J. Dairy Sci. 99:1–12
http://dx.doi.org/10.3168/jds.2015-10364

Retention payoff–based cost per day open regression equations: Application in a user-friendly decision support tool for investment analysis of automated estrus detection technologies

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ABSTRACT

Assessing the economic implications of investing in automated estrus detection (AED) technologies can be overwhelming for dairy producers. The objectives of this study were to develop new regression equations for estimating the cost per day open (DO) and to apply the results to create a user-friendly, partial budget, decision support tool for investment analysis of AED technologies. In the resulting decision support tool, the end user can adjust herd-specific inputs regarding general management, current reproductive management strategies, and the proposed AED system. Outputs include expected DO, reproductive cull rate, net present value, and payback period for the proposed AED system. Utility of the decision support tool was demonstrated with an example dairy herd created using data from DairyMetrics (Dairy Records Management Systems, Raleigh, NC), Food and Agricultural Policy Research Institute (Columbia, MO), and published literature. Resulting herd size, rolling herd average milk production, milk price, and feed cost were 323 cows, 10,758 kg, $0.41/kg, and $0.20/kg of dry matter, respectively. Automated estrus detection technologies with 2 levels of initial system cost (low: $5,000 vs. high: $10,000), tag price (low: $50 vs. high: $100), and estrus detection rate (low: 60% vs. high: 80%) were compared over a 7-yr investment period. Four scenarios were considered in a demonstration of the investment analysis tool: (1) a herd using 100% visual observation for estrus detection before adopting 100% AED, (2) a herd using 100% visual observation before adopting 75% AED and 25% visual observation, (3) a herd using 100% timed artificial insemination (TAI) before adopting 100% AED, and (4) a herd using 100% TAI before adopting 75% AED and 25% TAI. Net present value in scenarios 1 and 2 was always positive, indicating a positive investment situation. Net present value in scenarios 3 and 4 was always positive in combinations using a $50 tag price, and in scenario 4, the $5,000, $100, and 80% combination. Overall, the payback period ranged from 1.6 yr to greater than 10 yr. Investment analysis demonstration results were highly dependent on assumptions, especially AED system initial investment and labor costs. Dairy producers can use herd-specific inputs with the cost per day open regression equations and the decision support tool to estimate individual herd results.
Key words: cost of days open, estrus detection, precision dairy farming, investment analysis, decision support

INTRODUCTION

Reproductive performance is one of the largest factors affecting dairy farm profitability because of its direct relationship to milk production, replacement animal availability, genetic progress, and culling (Britt, 1985; Plaizier et al., 1997; Olynk and Wolf, 2008). A variety of reproductive management methods are used on dairy farms throughout the world, including bull breeding, visual observation for estrus (**VO**), visual detection aids (e.g., tail paint, heatmount detectors), timed artificial insemination (**TAI**), and automated estrus detection (**AED**). Reproductive management method profitability differs depending on associated costs (e.g., labor, tail paint, hormones, AED technologies) and resulting estrus detection rate (**EDR**) and conception rate (**CR**; Holmann et al., 1987; Olynk and Wolf, 2009). Additional reproductive management expenses include those linked to semen purchases, insemination costs, and pregnancy diagnosis.

Multiple models dedicated to calculating economic differences between reproductive management methods exist (Giordano et al., 2011, 2012; Galvão et al., 2013). Modeling is valuable for determining economic differences associated with changes in management (such as reproductive programs) because it allows comparisons between different levels of performance without the

Received September 7, 2015.
Accepted August 3, 2016.
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complexity of on-farm testing. However, application of economic models to investment analysis of AED technologies is rare. Dairy producers' concerns over large AED investment costs and uncertainty in AED system payback have been identified in multiple surveys (Russell and Bewley, 2013; Borchers and Bewley, 2015), emphasizing a need for these types of decision support tools.

