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Estimating US dairy clinical disease costs with a stochastic simulation model

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ABSTRACT

A farm-level stochastic model was used to estimate costs of 7 common clinical diseases in the United States: mastitis, lameness, metritis, retained placenta, left-displaced abomasum, ketosis, and hypocalcemia. The total disease costs were divided into 7 categories: veterinary and treatment, producer labor, milk loss, discarded milk, culling cost, extended days open, and on-farm death. A Monte Carlo simulation with 5,000 iterations was applied to the model to account for inherent system variation. Four types of market prices (milk, feed, slaughter, and replacement cow) and 3 herd-performance factors (rolling herd average, product of heat detection rate and conception rate, and age at first calving) were modeled stochastically. Sensitivity analyses were conducted to study the relationship between total disease costs and selected stochastic factors. In general, the disease costs in multiparous cows were greater than in primiparous cows. Left-displaced abomasum had the greatest estimated total costs in all parities ($432.48 in primiparous cows and $639.51 in multiparous cows). Cost category contributions varied for different diseases and parities. Milk production loss and treatment cost were the 2 greatest cost categories. The effect of market prices were consistent in all diseases and parities; higher milk and replacement prices increased total costs, whereas greater feed and slaughter prices decreased disease costs.
Key words: clinical disease, disease cost, stochastic modeling

INTRODUCTION

Cow health influences dairy farm profitability and alters biological mechanisms and productivity (Dijkhuizen and Morris, 1997; Galligan, 2006). Health issues change dairy cow performance, which affects current profits and future value of a cow. Disease influences profitability through direct and indirect effects (Dijkhuizen and Morris, 1997; Galligan, 2006). Furthermore, health conditions partially determine culling policy because of changes in the cow's potential value. Common dairy diseases include ketosis, lameness, left-displaced abomasum (**LDA**), mastitis, metritis, hypocalcemia, and retained placenta (**RP**). Robust epidemiological studies have focused on the effects of disease on dairy cow performance, especially for mastitis, lameness, and reproductive failure, which were generally ranked as the most expensive health issues in the dairy industry (Kossaibati and Esslemont, 1997; Juarez et al., 2003).

Mastitis is mostly caused by pathogenic bacteria invading and multiplying in the mammary gland (Harmon, 1994). The cost of mastitis has varied largely in previous studies. Halasa et al. (2007) summarized the cost of mastitis from 1990. Per-case cost varied from €102 (subclinical mastitis in the United Kingdom, equal to $116 in 2016 US dollars) to €287 (in England, equal to $325 in 2016 US dollars). Per-cow base mastitis cost varied from €2 (in Scotland, equal to $2.27 in 2016 US dollars) to €31 equal to (in Ohio, equal to $35.1 in 2016 US dollars). The top 2 cost categories were decreased milk production and treatment (Seegers et al., 2003; Cha et al., 2011; Heikkilä et al., 2012). The estimated average cost of clinical mastitis in 5 large New York Holstein dairy herds was $71 per cow per year ($179 per case), in which the highest loss was from a decrease in milk production (Bar et al., 2008).

Lameness is a foot or leg condition caused by multiple factors (Sanders et al., 2009). Lameness affects the dairy cow's productivity, welfare, and profitability (Cha et al., 2010). A recent US estimate with dynamic programming showed the estimated mean costs at $177.62 per case, ranging from $120.70 to $216.07 for different lameness types (Cha et al., 2010).

Retained placenta and metritis have a complex relationship. Retained placenta is widely considered to be a predisposing factor for metritis (Sandals et al., 1979; Markusfeld, 1984; Bartlett et al., 1986). A common definition of RP is either the presence of fetal membranes 24 h or later after parturition, or fetal membranes retained for more than 6 h (Laven and Peters,

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1996). Metritis is an inflammation of the uterus due to bacterial invasion (Sandals et al., 1979; Bartlett et al., 1986; Drillich et al., 2001; Bellows et al., 2002). Both RP and metritis have detrimental effects on milk production and reproductive performance (Gröhn and Rajala-Schultz, 2000; Bellows et al., 2002; Gilbert et al., 2005). In addition, metritis increases culling risks and could require antibiotic treatment (Bartlett et al., 1986; Rajala-Schultz and Gröhn, 1999; Pol and Ruegg, 2007). Guard (2008) estimated that the total cost of retained placenta and metritis was $315 per case in the United States.

