Predicting the future reproductive potential of dairy cows Cook

Economic success in dairy herds relies on obtaining pregnancies at an early stage of lactation. In this study we were able to categorise and predict the reproductive performance of dairy cows based on a limited number of data gathered from early lactation milk records. Capability to predict future reproductive outcomes has the potential to assist dairy producers with the planning and targeting of reproductive management strategies such as pharmacological intervention with the possibility for less reliance on such methods and better justification for their use when necessary.

Use of early lactation milk recording data to predict the calving to conception interval in dairy herds

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ABSTRACT

Economic success in dairy herds is heavily reliant on obtaining pregnancies at an early stage of lactation. Our objective in this study was to attempt to predict the likelihood of conception occurring by the 100th and 150th day of lactation (**DIM**) by Markov chain Monte Carlo (**MCMC**) analysis using milk recording data and reproductive records gathered retrospectively from 8750 cows from 33 dairy herds located in the United Kingdom. Overall 65% of cows recalved with 30%, 46% and 65% of cows conceived by 100 DIM, 150 DIM and beyond 150 DIM respectively. Overall conception rate (total cows pregnant/total cows inseminated) was 27.47%. Median and mean calving to conception intervals were 123 d and 105 d respectively. The probability of conception by both 100 DIM and 150 DIM was positively associated with week 4 milk production and protein percentage measured at 0-30 DIM and 31-60 DIM. Butterfat percentage was negatively associated with the probability of conception by 100 DIM but not at 150 DIM. Increased somatic cell count (**SCC**) up to 60 DIM was negatively associated with the probability of conception by 100 DIM whilst increased somatic cell count at 31-60 DIM was associated with a reduced probability of conception by 150 DIM. Increasing parity was associated with a reduced odds of pregnancy. Posterior predictions of the likelihood of conception for cows categorised as having 'good' or 'poor' early lactation attributes with actual observed values indicated model fit was good. The likelihood of a 'good' cow conceiving by 100 and 150 DIM were 0.39 and 0.57 respectively (observed values 0.40 and 0.59). The corresponding values for a 'poor' cow were 0.28 and 0.42 (observed values 0.26 and 0.37). Predictions of the future reproductive potential of cows may be possible using a limited number of early lactation attributes.

INTRODUCTION

Dairy herd profitability is highly dependent on reproductive performance (Louca and Legates, 1968; Oltenacu et al., 1981; Giordano et al., 2011; Giordano et al., 2012) probably because optimising the time cows spend in the most efficient part of the lactation curve has a significant impact on revenues obtained for milk sales (Ferguson and Galligan, 1999) as well as minimising replacement costs due to reproductive failure. The timing at which pregnancy occurs during lactation is of utmost importance in sustaining profitability (Giordano et al., 2011); ideally this should occur between 90 and 130 days of lactation (Giordano et al., 2011).

In this context the transition period has been recognised as a time when the dairy cow experiences an abrupt and severe change in demand for energy during the transition from the dry period to the onset of lactation (Baumann and Currie, 1980). At this time the cow's dry matter intake may be limited and so the demand for energy cannot be met by dry matter intake and most cows will experience a period of negative energy balance (**NEB**). The extent of NEB increases with energy output and increasing milk yield and has been linked to poor reproduction (Buckley et al., 2003; Patton et al., 2007).

Britt (1992) suggested that the biological environment in the relatively long period of follicular growth prior to ovulation is a major factor contributing to the 'syndrome of sub fertility' in dairy cows however to date the only long term demonstrable adverse effect on fertility is the effect of heat stress (Chebel et al., 2004). Leroy (2008a, 2008b) has reviewed the mechanisms by which the biochemical environment of the cow and in particular the metabolic changes associated with negative energy balance may influence fertility but many of these effects have been investigated only in the short term because in vitro studies examining long term effects of metabolism are difficult to conduct (Leroy et al., 2008a).

Therefore, it would seem likely then that negative energy balance in early lactation may at least in part be responsible for the creation of the biological environment that leads to sub fertility in dairy cows. Milk recording data from individual cows has been used in several studies to associate milk composition in early lactation with energy balance (Duffield et al., 1997; De Vries and Veerkamp, 2000; Heuer et al., 2001) and more recently Madouasse et al. (2010) have associated milk components in early lactation with the probability of conception at certain intervals during lactation. In particular Madouasse et al. identified an association between lower milk production on second test day, higher percentage of protein on second test day and higher percentage of lactose on first test day with increased probability of conception before 145 DIM whilst positive associations of a smaller magnitude were identified for percentage of protein at first test day and negative associations with first test butterfat and SCC on both first and second test days.

