GenTORE

Genomic management Tools to Optimise Resilience and Efficiency

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Report on the accuracy of prediction of future conception rate and implications of alternative breeding strategies

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Dissemination level:

- **X PU:** Public (must be available on the website)
- ☐ **CO:** Confidential, only for members of the consortium (including the Commission Services)
- ☐ **CI:** Classified, as referred to in Commission Decision 2001/844/EC

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1. Summary

Reproductive management is a component to herd profitability in any livestock enterprise that involves mature animals. While tools exist to predict when animals should be served, few are available to predict the likely pregnancy outcome from that service. The objective here was to use data from over 8000 services in dairy cows to attempt to predict the pregnancy outcome using phenotypic (and genomic) data not (yet) routinely available in dairy farms. Machine learning and traditional statistical approaches were applied to cow-level features with pregnancy outcome being the variable of interest. The traditionally used logistic regression approach was superior to the machine learning approaches but this could be a function of the relative small dataset size and fewer potential number of features being investigated. The area under the receiver operating curve (i.e., accuracy) when applied to external validation varied from 0.56 to 0.63; while this is more accurate (P<0.001) than flipping a coin, it is nonetheless relatively poor.

2. Introduction

Profitable livestock production systems rely on relatively regular parturition for either the production of offspring for subsequent growth and sale (e.g., beef, sheep) or for the female to begin lactating for milk production (e.g., dairy cows). Some countries operate strict seasonal calving systems where the importance of good pregnancy rates is even greater. The uptake of sexed semen is increasing globally, especially in dairy production systems; there is a general consensus that pregnancy rate is reduced following the use of sexed semen; hence, the recommendation is to limit it to “high fertility cows”; the rules around what a “high fertility cow” is vague but is broadly described as a cow that experienced no issues at calving (e.g., dystocia or retained fetal afterbirth), is a long time calved and in good body condition.

The objective therefore of this task was to attempt to predict the likelihood of conception using available phenotypes.

3. Approach

Data:

The data used from the present task originated from extensive data from 8 Teagasc dairy herds deeply phenotyped with good ancestry information collected between the years 2000 and 2019. The phenotype of interest in this task was conception/pregnancy or not to a given service. This was defined as a binary trait depending on whether or not the cow was thought to have conceived to that service given the extensive data available on the cow. A service to a given cow recorded prior to her last service for that lactation was assumed not to have resulted in pregnancy. Pregnancy diagnosis data were available on almost all cows and these data were used to establish the pregnancy status of the cow following the last service. Date of calving subsequent to service data were also used to validate the date of conception; a gestation length of 260 to 300 days was assumed for verifying the last recorded service date. In order to avoid the use of an inherently infertile cows in the analysis, only the first five services for a given lactation were retained; similarly, only cows that had no recorded calving difficulty were retained as calving difficulty affects cows differently and the purpose of the present task was to build a prediction model with “clean data”. Following all edits, the overall pregnancy rate in the final dataset was 64%.

Because of the seasonal calving system in Ireland, only cows calving in the first 5 months of the year were retained. Milk yield was recorded twice daily and summed to generate a daily yield; milk composition is recorded twice weekly on consecutive evening and morning milkings. The milk sample nearest the service date for a given lactation was retained for an input variable in the model as long as it was within 7 days prior to the service data. Therefore, milk yield, fat%, protein%, lactose% and also fat% - to – protein% variables were available for consideration in the statistical model. Cow live-weight on the research farms is recorded weekly; this enabled the calculation of live-weight at calving but also the live-weight nearest to the service being considered. The live-weight measure nearest to the service data was retained assuming it was within 14 days of the service date. Change in live-weight between calving and the service under investigation was then calculated. Body condition score nearest to calving, nearest to the service under investigation as well as BCS change between calving and the service date was calculated using a similar approach. The genetic merit for fertility was available from the national genetic evaluations; fertility in the Irish genetic evaluations is based on calving interval and while it is not a conception rate trait per se, it is correlated; hence, it could be useful in a model to predict phenotypic conception rate. The data were all collected into a single file for subsequent downstream analysis. Following edits, data on a total of 8,033 lactations are available for analysis.

Analysis

Preliminary analysis compared machine learning approaches and traditional statistical approaches. The machine learning approach of most promise was random forest but it was not comparable in accuracy to traditional logistic regression; this is consistent with other studies and is not unexpected given the small dataset size and relatively few number of features. Therefore, only the results pertaining to the logistic regression model are discussion. In the logistic regression model for the likelihood of conception; animal level features considered in the model were cow parity, a quadratic effect on days in milk at service, genetic merit for fertility, milk yield, fat%, protein%, lactose%, fat – to – protein ratio, BCS at calving, BCS at service, BCS change between calving and service, live-weight at calving, live-weight at service, and live-weight change between calving and service in all instances the logit of the probability was modelled. A forward-backward stepwise algorithm was used to determine the final model for analysis.

