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CHARACTERISTICS OF EXTENDED LACTATION AND PERSISTENCY IN AUSTRALIAN DAIRY COWS

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SUMMARY

The aim of this research is explore variation in Australian dairy cattle in their lactation curves over an extended lactation and obtain derived traits that could be used in genetic analyses. The Wood model was fitted to milk yield records from a random subset of 6,018 pure Holstein cows with 244,183 test-day records (29,882 lactations). Two traits of interest, namely persistency and extended lactation, were quantified and relevant descriptive traits derived. Variation among cows in their ability to maintain high production over a longer period of time was evident and a representation of the shape of average lactation curves in Australian dairy cows is presented. Findings showed that milk production during extended lactation phase (from day 305 to day 610 of lactation) is on average equivalent to 40% of the production of the first 305 days of lactation (standard lactation) with an average milk yield over the extended lactation of 8,887 L. Preliminary estimates of heritability for traits describing milk yield under extended lactation and persistency are in order of 0.10 and 0.09. This research will provide dairy farmers with a breeding tool to select cows that are best suited to milk for longer than the traditional 305 days.

INTRODUCTION

There has been a shift especially in Victoria, Australia for herds having a seasonally concentrated calving pattern from 63% in 2004 to 41% in 2006 (Dairy Australia, 2006). The reason for such a shift is from improved feeding of cows and the introduction of new germplasm from North American Holstein Friesian animals into some Australian dairy herds. Such impacts have resulted in an increase in the genetic potential of cows to produce more milk, while at the same time causing a decrease in reproductive performance largely as a consequence of changes in metabolic and physiological lactation requirements. The consequence is an ongoing trend of cows being milked beyond the traditional 305 day system to manage decreasing fertility through retaining high productive cows milking for longer, resulting in healthier, more productive cows and more profit for the dairy producer.

Lactation curve models are useful in helping to define and estimate lactation characteristics of individual cows for genetic selection (Dekkers *et al.* 1998; VanRaden *et al.* 2006), predicting milk yields and milk components, analyses responses of yield to environmental and management changes, and identify opportunities for maximising net value effectively (Dematawewa *et al.* 2007; Dijkstra *et al.* 2010). Thus a fundamental aspect of evaluating extended lactation is the modelling of extended lactation and persistency traits in Australian dairy cattle based on herd recording data.

While trait definitions in the literature differ, heritability estimates for extended lactation are in the range of 0.19 to 0.30 (±0.02) and for persistency traits 0.03 to 0.30 (±0.03). These moderate heritability estimates suggest that these traits are likely to respond well to selection. Limited information available for Australian dairy cows (Haile-Mariam and Goddard, 2008) suggests there are both phenotypic and genetic differences in the ability of cows to continue to milk for long periods. Furthermore predictions of which cows are better at milking for longer can be made based on their previous traditional 305 day milking performance. This current project examines the genetic differences observed in Australian dairy cows that can be successfully milked for longer than 305 days. Estimated breeding values (EBVs) for these cows will be derived, which to date is not available. For this paper the main focus is on preliminary exploration of phenotypes and the variation that exists between cows in their milk yield profiles (lactation curves) over an extended lactation and heritability estimates.

MATERIALS AND METHODS

Data were obtained from the Australian Dairy Herd Improvement Scheme (ADHIS) including approximately 158 million test-day records from 1985 to 2010 derived from around 7 million cows. Extended lactation milk traits include milk yield, fat, protein, lactose percentage, Australian Selection Index (fat + protein – volume) and energy outflow of fat, protein and lactose, as a measure of energy per lactation. This paper presents some preliminary analyses for milk yield using a random subset of 6,018 pure Holstein cows with 244,183 test-day records and 29,882 lactations after data editing.

Extended lactation curves have been modelled using the Wood (1967) model, the output from this model then being used to quantify the variation in the shapes of cows' lactation curves, particularly in relation to extended lactation and persistency. The model contains three parameters namely (*a*) an overall scaling factor, parameter (*b*) related to the rate of increase prior to the peak yield and parameter (*c*) related to the rate of decline after the peak (Wood, 1967). The model was fitted to the milk-yield data using the nlme nonlinear mixed model package in R (Pinhero and Bates, 2000), but specifically, each cow-lactation returned a set of (k=$\log_e a$, b, c) parameter estimates; further specific details can be found in Hall (2008) and Jonas *et al*. (2011). Other yield and milk component traits will be examined subsequently. In the context of this study, persistency (r_{305}) is defined as the ratio of model-based milk yield at day 305 (y_{305}) to model-based milk yield at peak ($y_{\max}$) (Hall, 2008; Jonas *et al*., 2011), and extended lactation (Ext Lac, XLAC) is defined as the ratio of expected milk yield from day 305 to day 610 (Area_B), given cows are in lactation for 2 years, relative to the cumulative yield up to day 305 (Area_A). Figure 1 illustrates the model approach. The cumulative yields comprising Area_A and Area_B are obtained from mathematical expression based on the ($k = \log_e a$, b, c) for each cow-lactation (Hall, 2008; Jonas *et al*., 2011).