More recently Shahinfar et al. (2014) have used milk yield data amongst a potential 25 other explanatory variables including genetic information and health history to predict insemination outcome success using machine learning algorithms. This research also showed that the quality of data can have a significant effect on the accuracy of predictions particularly where recording of data is subjective traits such as in the recording of health traits.

Transition management success used early lactation milk yield data was also studied by Lukas et al. (2015) however in this study transition management success was not linked to future reproductive outcomes.

Data from individual cow milk recordings is easily measured and readily accessible to both producers and consultants in the dairy industry globally and offers both a non-invasive and affordable method at both individual cow and herd level of assessing and monitoring energy status in early lactation as well as future reproductive potential. Readily accessible information that predicts an individual cow or herd’s future reproductive performance would be of use to producers in managing reproductive programs as it affords the opportunity to alter management programs to potentially optimise the use of hormonal synchronisation protocols, insemination methods (e.g., the use of sexed semen) or environmental management.

The objective of this research was to evaluate the usefulness of readily available production data to predict reproductive performance of dairy cows. Of particular interest was the difference between production parameters to predict early pregnancy (by day 100 of lactation) or later pregnancy (by day 150 of lactation).

MATERIALS AND METHODS

Herd Selection and Reproductive Management

Herds were identified and selected to be included in this study if they had been referred to the technical services department of Genus ABS (Nantwich, United Kingdom) for consultation because of perceived poor reproductive performance reported in the period 1st September 2010-31st December 2010 and as such were part of the normal daily workload of that team.

Data were available for a total of 8750 cows located in 33 herds. Mean and median herd size was 228 and 265 cows respectively. Overall 65% of cows (5693) became pregnant and re calved. The percentage of cows that had conceived by 100 days, 150 days and beyond 150 days of lactation were 30%, 46% and 65% respectively. Overall conception rate (total cows becoming pregnant/total cows served) for cows in this study was 27.47%. Mean and median calving to conception interval was 123 and 105 days respectively.

All herds practised all year round calving and were composed of Holstein Friesian cows. Herds participated in a commercial reproductive management program for heat detection, insemination and fertility data recording operated by Genus ABS (RMS®, Genus ABS). Briefly this service involved a daily visit to the farm premises by a trained technician using the tail chalk method to identify cows in oestrus alongside more detailed manual examination per rectum of the reproductive tract of cows showing changes in the distribution of the chalk which are indicative but not conclusive of the animal expressing oestrus since the previous visit. All cows identified in oestrus were then artificially inseminated. Cows scheduled for fixed time insemination (**TAI**) in accordance with veterinary protocols were also inseminated. The technician had responsibility to collect reproductive data on all cows including dates of calving, oestrus, insemination and dates and outcomes of veterinary examinations for pregnancy. In addition to reproductive data, date of dry off and the date when a cow is designated as ‘do not breed’ and removed from the reproductive management program as well as dates of cow deaths, disposals and exits were also recorded. Data collected was then entered into Dairy Comp 305 (Valley Agricultural Software, Tulare, USA).

All inseminations were carried out by trans-cervical artificial insemination (**AI**) on a once daily basis at the time of the technicians’ daily visit and all herds used a local veterinary practitioner to examine cows for pregnancy from 35 days from the last insemination. All herds undertook milk sampling through National Milk records or The Cattle Information Service on a monthly basis. Milk samples were collected at 2 consecutive milkings and all herds were milked twice daily.

Data Collation and Analysis

Records of individual cow milk composition for each herd were electronically downloaded and merged with reproductive management data in Dairy Comp 305. All data downloads were carried out in January 2012 and data were extracted for all cows with calving dates from 1st September 2009 until 1st September 2010. This ensured that every cow included had sufficient time to become pregnant for this analysis (>150 days). For each cow the unique identity, date of calving, lactation number, milk weights recorded at 0-30 DIM and 31-60 DIM milk protein percentage at 0-30 DIM and 31-60 DIM, butterfat percentage at 0-30 DIM and somatic cell count recorded at 0-30 DIM and 31-60 DIM were electronically extracted into a spreadsheet (Excel®, Microsoft Corporation). These data were chosen because previous studies indicated that they may be useful predictors of calving to conception interval in herds of this management type (Madousse et al 2010). In addition to these data the average daily milk weight produced by a cow during the fourth week of lactation (Week 4 Milk) was also extracted. Week 4 milk is a parameter which can be calculated internally in Dairy Comp 305 and has been used anecdotally to assess performance in early lactation.

