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USING MID-INFRARED SPECTROSCOPY PREDICTIONS OF FERTILITY TO OPTIMISE SEMEN ALLOCATION IN DAIRY HERDS

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SUMMARY

As most dairy cows require more than one artificial insemination (AI) to fall pregnant, prioritising more fertile cows for insemination with expensive semen could support optimised semen usage. In this study, we explored two approaches for identifying high (H) and low (L) fertility cows in dairy herds; the use of calving dates (CD) and probability of conception to first service (pMIR) predicted from milk mid-infrared (MIR) spectra and other early lactation data. We found cows classified as H fertility by pMIR had 1st service and overall conception rates (CR_1, CR_O) 2.0 to 6.2% higher compared to those classified H by CD. Both H subgroups had higher CR_1 and CR_O than herd average with the reverse also true for L subgroups. Differences in CR_1 between H and L cows were approximately 50% greater (up to 17.7%) when pMIR was used to classify cows compared to CD (up to 10.8%). This shows pMIR was better than CD at identifying cows most and least likely to conceive at first service. However, total number of AI events between cows classified using pMIR or CDs were similar. A preliminary case study exploring three strategies for assigning sexed dairy semen (SS), conventional dairy semen (DS) and beef semen (BS) in dairy herds found that the net benefit (calf values minus semen costs) was greatest when pMIR was used to assign SS and BS to H and L fertility cows, respectively, followed by CD and random semen allocation, \$70.26 ± 3.05, \$68.68 ± 3.05 and \$66.73 ± 3.11/cow, respectively. Differences in net benefit were largely due to the higher number of heifer replacements generated in the pMIR strategy. Therefore, pMIR has promise as a tool for identifying the most and least fertile dairy cows. The pMIR predictions could be used alone, or in conjunction with other fertility indicators to support optimised allocation of semen, including sexed semen, in dairy herds and offer the next generation of breeding tool.

INTRODUCTION

Average CR_1 in dairy herds in Australia is 39% but ranges from 22 to 61% (Dairy Australia 2011). This indicates there are differences in the ability to conceive at first service. Being able to identify cows that are more likely to conceive at first service could support optimised semen usage, particularly the incorporation of more expensive semen, such as sexed semen, into breeding programs. Cows with well-managed transition periods are more likely to fall pregnant again (Roche *et al.* 2013), conversely cows that calve later in the calving period are less likely to conceive in the subsequent joining period (Dennis *et al.* 2018). New phenotyping technologies and computational approaches offer additional opportunities to identify more fertile cows. Ho and Pryce (2020) have previously demonstrated that mid-infrared (MIR) spectroscopy and other data collected on-farm in early lactation can be used to rank cows on the probability of conception to first service (pMIR) with accuracies of up to 76% achieved in identifying cows that are least likely to fall pregnant. The hypothesis of Ho and Pryce (2020) is that cows that are phenotypically divergent in fertility give clearer biological signals for training MIR prediction models. Our aims were two-fold: firstly, to compare reproductive performance of cows identified as high or low likelihood of conceiving to first service based on pMIR or CD and second, to explore the net benefit of three strategies for allocating semen in dairy herds: random allocation, allocation based on earliest to latest CD and allocation based on highest to lowest pMIR.

MATERIALS AND METHODS

Lactation parameters including MIR data from first herd test after calving, subsequent AI records and calving details were available for 11,369 dairy cows (13,379 records) across 76 herd-year-calving seasons (HYC). The pMIR was generated for each cow using a model which combines MIR spectral data and other on-farm parameters (milk production, milk SCC, days from calving to insemination, calving season, days in milk and age at calving) previously described in Ho and Pryce (2020). Briefly, a training population of cows with good (conceived to first service) and poor (did not conceive within the mating season and had only one insemination) fertility was created and used to train a prediction model using partial least squares discriminant analysis. This model was then used to derive pMIR (0 to 1) of cows in a new herd that had not been included in the training set. To test the ability of pMIR to identify cows with higher and lower fertility compared to other approaches, each HYC was divided into H and L subgroups using one of the 2 classification approaches and reproductive parameters calculated for each subgroup. The H and L fraction (increments from 5 to 50%) of each HYC was selected based on pMIR in the first instance, and in the second approach were selected based on earliest (H subgroup) and latest (L subgroup) CD. Then CR_1, CR_O, average number of inseminations overall and to achieve a pregnancy were calculated and compared between H and L subgroups and to HYC average performance.

