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APPLICATION OF PID CONTROL TO SUPPORT DAIRY HEIFER PLANNING

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Accurate production of the target number of dairy heifers calving in a period on dairy farms is difficult. Often, the actual number of dairy heifers calving is determined using sexed female dairy semen approximately 32 months earlier, conception rates and actual losses to birth and to first calving. Dairy producers periodically review heifer projections and may manually adjust the use of sexed semen to make corrections when projections are deemed off target. Such adjustments are more art than science and are likely not optimal. In industrial control systems, PID (proportional–integral–derivative) controllers are the mechanism commonly used to manage processes that require continuous control and automatic adjustment to remain on target. The hypothesis for this study was that the application of PID controllers may improve the accuracy of heifer production. Therefore, the objective was to develop, apply, and optimize PID controllers to the problem of automatic control of the production of heifers through adjustment of the use of sexed semen.

To study the problem, a Monte Carlo process model of the heifer calf production system was built. The model was parameterized based on an actual dairy farm and included weekly variations in number of inseminations [90,110], actual and estimated conception rates [40%-50%], and actual number of conceptions from sexed inseminations. Autocorrelations created weekly dependencies on past data. The genetic merit of each animal was simulated from a N (0,100) distribution. The target was 20 conceptions to sexed semen weekly, which implied that roughly half of all inseminations should be to sexed semen (with the remainder to beef semen). A model run included 1000 weeks of simulations. Input into the PID controller was the weekly difference between expected and target number of conceptions to sexed semen. Two methods for the PID controller to automatically adjust the weekly expected number of sexed semen inseminations were explored. The first "number" method was to use sexed semen for every insemination until the desired number of sexed semen inseminations was reached in a week. This method therefore ignored the genetic merit of animals. The second "genetic" method adjusted a genetic merit threshold. Animals with a genetic merit above this threshold were inseminated with sexed semen. For each method, the best proportional, integral, and derivative settings were found by minimizing the sum of squared errors in one run. Results from 20 independent runs were averaged. Results showed that both PID control methods were able to automatically adjust the number of sexed semen inseminations to minimize the average weekly error (< 0.1), regardless of the starting inputs. The average weekly standard deviation was slightly smaller for the "number" method (3.8) vs. the "genetic" method (4.3) but the average genetic merit of animals inseminated with sexed semen was $87 for the "genetic" method vs $0 for the "number" method. Results using simple bang-bang adjustments were only slightly worse. In conclusion, this first exploration of PID control methods to the problem of dairy heifer production showed promising results, but many questions regarding optimal settings remain for further research.