.g., veterinarian, nutritionist, AI technician, county Extension agent, herd manager, banker) and designated a team leader who would be responsible for facilitating the team and collecting data.

At the first team meeting, the team leader recorded relevant data using a questionnaire designed for analyzing and identifying farm-specific critical control points for successful reproductive management. Data collected via the questionnaire included farm production characteristics, herd reproductive management details and outcomes, and herd health assessment (see Tables 1–3 in the "Results and Discussion" section for the specific types of data collected). All data available from farm records and management were evaluated. On the basis of these data points, plus the farm owner's input, the team set goals, developed an action plan, assigned specific responsibilities to team members, and determined appropriate evaluation strategies. The second and third team meetings were structured to ensure that team goals were on track. Action plans were farm-specific as agreed to by the team but normally included deadlines and team member responsibilities. At the fourth and final team meeting, the team reassessed the reproductive performance of the dairy and evaluated accomplishment of goals by implementing the same questionnaire tool used at the first meeting.

Data from all Wisconsin dairy farms that enrolled in and finished Repro Money (n = 40) were included in subsequent analysis. (The questionnaire and an interactive data set from participating farms are available at http://DairyMGT.info/; once at the site, go to the Tools page and then select the Repro Money Extension Program Wisconsin 2010-2014 link.)

Performance Measures

We used selected herd variables and general management variables to characterize the farms (see Tables 1–3). We defined and used key performance indicators to monitor and assess reproductive performance (see Table 4).

Economic Analysis

We calculated economic outcomes using the University of Wisconsin–Madison Dairy Management decision support tool The Economic Value of a Dairy Cow, which is available on the Tools page at http://DairyMGT.info/ (Cabrera, 2012). We analyzed each enrolled farm with regard to herd turnover ratio (%), rolling herd average (kg per cow per year), pregnancy loss after 35 days in gestation (%), and change in the 21-day PR (% before and after Repro Money). Input value of milk price was set at $18.80 per 45.5 kg for all farms. We used a constant milk price to facilitate comparing the value of reproductive efficiency across farms.

Results and Discussion

Program Compliance, Herd Characteristics, and Management Practices

Forty farms completed the Repro Money program out of the 45 that initially enrolled. Mean duration between first and last meeting was 9 months (range was 4 to 16 months).

The mean number of team members across farms was five (range was three to 10). Teams were composed of farm owners (100%), county Extension agents (100%), veterinarians (100%), nutritionists (90%), herd managers (62%), and AI company representatives (60%). Each farm owner selected a county Extension agent as the team leader. Participating Extension agents had extensive training in and understanding of dairy operations, and especially dairy reproductive management. The fact that every farm owner felt it was important to have a county Extension agent on his or her team indicates the importance of maintaining a strong county dairy educational focus (Chase, Ely, & Hutjens, 2006).

The initial questionnaire revealed that prior to program enrollment, only 57.5% of participating farms met with their veterinarians on a regular basis to discuss reproductive management. One explanation for this observation may be that many farmers view services provided by a veterinarian as one of the cost inputs in the production system that they must constantly evaluate for financial payoff (Kristensen, Østergaard, Krogh, & Enevoldsen, 2008). However, evidence exists of improved herd reproductive performance after veterinary intervention in longitudinal (Morris, Williamson, Blood, Cannon, & Cannon, 1978) and cross-sectional (Derks et al., 2012) studies. With subfertility as the most important reason for culling and its economic costs second only to costs associated with mastitis, the role of the veterinarian in fertility management on modern dairy farms should be obvious because the veterinarian is uniquely qualified to investigate reproductive performance (Mee, 2007).

Characteristics of dairy farms enrolled in Repro Money are depicted in Table 1. The average herd size (414 cows) is larger than the average herd in Wisconsin of 125 cows (U.S. Department of Agriculture National Agricultural Statistics Service, 2015). Mean daily milk yield (37.6 kg per cow per day) and rolling herd average (11,765 kg per cow per year) were similar to those reported by Caraviello et al. (2006). Because enrollment in Repro Money was voluntary, managers of larger herds may have received more information about the program through greater access to advisors aware of new technologies and tools (Chase et al., 2006).