Left-displaced abomasum is the predominant type of displaced abomasum in the United States (80–90%; Coppock, 1974). In a study of 161 multiparous cows in Oregon, the incidence of LDA was 4.3% during the first 7 wk in lactation (Qu et al., 2013). Left-displaced abomasum appears when the abomasum is filled with gas and subsequently trapped by the descending rumen to the left side of the abdominal cavity (Coppock, 1974; Markusfeld, 1986). The cost of LDA varied from $250 to $400 per case, depending on whether surgery was needed (Geishauser et al., 2000).

Ketosis occurs due to a negative energy balance, especially a glucose imbalance (Baird, 1982; Beem, 2003). The clinical ketosis incidence rate ranges from 2 to 15% (Beem, 2003). Ketosis leads to lower milk production and higher culling costs (Gröhn et al., 1998; Rajala-Schultz and Gröhn, 1999; Rajala-Schultz et al., 1999). Guard (2008) estimated the total ketosis cost at $232 per case, including $5 for the treatment.

Hypocalcemia, or milk fever, is low plasma calcium shortly following parturition (Horst et al., 1997; Kossaibati and Esslemont, 1997); milk fever is result of clinical hypocalcemia. The prevalence of subclinical hypocalcemia was 33% and clinical hypocalcemia was 5% in pasture-based systems (Roche, 2003). Hypocalcemia reduced the productive life of dairy cows by 3.4 yr. (Horst et al., 1997) and caused a decrease in milk production (Rajala-Schultz et al., 1999; Wilson et al., 2004). The total cost was estimated at $220 per case (Kossaibati and Esslemont, 1997); Miller and Dorn (1990) summarized that culling cost was the greatest part of total hypocalcemia cost.

Dijkhuizen and Morris (1997) suggested that modeling was an essential tool to understand economics in the dairy production system. With computer simulation, stochastic programming has been used to estimate disease costs and find optimal management strategies in large-scale models. The stochastic model captured the variation in key variables using the Monte Carlo simulation with a large number of iterations. In each iteration, as one trial, the model drew a number from a distribution for each stochastic variable. After many iterations, the model eventually covered the variations of stochastic variables. The objective of our study was to use a farm-level stochastic model with Monte Carlo simulation to estimate the cost of common dairy diseases in the United States with variation in farm and market conditions. The relationships among farm conditions, market prices, and total disease costs were further analyzed in this study.

MATERIALS AND METHODS

Basic Model

This farm-level, stochastic, Monte Carlo simulation model was first described by Bewley et al. (2010). The model was constructed in Microsoft Excel 2010 (Microsoft Corp., Redmond, WA) with @Risk 6.1.2 (Palisade Corporation, Ithaca, NY). The basic model was deterministic; however, several key variables were modeled stochastically, including dairy related market prices (milk, feed, slaughter, and replacement cow prices), product of conception rate and heat detection rate (**PHC**), rolling herd average milk production (**RHAM**), and age at first calving (**AFC**). The stochastic model takes the parameter variation into calculation to generate the results with a distribution, representing variation in results. A deterministic model does not assess these variations. This model was designed to describe and examine a cow's value with variation in farm and market conditions. To increase model accuracy and detail, the model was modified from the original monthly based model (Bewley et al., 2010) to a daily based model because the replacement decision is made on a daily basis. This model was constructed with the flexibility for users to input their farm-level parameters into this model as inputs instead of default parameters.

Farm Level Model with Average Cow

This farm-level model used an average cow to represent all cows in the herd. This model assumed the herd structure was steady across time, and if a disease occurred it would not change the herd structure. Productive lifetime was set as 6 parities, which meant the model calculated the average cow's daily performance until the end of the sixth lactation regardless of the estimated optimal culling time. All daily production and reproduction data were calculated based on the methodology described in Bewley et al. (2010). Parameters calculated each day for each cow included milk production, BW, and DMI; reproduction performance included pregnancy status and days carrying calf. The lactation curve developed by Oltenacu et al. (1981),

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