Genetic parameter estimates and estimated breeding values for these traits were derived using linear mixed animal models using the ASReml-R statistical program. However, for this paper only heritability and repeatability estimates have been reported. Various combinations of fixed effects were fitted and the best model includes herd, year and season and parity group which was analysed as a two category factor, parity 1 = Maiden, Parity two or more = Adult. These effects were fitted additively instead of combining herd, year and season as a proxy to identify the effects of each on extended lactation.

The animal model fitted to the phenotypic data was:

$$Y = \mu + \text{H} + \text{TY} + \text{CM} + \text{PG} + \text{A} + \text{CowID} + \varepsilon$$

where Y = extended lactation (XLAC), persistency (r_{305}) or cumulative 610 milk yield; the fixed effects in the model were National.Herd.ID (H), testYear (start year when test day records were taken) (TY), calveMonth (month of calving/season) (CM) and parity group (2 categories parity 1= Maiden, parity 2 and above (Adult) (PG). The random effects in the model were Animal (A) (polygenic term incorporating pedigree structure) and National.cow.ID (CowID) to account for repeated lactations per cow as well as ε, a random error term.

RESULTS AND DISCUSSION

There is variation in the shape of lactation curves of different cows with extended lactation (beyond the traditional 305 day lactation) as shown in Figure 2. This is also supported with all measures expressing a high degree of variation (CV range 8% - 72%, Table 1). Some cows have a steeper rate of decline with a rapid drop in milk production straight after peak lactation while other cows have a slower rate of decline in milk yield after peak lactation. The latter are more persistent cows and tend to have flatter curves than traditional 305 day lactation curves. Figure 2 also shows two different lactation curves, one illustrating a non-ideal lactation curve (worst cow: bold line A) and the other illustrating an ideal lactation curve (best cow: bold line B) in terms of high persistence while maintain peak production over a longer period of time. The best cow has a more persistent lactation ($\boldsymbol{r_{305}}$ = 0.92) curve where peak production is maintained for a longer period of time, c = 0.001847, which is a lower than average rate of decline after the peak. For the worst cow the rate of decline is higher (c = 0.004361) than all the other curves, and its persistency is higher than average but lower ($\boldsymbol{r_{305}}$ = 0.55) when compared to the best cow presented in Figure 1. It is evident that some cows that have extended lactation may not necessarily be highly persistent and vice versa, which is illustrated by the two curves labelled C and D in Figure 2 where one of the cows is highly persistent with high yield (C) while the other has a rapid decline from peak production (low persistency) and has lower yield (D).

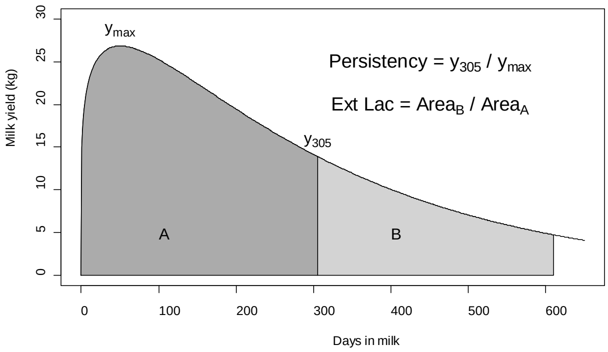

Figure 1. Definition of extended lactation and lactation persistency as a ratio of yields

Table 1 below shows summary statistics from the estimated Wood model parameters and derived persistency and extended lactation traits from a subset of 6,018 pure Holstein cows, from which the mean represents the full dataset (population). Milk production during extended lactation phase (from day 305 to day 610 of lactation) is on average equivalent to 40% of the production of 305 days lactation (standard lactation) with an average milk yield over the extended lactation of 8,887 L. The average persistency is 0.465, indicating that cows can maintain on average, almost 50% of their peak production up to day 305 of lactation.

Heritability estimates (Table 1) for extended lactation, persistency of milk yield and cumulative yield up to day 610 were 0.10 ± 0.03, 0.09 ± 0.03, 0.13 ± 0.05 with repeatabilities of 0.20, 0.19 and 0.42 respectively.

CONCLUSION

Overall there is considerable variation between cows in the Australian dairy herd for persistency and extended lactation. There are certain cows that have higher persistency than others and who are able to maintain production over a longer period of time (extended lactation). The derived traits adequately describe such differences between cows and could be used as input variables in genetic analyses. Genetic parameters such as heritability, genetic, phenotypic, environmental correlations and more importantly breeding value estimates can now be derived for extended lactation and lactation persistency. Thus the findings of such research will provide dairy farmers with a breeding tool to select cows (as well as bulls for breeding) that are best suited to milking for longer than the traditional 305 days.