As similar trends in performance of H and L subgroups were seen irrespective of fraction selected, a case study was used to compare 3 strategies for allocating SS, DS and BS. The case study assumed 20% of cows (H subgroup) were assigned to SS at first service and DS for subsequent services, 20% of cows (L subgroup) received BS only, and the remaining 60% of cows received DS within each HYC. The strategies were as follows:

Strategy 1 (pMIR): cows were assigned to H and L subgroups based on pMIR.

Strategy 2 (CD): cows were assigned to H and L subgroups based on earliest to latest CD.

Strategy 3 (random): cows within a HYC were randomly sorted using a random number generator then split into subgroups representing 20%, 60% and 20% of cows and assigned SS, DS and BS, respectively. The results were averaged over 100 replicates of random sampling.

Net benefit was calculated as calf values minus semen costs, assuming number of AI events and calves born remained static across strategies. National average semen prices of $50, $20 and $10 were assumed for SS, DS and BS, respectively, while dairy heifers, male dairy calves and dairy-beef crossbred calves were valued at $275, $54.30 and $100, respectively (Byrne *et al.* 2016). All analyses were conducted within HYC with overall averages presented here.

RESULTS AND DISCUSSION

High subgroups selected by CD and pMIR both identified cows with higher conception rates than HYC averages, regardless of the fraction of the herd chosen (Figure 1a,b). However, cows with higher pMIR had higher CR_1 and CR_O than cows that calved earliest in the calving period. For example, the average CR_1 in the data set was 38.8%. When 20% of cows were selected as H using pMIR, CR_1 was 45.7% compared to 41.5% when H cows were selected using CD, thus showing a 4.2% advantage of using pMIR. Conversely, CR_1 was on average 2.8% lower in L sub-herds selected on pMIR, compared to CD. Both L subgroups had lower conception rates than average HYC, regardless of fraction of herd compared. The difference in CR_1 between H and L subgroups ranged from 9.7% to 17.7% when cows were chosen based on pMIR, while the difference was only 5.6 to 10.8% when cows were chosen based on CD. This suggests that pMIR may be better than CD at identifying cows with highest and lowest likelihood of conceiving.

When more than 15% of cows were selected (Figure 1c), H subgroups had slightly fewer total AI events that L subgroups ranging from 0.05 to 0.08 fewer AI events/cow. No clear difference was seen between classification based on pMIR or CD. When less than 20% of HYC was selected, H cows had up to 0.11 and 0.09 more AI events to conceive than L cows, for CD and pMIR,

respectively (Figure 1d). In scenarios above 20%, L cows had more AI events to achieve pregnancy though differences were small (<0.03). These small observed differences in AI records could be influenced by the strategy used for classifying L cows using pMIR. Ho and Pryce (2020) defined a poor fertility as a cow with only 1 recorded AI event who did not fall pregnant. A failure to show return of oestrus after first insemination could indicate physiologically different reasons for not conceiving than a cow who fails to conceive after multiple AI events.