To allow the effect of parity and season of calving to be tested as confounding variables, cows were categorised by parity and calving date into groups. Group 1 contained cows only in first parity, group 2 contained cows only in second parity and group 3 containing cows in third parity and above. Cows were also categorised by month of calving.

The outcomes of interest were conception by 100 days or by 150 days of lactation. Conception by these times were chosen as the outcomes of interest because previous studies have suggested that pregnancy status at 150 DIM is a composite trait that is relatively robust to the heterogeneity of reproductive programs that occurs between farms (Caraviello et al., 2006). These points in lactation also approximate to the economic optimum time during lactation for a cow to become pregnant (Giordano et al., 2011) as well as allowing the differentiation of covariates that may predict pregnancy at different stages of lactation. Covariates tested in each model were parity group, month of calving, and milk weights at 0-30 DIM and 31-60 DIM, week 4 milk production, percentage of protein at 0-30 DIM and 31-60 DIM, somatic cell count at 0-30 DIM and 31-60 DIM and percentage of fat at 0-30 DIM. Farm was included as a random effect to account for confounding of cows within farm.

Initial analysis consisted of descriptive statistics and graphical assessments. Multilevel (random effects) models (Goldstein, 1995) were specified so that correlations within the data (cows within farms) were accounted for appropriately. Model specifications took the form;

$$Preg_{ij} \sim \text{Bernoulli (probability} = \pi_{ij})$$

$$\text{Logit}(\pi_{ij}) = \alpha + \beta_1 X_{ij} + \beta_2 X_j + v_j$$

$$V_j \sim N(0, \sigma^2_v)$$

where the subscripts i, and j denote the i^{th} cow and the j^{th} farm respectively, $Preg_{ij}$ was the outcome variable (pregnant or not) for cow i in herd j either by day 100 (Model 1) or by day 150 (Model 2), α the regression intercept, X_{ij} the matrix of covariates at cow level, β_1 the coefficients for covariates X_{ij}, X_j the matrix of farm-month level covariates, β_2 the coefficients for covariates X_j and v_j the random effect to reflect residual variation between farms.

Initial covariate assessment was carried out using MLwiN (Centre for Multilevel modelling, University of Bristol) (Browne, 2009) with penalised quasi-likelihood for parameter estimation (Rasbash et al., 2005). Final models, with the same specification as that above, were constructed in a Bayesian framework using MCMC for parameter estimation in WinBUGS (Spiegelhalter et al., 2004), to avoid the potential biased estimates that can arise from quasi-likelihood methods with binary data (Browne and Draper, 2006). Final model parameters were estimated using MCMC with a burn-in of at least 2,000 iterations during which time model convergence had occurred. Parameter estimates were based on a minimum further 8,000 iterations. Vague prior distributions were used for β (Normal (0, 10^6)) and σ^2_v (Gamma (0.001, 0.001)) (Green et al., 2004). Investigation of model fit was made from plots of cumulated fitted probabilities and residuals (Langford and Lewis, 1998; Green et al., 2004). To further assess model fit and predictive value, posterior predictive assessments were used (Gelman et al., 1996; Green et al., 2008) to evaluate the probabilities of pregnancy for cows with different production characteristics. This allowed ready comparisons to be made between cows with 'good' and 'poor' production attributes, as identified in the statistical models, and to place these into a clinical context.

RESULTS

The final models are presented in Tables 1 and 2. Increased milk yield in the fourth week of lactation was associated with an increased odds of a cow becoming pregnant by day 100 and 150 of lactation. Protein percentage up to 60 days of lactation remained in both models with increased protein percentage being associated with an increased odds of pregnancy. Fat percentage was associated with reduced odds of a cow becoming pregnant by day 100 but not by day 150. Increased somatic cell count up to 60 days of lactation was associated with a decreased odds of a cow becoming pregnant by day 100 of lactation and increased somatic cell count 31- 60 days of lactation was associated with a decreased odds of a cow becoming pregnant by day 150 of lactation. In both models, increasing parity was associated with a reduced odds of pregnancy.