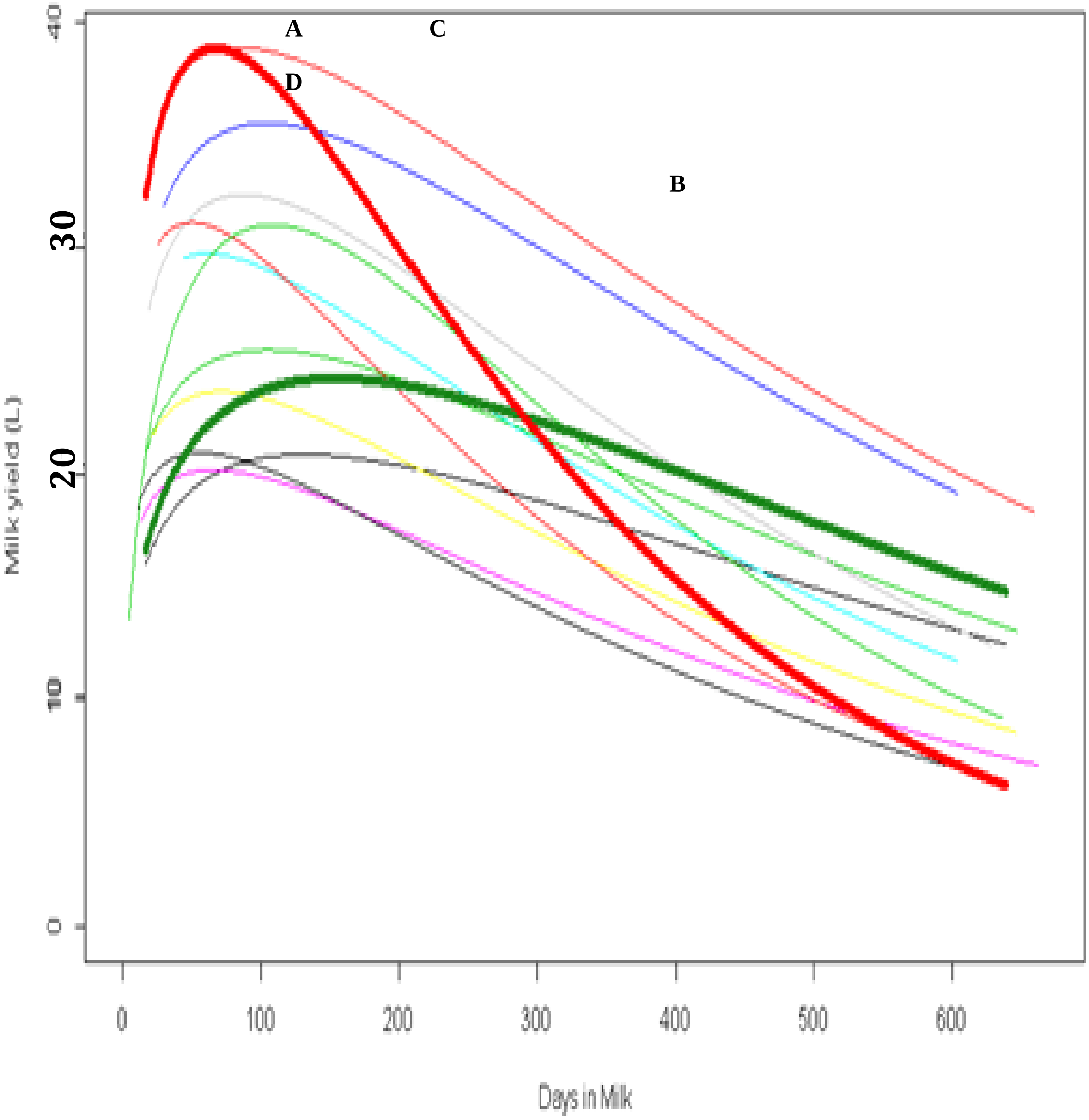

Figure 2. Illustration of the variety of shapes of lactation curves of a sample of 13 cows selected with extended lactations (610 days) modelled using the Wood model. There are cows with more persistent flatter curves, slower rate of decline in milk production after peak milk yield. The best (bold green) cow and worst (bold red) cow in terms of lactation persistency and extended lactation are highlighted.

Table 1. Summary statistics for Wood model parameter estimates (k(=log$_e$$a$),$b$,$c$) of milk yield for subset of 6,018 pure Holstein cows, derived traits, heritability and repeatability for persistency (r_{305}) extended lactation (XLAC) and cumulative yield up to day 610

Trait	Mean	SD	Min	Max	CV (%)	h^2 ± SE	r
k (=log$_e$$a$)	18.32	1.468	4.11	86.57	8		
b	0.14280	0.103	-0.268	0.555	72		
c	0.0040	0.0016	0.0001	0.0100	40		
r_{305}	0.465	0.148	0.073	0.999	32	0.09±0.03	0.19
XLAC	0.3917	0.147	0.082	0.9756	37	0.10±0.03	0.20
CUMYT610	8,887	2,634	2,891	19,631	30	0.13±0.05	0.42

Abbreviations: r_{305} = Persistency, XLAC = extended lactation, CumYT610 = cumulative yield (L) total up to day 610, CV = coefficient of variation (%), h^2 ± SE = heritability ± standard error and r = repeatability

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