Table 1.
Characteristics of Dairy Farms at Enrollment in the Repro Money Program (*n* = 40 Farms)

Variable	***M* ± *SE***	**Range**
Herd size (lactating and dry), no.	414 ± 47	54 to 1,157
Milking cows, no.	373 ± 42.8	50 to 1,043

First-lactation cows, % cows	43.4 ± 4.0	42 to 50
Milk production, kg/cow/day	37.6 ± 0.72	20.4 to 47.6
Rolling herd average, kg/cow/year	11,765 ± 245	6,382 to 14,515
Milk butterfat, % fat	3.83 ± 0.03	3.2 to 4.3
Milk protein, % protein	3.15 ± 0.02	2.8 to 3.3

On average, two people were responsible for observing estrus, and observations were conducted three times per day (Table 2). On 85% of farms, detection of estrus was always combined with other activities (Table 2). These observations are similar to those reported by Caraviello et al. (2006). Such a "multitasking" approach to detection of estrus may be a limiting factor with respect to estrous detection efficiency because decreased duration and expression of estrus in high-producing dairy cows presents challenges for detection of estrus (Lopez, Satter, & Wiltbank, 2004). This situation is critical on farms that participated in Repro Money because 42.5% of farms relied solely on visual detection of estrus (Table 2).

Nearly all farms (97.5%) used some type of hormonal synchronization protocol to inseminate their cows (Table 2). A recent meta-analysis showed that 100% timed AI after a Presynch-Ovsynch protocol had greater conception risk than a protocol combining detection of estrus with timed AI (Borchardt, Haimerl, & Heuwieser, 2016). Ovsynch alone without presynchronization was still the most common protocol used for first service (43% vs. 33% for Presynch-Ovsynch) (Table 2).

Transrectal ultrasonography was the most popular (65%) method used for pregnancy diagnosis at 32 days after insemination (Table 2). Caraviello et al. (2006) reported that the majority of farms they studied used transrectal palpation for pregnancy diagnosis, but Fricke (2002) envisioned that ultrasound would eventually displace rectal palpation as the method of choice for pregnancy diagnosis. Although the identification of nonpregnant cows early after insemination can increase reproductive efficiency of the dairy herd, conducting pregnancy diagnosis using transrectal ultrasonography earlier than 30 days after timed AI can decrease the accuracy of the diagnosis (Fricke, Ricci, Giordano, & Carvalho, 2016).

Table 2.
Reproductive Management at Enrollment in the Repro Money Program (*n* = 40 Farms)

Management practice	**Value**
Estrous detection, % farms	
No estrous detection	7.5
1 person for estrous detection	50.0
≥ 2 people for estrous detection	42.5
Cows serviced off cycle, % cows	6.0
Estrous detection method, % farms	
Accelerometer	12.5
Chalk	27.5

Visual	42.5
Combination of chalk and visual	17.5
Personnel used for estrous detection, % farms	
Farm personnel	67.5
Professional technician	32.5
Frequency of estrous detection, mean times/day ± SE (range)	3.0 ± 0.1 (0 to 6)
Standing surface when cows observed for estrus, % farms	
Dirt	5.0
Concrete	95.0
Number of people for estrous detection, mean ± SE (range)	2.0 ± 0.2 (1 to 6)
Estrous detection combined with other activities, % farms	85.0
Natural service bulls used in the herd, % farms	5.0
Semen cost, $/straw (range)	19.0 (4 to 32)
Number of straws thawed at once, no. (range)	3.0 (1 to 6)
Artificial insemination frequency, % farms	
Once daily	85.0
Twice daily	15.0
Timed AI protocol used, % farms	97.5
Ovsynch for first AI	42.5
Presynch-Ovsynch for first AI	32.5
Double-Ovsynch for first AI	20.0
Ovsynch for second and greater AI	97.5
Headlocks in breeding pens, % farms	72.5
Frequency of pregnancy diagnosis, % farms	
Weekly	35.0
Every 2 weeks	52.5
Monthly	12.5
Pregnancy diagnosis method, % farms	
Transrectal palpation	35.0
Transrectal ultrasonography	65.0
Timing of pregnancy diagnosis, days after AI (range)	31.7 (26 to 36)
Pregnancy reconfirmation, % farms	90.0

Pregnancy reconfirmation at dry-off, % farms	52.5

Note. AI = artificial insemination.