Posterior predictive assessments indicated model fit for both models was good. Posterior predictions for the likelihood of pregnancy were made from both models using cows with relatively good and poor production attributes. ‘Good’ cows were defined as those with a milk yield in week four >30Kg, protein percentage 0-30 days in milk >3.2% and protein percentage 31-60 days in milk >3.2%. 1337 cows were classified as ‘good’. ‘Poor’ cows were defined as those with a milk yield in week four <21Kg, protein percentage 0-30 days in milk >3.0% and protein percentage 31-60 days in milk >3.0%. The posterior predicted probability of a ‘good’ cow becoming pregnant by day 100 of lactation was 0.39 (95% credible interval 0.35-0.43) and this compared to the observed value of 0.40. The posterior predicted probability of a ‘poor’ cow becoming pregnant by day 100 of lactation was 0.28 (95% credible interval 0.23-0.33) and this compared to the observed value of 0.26. The posterior predicted relative risk of pregnancy in a ‘good’ cow in relation to a ‘poor’ cow was 1.40 (95% credible interval 1.14-1.76).

The posterior predicted probability of a ‘good’ cow becoming pregnant by day 150 of lactation was 0.57 (95% credible interval 0.54-0.61) and this compared to the observed value of 0.59. The posterior predicted probability of a ‘poor’ cow becoming pregnant by day 150 of lactation was 0.42 (95% credible interval 0.37-0.48) and this compared to the observed value of 0.37. The posterior predicted relative risk of pregnancy in a ‘good’ cow in relation to a ‘poor’ cow was 1.36 (95% credible interval 1.18-1.59).

DISCUSSION

Many studies have reported associations between milk yields, constituents and energy balance, consistent with the idea that milk composition reflects energy status (Grieve et al., 1986; Duffield et al., 1997; De Vries and Veerkamp, 2000; Heuer et al., 2001) and NEB has been linked to poor reproduction (Buckley et al., 2003; Patton et al., 2007).

In this study we were able to use a limited number of early lactation production characteristics to accurately assess and predict the risk of pregnancy occurring by 100 or 150 DIM. Clear and sizeable differences were also demonstrated in the risk of pregnancy occurring at either 100 or 150 DIM between cows categorised as showing either ‘good’ or ‘poor’ early lactation production characteristics suggesting that these parameters may be of use for incorporation into decision support models to allow early identification of a cow’s likely reproductive potential soon after calving and importantly, before the breeding period begins. Management interventions such as feeding strategies, synchronisation protocols and the use of sexed semen could then be targeted with better efficiency.

In contrast to some other studies (Shahinfar et al., 2014) this study sought to predict future reproductive outcomes from a limited number of early lactation production characteristics that are readily available on most dairies. Week 4 Milk in particular can be calculated from milk weights automatically collected at every milking from every cow via milk meters located in the milking parlour and as such is less subject to data quality issues.

More notably the findings of this study and in particular the large difference between ‘good’ and ‘poor’ cow’s demonstrates that a cows reproductive potential may be determined some weeks in advance of the breeding period before the active efforts by managers to obtain a pregnancy begins and that the overall reproductive success of these herds is at least in part determined by the proportion of cows falling into each category. Although outside the scope of this study it is also interesting to speculate upon which factors may interact to determine which category a cow falls into and over what time period that impact occurs. The 33 herds participating in this study all reported recent disappointing reproductive outcomes but it seems highly unlikely that the same combinations of management factors were present on each dairy at a similar time.

In particular the degree and extent to which TAI was used in different herds and at different times may have produced a bias in our findings as cows subjected to TAI may be more likely to become pregnant earlier in lactation. However it is also likely that any bias would have been in favour of the ‘poor’ cows as they are perhaps less likely to have resumed normal oestrus cyclicity post-partum and been inseminated to a natural oestrus (Santos et al., 2010). Pregnancy status at 150 DIM is also a composite trait that is relatively robust to the heterogeneity to the extent of hormonal synchronisation and duration of the voluntary waiting period (Caraviello et al., 2006). Giordano et al (2012) have also shown that the influence of the extent of hormonal synchronisation on overall herd reproductive performance as measured by 21d pregnancy rate (Ferguson and Galligan, 1999) is minimal at the conception rates achieved by the herds in this study unless 100% of inseminations are carried out to TAI.

