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Prediction of the lifetime productive and reproductive performance of Holstein cows managed for different lactation durations, using a model of lifetime nutrient partitioning

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ABSTRACT

The GARUNS model is a lifetime performance model taking into account the changing physiological priorities of an animal during its life and through repeated reproduction cycles. This dynamic and stochastic model has been previously used to predict the productive and reproductive performance of various genotypes of cows across feeding systems. In the present paper, we used this model to predict the lifetime productive and reproductive performance of Holstein cows for different lactation durations, with the aim of determining the lifetime scenario that optimizes cows' performance defined by lifetime efficiency (ratio of total milk energy yield to total energy intake) and pregnancy rate. To evaluate the model, data from a 16-mo extended lactation experiment on Holstein cows were used. Generally, the model could consistently fit body weight, milk yield, and milk components of these cows, whereas the reproductive performance was overestimated. Cows managed for repeated 12-, 14-, or 16-mo lactation all their life were simulated and had the highest lifetime efficiency compared with shorter (repeated 10-mo lactations: scenario N-N) or longer lactations (repeated 18-, 20-, or 22-mo lactations). The pregnancy rates increased slightly from a 10-mo to a 16-mo lactation but not significantly. Cows managed for a 16-mo lactation during their first lactation, followed by 10-mo lactations for the rest of their lives (EL-N scenario), had a similar lifetime efficiency as cows managed for 16-mo lactation all of their lives (EL-EL scenario). Cows managed for a 10-mo lactation during their first lactation, followed by 16-mo lactations for the rest of their lives (N-EL scenario), had a similar lifetime efficiency as that of the N-N scenario. The pregnancy rates of these 4 scenarios (N-N, EL-EL, N-EL, and EL-N) were similar to one another. To conclude, the GARUNS model was able to fit and simulate the extended lactation of Holstein cows. The simulated outputs indicate that managing the primiparous cows with a 16-mo extended lactation, followed by 10-mo lactations, allows their lifetime efficiency to increase and become similar to cows managed for 16-mo lactation during their entire lives. Further work should include health incidence (i.e., diseases) in the prediction model to have more accurate and realistic predictions of lifetime efficiency.
Key words: lifetime efficiency, nutrient partitioning, extended lactation, modelling

INTRODUCTION

High-yielding cows have been selected over generations for an increased milk yield (**MY**), which is unfortunately associated with impaired health and reproductive performance (Butler, 2000; Gilmore et al., 2011). The decrease in pregnancy rate is mainly due to the negative energy balance associated with high yields in early lactation (Lucy, 2001; Walsh et al., 2011) and the relationship between body lipid reserves and the reproductive cycle (Friggens, 2003). Consequently, the traditional 365-d calving interval (10-mo lactation) has become more challenging to achieve as pregnancy rates continue to decline. Moreover, the full capacity of the animals is not well exploited as the dry-off often occurs at a time when they are still producing a large amount of milk (Knight, 2005). An extended lactation management, such as delaying rebreeding until 8 mo after calving, would prolong the cow's lactation duration (Osterman and Bertilsson, 2003), decrease the number of calvings per year, decrease the number of health-risk periods associated with calving (Knight, 2005; Ingvartsen, 2006), and decrease farm methane emissions through having less replacement stock, which are known to be responsible for 27% of farm methane emissions (Garnsworthy, 2004). Within an extended lactation management, the cow is inseminated at a stage of lactation with a more positive energy balance and is dried off with a lower MY rather than the

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traditional 10-mo lactation system. However, to our best knowledge, no studies have been conducted to explore the long-term effect of extended lactation on cows' productive and reproductive performance. It is partly because experiments on extended lactation are time consuming, and the number of animals is often restricted. In this context, prediction models can be useful to forecast the consequences of different management strategies in terms of production and reproduction. The simulation of nutrient partitioning across physiological functions and according to genotypes has been the subject of several models (Dumas et al., 2008; Friggens et al., 2013) with the aim to predict the performance of an animal and help farmers make the best management decisions. A dynamic and stochastic model, referred to here as GARUNS, which takes into account the changing priorities of an animal during its life, and through repeated reproduction cycles, has been previously developed (Martin and Sauvant, 2010) and tested for cows managed for a 10-mo lactation, for different breeds and parities (Phuong et al., 2015).