At enrollment, only 22% of farms performed routine body condition scoring, and only 10% performed routine lameness scoring on cows in the breeding group (Table 3). Farmers could benefit greatly from implementing these practices to monitor and predict postpartum health (Derks et al., 2012). Increased nutrient needs associated with suppression of appetite in early lactation result in a state of negative energy balance. Changes in body condition and weight during the first 3 weeks after calving have profound effects on embryo quality and fertility at first timed AI (Carvalho et al., 2014). Also, Gomez, Cook, Socha, and Döpfer (2015) found that digital dermatitis events decreased conception at first service and increased days open.

Table 3.

Health Management at Enrollment in the Repro Money Program (*n* = 40 Farms)

Characteristic	**Value**
Routine body condition scoring, % farms	22.0
Routine lameness scoring, % farms	10.0
Foot bath use, % farms	100.0
Foot problems reported, % farms	
Ulcers	20.0
Warts	65.0
Abscesses	10.0
Foot rot	5.0
Frequency of foot trimming, % farms	
Twice per month	20.0
Once per month	37.5
Four times per year	20.0
Twice per year	17.5
Once per year	5.0
Culling rate, mean % farm ± SE (range)	35.0 ± 1% (21 to 50)
Reasons for culling, % farm	
Excessive number of services	40.0
Late lactation	22.5
Cow conformation	7.5
Health problems	12.5
Low milk productivity	17.5

Cows sold or died ≤ 60 days postpartum, % cows (range)	10.0 (1 to 42)
Abortion rate, mean % cows ± SE	7.5 ± 0.7%

Repro Money Program Outcomes

Changes in reproductive performance and associated health indicators after Repro Money are shown in Table 4 (at the end of this section). After completion of Repro Money, mean 21-day PR increased by 1.6 ± 0.4 percentage points (18.0% ± 0.8% to 19.6% ± 0.8%). A similar increase in reproductive performance was reported in New Zealand (McDougall, Heuer, Morton, & Brownlie, 2014) as a result of implementation of the InCalf (2007) Extension program.

The increase in the 21-day PR for farms in Repro Money was driven by a corresponding increase in the 21-day insemination risk (52.9% ± 1.4% to 55.6% ± 1.1%), whereas overall conception risk (35.0% ± 1.3% to 35.8% ± 1.0%) did not change. Although it is commonly believed that service risk is the factor most under management control, new modifications to hormonal synchronization protocols since Repro Money was completed can now dramatically increase fertility at first timed AI (Wiltbank et al., 2015) and at subsequent timed AI (Carvalho et al., 2015; Santos et al., 2016). The Repro Money program was conducted during a time when these other synchronization programs that enhance the fertility of the cow (conception risk) were not yet available to farmers.

Another herd reproductive performance indicator evaluated in our study was the proportion of cows serviced within 21 days of the end of the voluntary waiting period, which increased from 78% to 84%. Other indicators that would support a concurrent increase in the service risk were a decrease in the interbreeding from 44 to 41 days and a decrease the days in milk for lactating cows from 188 to 182 days.

Monthly rate of clinical cases of mastitis also decreased after farms completed Repro Money. Many studies have shown the effect of clinical and subclinical mastitis not only on profitability (Bar et al., 2008) but also on reproductive performance. Compared with pregnancy rates for healthy cows, the odds of pregnancy were 0.56, 0.67, and 0.75 for cows experiencing chronic clinical mastitis, chronic mastitis, or subclinical mastitis, respectively, from 3 days before to 32 days after first AI (Fuenzalida, Fricke, & Ruegg, 2015). Cows diagnosed with subclinical mastitis that later developed into clinical mastitis had increased days to first service, days open, and services per conception as compared to healthy cows (Schrick et al., 2001). Preliminary field evidence by Moore, Cullor, Bondurat, and Sischo (1991) suggested that clinical mastitis indirectly impairs reproductive performance in dairy cows by altering interestrus intervals and shortening the luteal phase.

Table 4.

Outcomes of Farms That Completed the Repro Money Program (*n* = 40 Farms)

Outcome	**Before** ***M ± SD***	**After** ***M ± SD***	**Change** ***M ± SD***	***p*-value**
Overall 21-day pregnancy rate, % per farm	18.0 ± 0.8	19.6 ± 0.8	1.6 ± 0.42	.0004
Overall insemination rate, % per farm	52.9 ± 1.4	55.6 ± 1.1	2.7 ± 0.8	.003
Overall conception rate, % per farm	35.0 ± 1.3	35.8 ± 1.0	0.8 ± 0.7	.29