4. Results

The mean performance statistics of the animals included in the final analysis are in Table 1. Cow parity number was, on average, 2.6 with cows being served, on average, 83 days post-calving. The mean milk yield, fat%, protein% ad fat:protein ratio was 23.98 kg, 4.21%, 3.144% and 1.22%. Cows weighed, on average, 490 kg and has a BCS of 2.92 BCS units (Scale 1 to 5)

Table 1. Mean and standard deviation of the animal level features.

Variable	Mean	Std Dev
Days in milk at service	83.33	28.97
Milk yield (kg)	23.97	6.34
Fat %	4.21	0.92
Protein %	3.44	0.44
Fat:protien ratio	1.22	0.22
BCS calving (1-5)	3.14	0.30
Lwt calving (kg)	509.28	76.23
BCS change (1-5)	0.21	0.27
Lwt change (kg)	15.24	40.63
Lwt service	490.35	69.49
BCS service (1-5)	2.92	0.24

The features which remained in the statistical model after the backward-forward selection was days post-calving at service, genetic merit, milk yield at service, BCS at service and live-weight at service (Table 2); the association between days in milk and (the logit of the probability of) conception was only linear with no non-linear association detected. Nonetheless, as expected, the likelihood of conception increased with days post-calving which is relatively common knowledge. Genetic merit in Ireland for fertility is based on calving interval in that a longer calving interval is expected when conception rate is poor; hence the negative relationship observed between genetic merit for calving interval and conception is not unexpected. The association between genetic merit and conception rate is nonetheless a little surprising given the low heritability for fertility traits; the heritability for fertility traits tends to be ~3%. Interestingly greater milk yield was associated with greater conception; this is not totally expected but because days post-calving was adjusted for as was genetic merit for fertility, this association with higher milk yield is likely an artefact of better managed, more healthy cows having higher yield which could predispose them to a greater likelihood of conception. The positive association between BCS and conception rate is in-line with international observations in dairy cows. Studies relating live-weight to conception rate are inconsistent in their associations, in the present study the association was negative but this is likely due to its associations with milk yield which was also in the model; in fact, when milk yield was removed from the model, the association between live-weight and conception rate became positive. The area under the curve for this full model was 0.583 with a percent concordant being 58%.

Table 2. Animal-level features in the final model and the model solutions, standard error (SE) and significance level

Feature	Solution	SE	P-value
Intercept	-1.8584	0.6224	<0.01

Days in milk at service	0.0147	0.00198	<0.001
Genetic merit	-0.0271	0.0135	<0.05
Yield	0.022	0.0103	<0.05
BCS at service	0.3842	0.1775	<0.05
Weight at service	-0.00105	0.000378	<0.01

The accuracy of predicting conception rate in the 8 different herds following leave one (herd) out cross-validation is in Table 3. The area under the curve varied from 0.555 to 0.629. All values differed from 0.5, which is the equivalent of flipping a coin; hence, the developed models have some predictive ability. The AUC of the ROC is the probability that a classifier (e.g., prediction probability from a statistical model) will rank a randomly chosen positive outcome higher than a randomly chosen negative outcome; the AUC is similar to the Mann-Whitney U statistical test, which evaluates whether the model ranking of positive outcomes is higher than the ranking of negative outcomes. An AUC of 0.50 indicates no discriminative ability of the classifier (e.g., statistical model). An AUC of 0.50 to 0.75 is assumed to be fair, 0.75 to 0.92 is assumed to be good, 0.92 to 0.97 is assumed to be very good, and 0.97 to 1.00 is assumed to be excellent. Hence, the fact that the prediction model may be viewed as "fair" suggests that it has limited usefulness in a real life setting. While others have reported greater accuracy, these approaches were not completely valid since they included contemporary group effects in their prediction model which would not be available a priori.

Table 3. Percent concordant and area under the receiver operating characteristic curve when externally validated on leave a farm out for each of the eight farms

Farm	Percent Concordant	AUC
A	57.2	0.576
B	55.0	0.555
C	58.4	0.587
D	62.6	0.629
E	56.3	0.569
F	56.2	0.568
G	58.6	0.589

5. Conclusions

In conclusion, the prediction model developed included variables that were biologically sensible with model coefficient consistent with expectation. Nonetheless, the accuracy of prediction was "fair". In hindsight, this relatively poor predictive ability is not unexpected given the many other factors that contribute to the success of pregnancy establishment from a given insemination, which are not generally known a priori; these factors include herd-year-season of insemination, insemination technician capability, and mate fertility.