Reductions in milk proteins are a consistent feature of cases of NEB. Milk protein is synthesised in the mammary gland, a process requiring energy and amino acids supplied via the blood stream. Attempts to predict milk protein content from amino acid supply however have been disappointing and it is now becoming clearer that the signalling pathways responsible for milk protein synthesis are capable of responding to a variety of nutritional and hormonal signals such that activation of the pathways responsible for protein translation in bovine mammary epithelial cells are capable of being modulated by signals other than simple amino acid supply (Burgos et al., 2010). During the physiological change from the dry period to the lactating state there are substantial changes to both the nutrient supply and hormonal environment and it is not unreasonable to suggest that at this time these factors become limiting for the production of milk protein synthesis resulting in cows with poor transition demonstrating lower milk protein production in early lactation which may then allow for early lactation milk proteins to be used as an indicator of both the nutrient and hormonal state of the cow as she entered lactation and her future reproductive potential.

The link between high milk production and poorer reproduction is equivocal with some studies indicating a negative effect whilst others show no effect (Lucy, 2001). Uniquely in this study week 4 milk production was used as an early indicator of production and a positive association was identified between week 4 milk and the probability of pregnancy at both 100 and 150 DIM. Lactose is the major sugar in milk composed of a single molecule of glucose and one of galactose. Synthesis takes place in the mammary gland from glucose supplied via the blood stream and secretion of lactose by the mammary epithelial cell into milk has a major impact on milk volume via its osmotic effect. Cows in good energy balance will be able to sustain better supplies of glucose to the mammary gland to drive lactose synthesis and milk volume.

The changes in milk yield and constituents and their association with energy balance has also become a basis for on farm monitoring using indicators such as fat to protein ratio. In this study fat percentage at 0-30 DIM was negatively associated with the probability of pregnancy at 100 DIM but not at 150 DIM, a finding which suggests that the use of fat percentage in predicting energy balance may be limited and that early lactation changes in fat percentage may be indicative of energy balance problems but that the impairment may be relatively mild and appears to be recoverable deeper into lactation whereas protein percentage in early lactation shows a stronger and longer lasting association with the predicted probability of pregnancy possibly indicative of a more serious and damaging impact on energy balance during transition. The findings of this study also indicate that fat to protein ratio may be confounded as variations may be due to changes in fat percentage, protein percentage or both and will be further affected as the normal variations in fat percentage observed throughout lactation and season are of greater magnitude than changes in protein percentage and will have a greater influence on changes in the ratio observed.

Somatic cell count around the time of insemination has been shown to influence the probability of conception (Lavon et al., 2011) however in this study the somatic cell count in early lactation was shown to have an influence on the probability of pregnancy much deeper into lactation and there may be a number of explanations for this finding. Changes in cell count were not tracked into lactation in this study and it is possible that cows with high somatic cell counts early in lactation are infected and retain their infected status into lactation so that the cell count remains high around the time of insemination. Alternatively it may be that the elevated cell count observed in early lactation in these cows may be indicative of excess body condition loss, more severe NEB and more severe metabolic issues in early lactation (Van Straten et al 2009) which predisposes them to udder inflammation. It is interesting to note that in this study high somatic cell count at both 0-30 DIM and 31-60 DIM had a negative effect on pregnancy outcome by 100 d and 150 d of lactation but only cell count at 31-60 DIM had an influence on pregnancy outcome by 150 d, perhaps suggesting that in cows with elevated cell counts only at 0-31 days the cell count indicates mild early lactation body condition loss which recovers as lactation progresses whilst cows with elevated cell counts at 31-60 days may be either cows with persistent mammary infections or cows that suffered a more severe body condition loss requiring a more prolonged recovery.