First service conception rate, % per farm	37.1 ± 1.5	37.8 ± 1.3	0.7 ± 0.9	.41
Later services conception rate, % per farm	34.4 ± 1.3	34.6 ± 1.1	0.2 ± 0.7	.79
Service rate after 21 days after voluntary waiting period, % per farm	78.0 ± 3.0	84.1 ± 2.1	6.1 ± 2.1	.005
Interbreeding interval, days	43.7 ± 1.9	40.7 ± 1.2	−3.0 ± 1.3	.02
Days in milk for milking cows	187.9 ± 3.4	182.0 ± 3.3	−5.9 ± 3.1	.06
Heat detection, times/day	1.5 ± 0.2	1.9 ± 0.2	0.4 ± 0.1	.007
Cows serviced off cycle, % cows	6.4 ± 0.5	6.3 ± 0.6	−0.1 ± 0.4	.78
Herd size, adult cows, no.	414.0 ± 47.3	416.1 ± 46.3	2 ± 3.8	.57
Voluntary waiting period, days	61.0 ± 1.6	61.4 ± 1.6	0.4 ± 0.6	.47
Abortion rate, % per farm	7.5 ± 0.8	7.3 ± 0.8	0.2 ± 0.4	.60
Culling rate, % per farm	35.3 ± 1.0	35.5 ± 1.1	0.3 ± 1.1	.77
Log SCC cells/mL first lactation	5.0 ± 0.1	5.0 ± 0.1	0.0 ± 0.0	.57
Log SCC cells/mL later lactations	5.5 ± 0.1	5.4 ± 0.1	−0.1 ± 0.1	.28
Clinical mastitis, cases/month	14.9 ± 2.4	14.8 ± 2.9	−0.1 ± 1.1	.95
Ketosis, cases/month	5.5 ± 1.0	5.2 ± 0.9	−0.3 ± 0.9	.85
Displaced abomasum, cases/month	2.1 ± 0.4	2.1 ± 0.4	0.0 ± 0.0	.99
Retained placenta, cases/month	4.7 ± 0.8	4.3 ± 0.6	−0.4 ± 0.4	.28
Sold/died per month	10.3 ± 1.3	9.3 ± 1.1	−1.0 ± 0.7	.18

Note. SCC = milk bulk tank somatic cell count.

Economic Impact

The economic impact of Repro Money is presented in Table 5. The overall 2-percentage-point increase in the mean 21-day PR resulted in an estimated economic gain of $31 per cow per year ($10,029 per herd per year). Overall, 85% of farms enrolled in Repro Money increased their 21-day PR, and the average economic gain for these farms was $44 per cow per year ($14,482 per herd per year). Large ranges in 21-day PR and economic gain was a reflection of the condition and management variability found at the participant farms. Ranges between less than 10% and greater than 40% in 21-day PRs are plausible. An increase of $20 or more per each 1 percentage point of improvement of 21-day PR has been documented (Cabrera, 2012).

Table 5.
Economic Impact Due to Change in 21-Day Pregnancy Rate (PR) Resulting from Participation in the Repro Money Extension Program (*n* = 40 Farms)

		21-day PR % per farm (range)			Economic impact of change, $ (range)	
21-day PR	**% farms**	**Before**	**After**	**Change**	**$/cow per year**	**$/herd per year**
Increased or maintained	85	18 (8 to 27)	20 (11 to 30)	2 (0 to 7)	44 (0 to 137)	14,482 (0 to 38,430)
Decreased	15	19 (11 to 25)	17 (16 to 21)	−2 (−3 to −1)	−40 (−62 to −17)	−15,207 (−2,128 to −21,984)
All farms	100	18 (8 to 27)	20 (11 to 30)	2 (−3 to 7)	31 (−62 to 137)	10,029 (−2,128 to 38,430)

Note. Calculated with the decision support tool The Economic Value of a Dairy Cow, available on the Tools page at http://DairyMGT.info/ (Cabrera, 2012).

Conclusions

The design of the Repro Money Extension program was based on a farmer-directed, team-based approach that consisted of an initial assessment, identification of areas for improvement, goal setting, implementation of an action plan, and a final evaluation. Results from Repro Money demonstrate the benefits of a team-based approach to increasing reproductive performance and profitability. Forty farms that completed the program averaged a 2-percentage-point increase in the 21-day PR, which resulted in a gain of $31 per cow per year. This increase in the 21-day PR was driven by a corresponding increase in the 21-day insemination risk. Improvement in reproductive performance of these herds with Repro Money suggests the effectiveness of a focused team-based Extension program in increasing reproductive efficiency of dairy farms.