Some economic analysis of AED technologies has begun. Rutten et al. (2014) estimated changes in calving interval, milk production, feed requirements, sellable calves, insemination number, inseminations per calf, culling occurrence, and labor hours when switching from visual estrus detection to activity meters on an average Dutch dairy using a stochastic simulation approach. The advantage of stochastic simulation is that a large variety of scenarios can be tested to improve accuracy of expected outcome estimates. The disadvantage of stochastic simulation is that the complexity and software requirements limit the number of users that can benefit from individual farm use of the tool. Fricke et al. (2014) estimated the net present value (**NPV**) of using AED at first insemination on a 1,000-cow commercial Wisconsin dairy using a previously developed Markov-chain simulation model (Giordano et al., 2012). Although this approach may reduce the accuracy of results compared with stochastic simulation in some scenarios, it presents more opportunities as a user-friendly decision support tool. Ideally, decision-making models should be as simple as possible, while maintaining as much accuracy as possible (Groenendaal et al., 2004).

Because of the pros and cons associated with each modeling approach, our research included a combination of multiple modeling techniques. First, a stochastic simulation model was used to collect data for building herd and parity-specific cost per day open (**DO**) equations. Such equations could be useful for estimating the value associated with changes in reproductive performance. Second, a deterministic, partial budget model was used to apply the new cost per DO equations in the creation of a user-friendly, decision support tool for investment analysis of AED technologies. A demonstration of the tool was conducted using data representative of a mid-sized US dairy herd.

MATERIALS AND METHODS

Objective 1

Data sets including both herd-specific financial and production parameters are limited. Therefore, data sets were created using the whole-farm, stochastic simulation model previously described by Bewley et al. (2010). In short, the model simulates a dairy herd over a 10-yr period with daily time steps. Revenues associated with milk yield and calf production and costs associated with feeding, breeding, veterinary needs, and mortality are each calculated on a daily basis. Ten thousand iterations of the model were simulated for each parity (1–5) to collect data used to build the parity-specific cost per DO regression equations.

Stochastic Variable Estimates. The stochastic nature of the model allowed key variables assumed to influence cost per DO to change with each iteration of the model. The goal was for each of the 10,000 iterations to represent a unique farm situation. The herd-level variables defined as stochastic for this model included CR, HDR, voluntary waiting period (**VWP**), age at first calving, rolling herd average milk production, semen cost, replacement price, mature cow live weight, cull cow price, DIM to assign an open cow as a reproductive cull, feed price, milk price, and yearly veterinarian costs per cow. The values of the stochastic variables in each iteration were determined by randomly drawing a value from a predefined probability distribution via the @Risk add-on (Palisade Corporation, Ithaca, NY) for Excel 2013 (Microsoft, Redmond, WA). All stochastic variables used either a PERT distribution (defined by a minimum, maximum, and mode) or a PERTAlt distribution (defined by the expected 2.5th percentile, "most likely" value, and 97.5th percentile). Values used to define probability distributions were selected based on industry data from DairyMetrics (Dairy Records Management Systems, Raleigh, NC), the Food and Agricultural Policy Research Institute (Columbia, MO), and published literature and were adjusted to represent feasible and realistic scenarios as determined by the authors. Table 1 includes the range of stochastically drawn values for each variable after outlier removal (see Regression Equations section for description of outlier removal).

Cost per DO Estimates. For each iteration of the simulation, the daily revenues and costs calculated by the whole-farm model were used to calculating the retention payoff (**RPO**) value of the average cow in the simulated herd on each day of each parity. The RPO value represents the future profitability of a cow compared with her immediate replacement (Groenendaal et al., 2004). Groenendaal et al. (2004) previously used RPO values to estimate the cost of DO on a monthly basis. In our model, the calculation of cost per DO was adapted to be identical to that of Groenendaal et al. (2004), except that it used daily RPO values, therefore allowing daily cost per DO estimates.

In short, the cost per DO was calculated by comparing the RPO of the average cow in the herd under 2 sce-