Accordingly, the objectives of the present study were (1) to determine if the GARUNS model of Martin and Sauvant (2010) was able to fit individual curves of MY, BW, BCS, DMI, milk fat (**MCF**), milk protein (**MCP**), and milk lactose (**MCL**) of cows managed for 16 mo of lactation; (2) to determine if the full model, including the reproductive submodel of Phuong et al. (2016) can predict the reproductive performance of cows managed for a 16-mo lactation; and (3) to predict which lifetime scenarios, based on the lactation length, will be most beneficial in terms of performance and reproduction. It was hypothesized that lifetime efficiency and pregnancy rates would be maximized when first calving cows were allowed more time to reestablish pregnancy (16-mo lactation) compared with those with shorter intercalving intervals. This follows indications that extended lactations are more advantageous for primiparous cows than multiparous cows (Arbel et al., 2001; Osterman and Bertilsson, 2003) and that postponing rebreeding increases pregnancy rates (Schindler et al., 1991; Larsson and Berglund, 2000; Kolver et al., 2007).

MATERIALS AND METHODS

Facilities and Animal

The data were obtained from the REPROLAC experiment described by Gaillard et al. (2016b). This experiment was conducted at the Danish Cattle Research Centre at Aarhus University, AU-Foulum, Denmark, from November 2012 to January 2015, and approved by the Animal Experiments Inspectorate under the Danish Veterinary and Food Administration. A total of 62 Holstein cows from a nonseasonal dairy system, including 17 first parity cows, were managed for a 16-mo lactation by delaying rebreeding to 220 DIM. All the cows were housed in a single pen with slatted floor and cubicles with mattresses. They had free access to water and were fed ad libitum through automatic feeders (Insentec RIC system, Marknesse, the Netherlands). Cows had access to an automatic milking unit (DeLaval AB, Tumba, Sweden) where they received 3 kg of extra concentrate per day and had to visit it at least twice a day. In the REPROLAC experiment, half of the cows were fed a diet enriched in energy in early lactation (on average the first 7 wk of lactation) compared with the standard diet. To simplify the present analysis, and because the difference in energy between the diets was observed to have very few effects on the production variables (Gaillard et al., 2016a), only the standard diet was considered. This diet had an average energy density of 11.5 MJ of ME/kg of DM.

Data Recording

The MY was recorded at each individual milking in the milking robot, and the milk components (fat, protein, lactose, and cells) were measured every week. Daily BW was recorded through a platform scale (Danvaegt, Hinnerup, Denmark) in the milking robot. The BCS of all cows was scored manually every second week by the same 2 evaluators. A scale of 1 to 5 with 0.25-point increments was used (Ferguson et al., 1994). Daily DMI was calculated by adding the concentrate eaten at the milking robot and the DMI was registered by the automatic feeders.

GARUNS Model

The GARUNS model is a dynamic and stochastic model that takes into account the changing physiological priorities of an animal during its life and through repeated reproduction cycles (Martin and Sauvant, 2010). In this model, an individual cow is the unit modeled. The model is composed of a regulating submodel and an operating submodel. The regulating submodel describes the priorities in terms of Growth, Aging, body Reserves, energy supply to the Unborn calf, to the New born calf, and to the calf through Sucking (GARUNS), whereas the operating submodel distributes the energy between the physiological functions according to the priorities and the genetic scaling parameters. To simulate the differences between animals in genetic potential for milk production level, milk components, BW, and body reserves, the model uses the following genetic scaling parameters: peak MY potential (μ_Y), milk fat secretion (μ_F), milk protein secretion (μ_P), milk lactose secre-