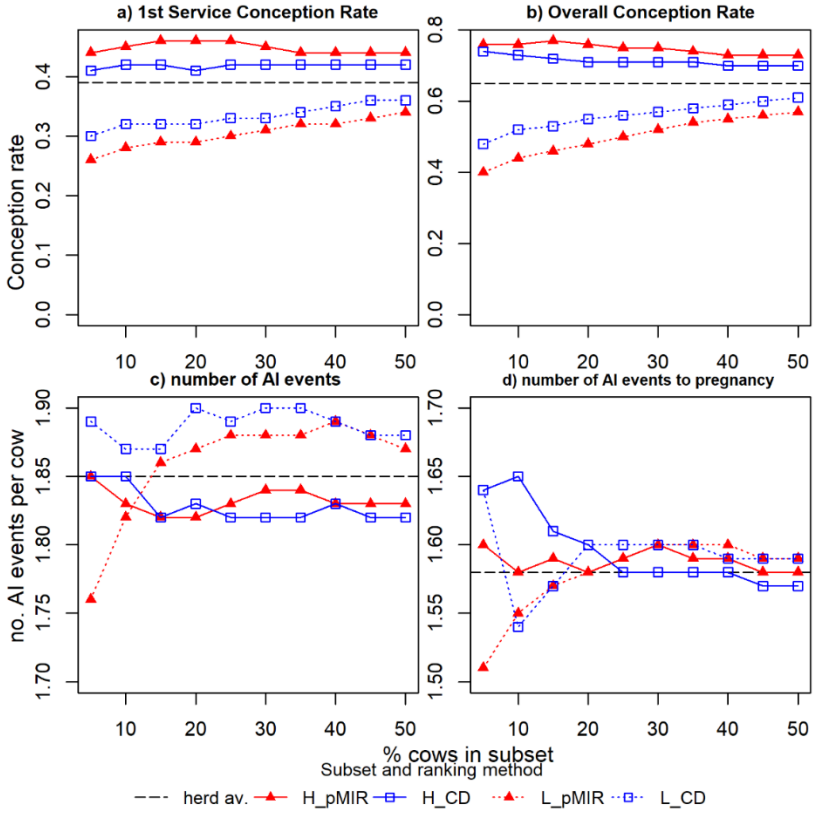

Figure 1. Comparison of average (av.) 1st service conception rate (CR), overall CR, number of artificial insemination (AI) events and number of AI events to achieve pregnancy in a variable (5-50%) proportion of cows within a contemporary group, selected as having highest (H) or lowest (L) probability of conceiving to 1st service (pMIR) or earliest (H) or latest (L) calving date (CD). Dotted line shows herd av.

In our case study, semen allocation using pMIR resulted in a higher net benefit than CD or randomly assigning semen, though all strategies showed a high level of variability (Table 1). Average net benefit per cow for pMIR was \$70.26 ± 3.05 compared to \$68.68 ± 3.05 for CD and \$66.73 ± 3.11 for random semen allocation. Average semen costs only differed by ~\$0.10/cow across the 3 strategies. Differences in net benefit were mainly driven by differences in the number of each calf type, with 1.0 and 3.28 more dairy heifer calves in the pMIR strategy compared to CD and random semen allocation strategies, respectively. This was largely driven by higher CR_1 to SS in H cows selected by pMIR. Conversely, lower CR_1 in L subgroups saw fewest dairy-beef calves

in the pMIR strategy, followed by CD while random allocation resulted in most dairy beef calves. As a preliminary case study of potential applications of pMIR applications on farm, the net benefit calculations solely considered semen prices and calf value. Potential effects of reduced CR_1 with SS were ignored. Although SS conception rates are approaching parity with DS, this area warrants further study. Future analyses could also consider a wider range of semen prices, calf genetic merit and the impact of calving date on a calf's future value on-farm.

Table 1. Overview of average (and standard error[1]) net benefit ($/cow, calf value minus semen costs), number of dairy heifers and dairy beef calves for 3 semen allocation strategies, allocation based on MIR predictions of fertility (pMIR), calving date (CD) or random allocation

Semen strategy	Net benefit ($/cow)	Calf value ($/cow)	Semen costs ($/cow)	No. heifers	No. dairy beef calves
1. pMIR	70.26 (3.05)	109.55 (2.90)	39.29 (0.90)	56.26 (4.78)	18.38 (1.85)
2. CD	68.68 (3.05)	115 (3.18)	39.23 (0.91)	55.26 (4.73)	19.80 (2.01)
3. random	66.73 (3.11)	106.07 (2.96)	39.33 (0.92)	52.98 (4.64)	23.52 (2.07)

[1]reported across herd-year-season contemporary group (n=76)

These preliminary results show pMIR has potential to support an optimised semen allocation strategy. While the additional net benefit from allocating semen using pMIR is small, given the importance of fertility to dairy farms opportunities for incremental net benefit increases should be considered. More accurate identification of cows most likely to conceive at first service may be possible through the development of an index which combines pMIR predictions with other easily accessible information like past calving dates, fertility breeding values or novel phenotypes like sensor data. As pMIR is derived from first herd test after calving, there could be a period of up to 8 weeks between availability of pMIR data and the start of joining. This could also offer opportunities to provide management interventions for cows, especially those identified as least likely to conceive at first service (Ho and Pryce, 2020). Validating whether management interventions based on pMIR data are then capable of increasing herd reproductive performance could be challenging to achieve, but if successful would create a strong value proposition for adoption of the pMIR by industry.

CONCLUSION

This study shows that pMIR identifies the most and least fertile cows in the milking herd better than CD and has potential as a next generation breeding tool. The pMIR predictions could be used alone, or in conjunction with other fertility indicators to support optimised allocation of semen, including sexed semen, to increase the number of dairy heifer replacements on farm or to support additional income streams like dairy beef.

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