A farmer-directed, team-based Extension program, such as the Repro Money program described here, can be applied to improve any area of farm management. It is especially relevant for addressing complex, multifactorial problems that involve various decision makers. The successful application of farmer-directed, team-based Extension programs requires larger commitments of time, organization, and effort, but such programs can be very effective for tackling multifaceted, interrelated problems that otherwise would be only partially addressed.

Acknowledgments

This research was supported by Agriculture and Food Research Initiative Competitive Grant no. 2010-85122-20612 from the U.S. Department of Agriculture National Institute of Food and Agriculture.

References

Bar, D., Tauer, L. W., Bennett, G., Gonzalez, R. N., Hertl, J. A., Schukken, Y. H., . . . Gröhn, Y. T. (2008). The cost of generic clinical mastitis in dairy cows as estimated by using dynamic programming. *Journal of Dairy Science*, *91*, 2205–2214.

Bitsch, V., & Thornsbury, S. (2010). Building teamwork into an integrated Extension program: Faculty perspectives on area of expertise teams. *Journal of Extension*, *48*(4), Article 4FEA2. Available at: https://www.joe.org/joe/2010august/a2.php

Borchardt, S., Haimerl, P., & Heuwieser, W. (2016). Effect of insemination after estrous detection on pregnancy per artificial insemination and pregnancy loss in a Presynch-Ovsynch protocol: A meta-analysis. *Journal of Dairy Science*, *99*, 2248–2256.

Cabrera, V. E. (2012). A simple formulation and solution to the replacement problem: A practical tool to assess the economic cow value, the value of a new pregnancy, and the cost of a pregnancy loss. *Journal of Dairy Science*, *95*, 4683–4698.

Cabrera, V. E. (2014). Economics of fertility in high-yielding dairy cows on confined TMR systems. *Animal*, 8, 211–221.

Carvalho, P. D., Fuenzalida, M. J., Ricci, A., Souza, A. H., Barletta, R. V., Wiltbank, M. C., & Fricke, P. M. (2015). Modifications to Ovsynch improve fertility during resynchronization: Evaluation of presynchronization with GnRH 6 days before Ovsynch and addition of a second prostaglandin F2α treatment. *Journal of Dairy Science*, *98*, 8741–8752.

Carvalho, P. D., Souza, A. H., Amundson, M. C., Hackbart, K. S., Fuenzalida, M. J., Herlihy, M. M., . . . Wiltbank, M. C. (2014). Relationships between fertility and postpartum changes in body condition and body weight in lactating dairy cows. *Journal of Dairy Science*, *97*, 3666–3683.

Caraviello, D. Z., Weigel, K. A., Fricke, P. M., Wiltbank, M. C., Florent, M. J., Cook, N. B., . . . Rawson C. L. (2006). Survey of management practices on reproductive performance of dairy cattle on large US commercial farms. *Journal of Dairy Science*, *89*, 4723–4735.

Chase, L. E., Ely, L. O., & Hutjens, M. F. (2006). Major advances in Extension education programs in dairy production. *Journal of Dairy Science*, *89*, 1147–1154.

Derks, M. L., van de Ven, M. A., van Werven, T., Kremer, W. D. J., & Hogeveen, H. (2012). The perception of veterinary herd health management by Dutch dairy farmers and its current status in the Netherlands: A survey. *Preventive Veterinary Medicine*, *104*, 207–215.

Fricke, P. M. (2002). Scanning the future—Ultrasonography as a reproductive management tool for dairy cattle. *Journal of Dairy Science*, *85*, 1918–1926.

Fricke, P. M., Ricci, A., Giordano, J. O., & Carvalho, P. D. (2016). Methods for and implementation of pregnancy diagnosis in dairy cows. *Veterinary Clinics: Food Animal Practice*, *32*, 165–180.

Fuenzalida, M. J., Fricke, P. M., & Ruegg, P. L. (2015). The association between occurrence and severity of subclinical and clinical mastitis on pregnancies per artificial insemination at first service of Holstein cows. *Journal of Dairy Science*, *98*, 3791–3805.

Galvão, K. N., Federico, P., De Vries, A., & Schuenemann, G. M. (2013). Economic comparison of reproductive programs for dairy herds using estrus detection, timed artificial insemination, or a combination. *Journal of Dairy Science*, *96*, 2681–2693.