The final models also indicated that month of calving had no influence on the probability of pregnancy occurring by 100 DIM but did have an influence at 150 DIM. This finding is difficult to explain but may be related to several factors. Firstly it has been shown that both milk yield and constituents vary with season in dairy herds located in England and Wales where the herds in this study were located (Madouasse et al 2010) and that feeding regimen is known to influence butterfat (Baumann and Griinari, 2003). The grazing practices of the herds in this study may have varied considerably and it is common for seasonal grazing and pasture to form a part of the feeding management of dairy herds in England and Wales. This was not accounted for in the study design and may have contributed to this finding. All the herds in this study utilized a program of tail chalking (RMS®, Genus ABS) to identify cows expressing heat and it is known that cows which remain metabolically stable around calving are likely to return to cycling behaviour and be detected in heat and inseminated well before 100 days of lactation (Santos et al., 2010). The reproductive behaviour of these cows is predictable. In the UK it is not common practice for cows that fail to express heat and be inseminated by a certain days in milk to be enrolled to synchronisation programs to ensure a timely first insemination (Higgins et al., 2013). Instead they are more commonly presented for veterinary examination by ultrasound when individual treatments would be applied to each cow based on the ultrasonic appearance of the ovaries and uterus. It is likely that the cows presented for such examination are cows that passed through transition in a relatively poor metabolic state and so fail to return to normal cycling behaviour. The reproductive behaviour of these cows will be less predictable, they will be less likely to be detected in heat by the chalking program and perhaps more exposed to seasonal influences. In the UK it is also common practice for lists of cows scheduled for veterinary examination to be heavily edited by herdsman and also for routine veterinary visits to be rescheduled when there is a conflict with staff holidays or other farm tasks considered of greater importance such as silage making are taking place. Any or all of these circumstances could have been present at differing times on the farms represented in this study.

The findings of this study should be interpreted with caution as the relatively small number of farms in this study were recruited because of perceived poor reproductive performance and as such may not be representative of all herds. Further work would be needed to clarify if these findings are truly representative of all herds.

CONCLUSIONS

Milk protein percentage between 0-30 and 30-60 days in milk, week 4 milk yield, milk fat percentage in the first 30 days of lactation, parity and somatic cell count at 0-30 days and 30-60 days of lactation were found to be significant predictors of the probability of pregnancy by 100 days of lactation. Of these only 0-30 day and 30-60 day milk protein percentage, week 4 milk, parity and somatic cell count along with month of calving were shown to be significant predictors of pregnancy by 150 days of lactation. Selecting a limited number of these parameters with the strongest associations with the outcomes of interest we were then able to categorise cows and use posterior predictions to accurately predict the probabilities of the occurrence of pregnancy. Sizeable and significant differences in reproductive potential were shown between cows categorised as having ‘good’ or ‘poor’ production characteristics in early lactation.

Table 1. Final multilevel logistic regression model with response variable pregnant by 100 days in milk

Model terms	Coefficient	Odds Ratio	Credible Interval	
			2.5%	97.5%
Intercept	-2.87			
Week 4 milk yield (Kg)		1.02	1.01	1.02
Protein % 0-30 DIM		1.35	1.30	1.39
Protein % 31-60 DIM		1.91	1.86	1.96
Fat % 0-30 DIM		0.92	0.90	0.95
Parity 1 Reference category				
Parity 2		0.67	0.61	0.74
Parity 3+		0.53	0.47	0.60
Log SCC 0-30 DIM		0.92	0.91	0.93
Log SCC 31-60 DIM		0.95	0.93	0.96
Random effect; between farm variance	0.38			

Table 2. Final multilevel logistic regression model with response variable pregnant by 150 days in milk

Model terms	Coefficient	Odds Ratio	Credible Interval 2.5%	Credible Interval 97.5%
Intercept	-2.95			
Week 4 milk yield (Kg)		1.02	1.02	1.03
Protein % 0-30 DIM		1.27	1.17	1.37
Protein % 31-60 DIM		2.17	2.05	2.30
Parity 1 Reference category				
Parity 2		0.68	0.60	0.77
Parity 3+		0.47	0.43	0.52
Log SCC 31-60 DIM		0.92	0.89	0.95
MONTH 1		0.94	0.75	1.17
MONTH 2		0.87	0.70	1.08
MONTH 3		0.99	0.80	1.23
MONTH 4		0.84	0.68	1.04
MONTH 5		1.01	0.80	1.27
MONTH 6		1.05	0.82	1.34
MONTH 7		0.84	0.65	1.07
MONTH 8		0.76	0.61	0.96
MONTH 9		0.89	0.70	1.13
MONTH 10		0.99	0.80	1.22
MONTH 11		0.99	0.78	1.25
MONTH 12 Reference category				
Random effect; between farm variance	0.57			

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