Giordano, J. O., Kalantari, A., Fricke, P. M., Wiltbank, M. C., & Cabrera, V. E. (2012). A daily herd Markov-chain model to study the reproductive and economic impact of reproductive programs combining timed artificial insemination and estrous detection. *Journal of Dairy Science*, *95*, 5442–5460.

Gomez, A., Cook, N. B., Socha, M. T., & Döpfer, D. (2015). First-lactation performance in cows affected by digital dermatitis during the rearing period. *Journal of Dairy Science*, *98*, 4487–4498.

Hohmann, K. J., & Ruegg, P. M. (2012). The influence of Extension on team success of a milk quality improvement program. *Journal of Extension*, *50*(5), Article 5FEA6. Available at: https://joe.org/joe/2012october/a6.php

Kristensen, E., Østergaard, S., Krogh, M. A., & Enevoldsen, C. (2008). Technical indicators of financial performance in the dairy herd. *Journal of Dairy Science*, *91*, 620–631.

Lopez, H., Satter, L. D., & Wiltbank, M. C. (2004). Relationship between level of milk production and estrous behavior of lactating dairy cows. *Journal of Dairy Science*, *81*, 209–223.

McCullock, K., Parsons, J., & Roman-Muniz, I. N. (2012). Extension's guide to sexed semen: A dairy case study. *Journal of Extension*, *50*(4), Article 4RIB7. Available at: https://joe.org/joe/2012august/rb7.php

McDougall, S., Heuer, C., Morton, J., & Brownlie T. (2014). Use of herd management programs to improve the reproductive performance of dairy cattle. *Animal*, *8*, 199–210

Mee, J. F. (2007). The role of the veterinarian in bovine fertility management on modern dairy farms. *Theriogenology*, *68*S, S257–S265.

Moore, D. A., Cullor, J. S., Bondurat, R. H., & Sischo, W. M. (1991). Preliminary field evidence for the association of clinical mastitis with altered interestrus intervals in dairy cattle. *Theriogenology*, *36*, 257–265.

Morris R. S., Williamson, N. B., Blood, D. C., Cannon, R. M., & Cannon, C. M. (1978). A herd health program for commercial dairy herds 3. Changes in reproductive performance. *Australian Veterinary Journal*, *54*, 231–246.

Niles, D., Eicker, S., & Stewart, S. (2001). *Proceedings from the 5th Western Dairy Management Conference,* Las Vegas, Nevada.

O'Connor, M. L., Baldwin, R. S., Adams, R. S., & Hutchinson, L. D. (1985). An integrated approach to improving reproductive performance. *Journal of Dairy Science*, *68*, 2806–2816.

Overton, M. W. (2010a). Economic principles of dairy cattle reproduction. *Proceedings of the 2010 Wisconsin Veterinary Medicine Association Annual Convention.*

Overton, M. W. (2010b). Managing and monitoring fresh cows for improved reproductive success. *Proceedings of the Dairy Cattle Reproduction Conference,* Saint Paul, Minnesota.

Rodrigues, A. C. O., Caraviello, D. Z., & Ruegg, P. L. (2005). Management of Wisconsin dairy herds enrolled in milk quality teams. *Journal of Dairy Science*, *88*, 2660–2671.

Santos, V. G., Carvalho, P. D., Maia, C., Carneiro, B., Valenza, A., Crump, P. M., & Fricke, P. M. (2016). Adding a second prostaglandin F2α treatment to but not reducing the duration of a PRID-Synch protocol increases fertility after resynchronization of ovulation in lactating Holstein cows. *Journal of Dairy Science*, *99*, 1050–1058.

Schrick, F. N., Hockett, M. E., Saxton, A. M., Lewis, M. J., Dowlen, H. H., & Oliver, S. P. (2001). Influence of subclinical mastitis during early lactation on reproductive parameters. *Journal of Dairy Science*, *84*, 1407–1412.

U.S. Department of Agriculture National Agricultural Statistics Service. (2015). Retrieved from http://www.nass.usda.gov

Wiltbank, M. C., Baez, G. M., Cochrane, F., Barletta, R. V., Trayford, C. R., & Joseph, R. T. (2015). Effect of a second treatment with prostaglandin F2α during the Ovsynch protocol on luteolysis and pregnancy in dairy cows. *Journal of Dairy Science*, *98*, 8644–8654.