EVALUATION OF THE FITNESS OF THREE MATHEMATICAL MODELS TO DESCRIBE THE LACTATION CURVE OF MASTIC AND NON-MASTITIC FRIESIAN X BUNAJI COWS

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ABSTRACT

This study evaluated the fitness of three mathematical models (Wood, Wilmink and Dijkstra models) in describing the lactation curve of Friesian x Bunaji cows. The data used comprised of daily milk yield record between 2000-2015 kept in the Farm Unit of the Dairy Research Programme National Animal Production Research Institute, Shika-Zaria. The Goodness of fit comparison used for the models were the root mean square error (RMSE) and adjusted coefficient of determination (R^2_{adj}) values. Non mastitic cows of parities 1-4 had R^2_{adj} values ranging from 0.3781to 0.9993 and RMSE ranging from 0.2390 to 0.4234 for the three models. Mastitc cows of parities 1-4 had R^2_{adj} and RMSE values ranging from 0.7255-1 and 0.00002-0.2245 respectively for the three models. The results of this study shows that Dijkstra model gave best fit for parity 1 of non mastitc cow's lactation and parities 1-4 of mastitic cow's lactation; while Wilmink model gave best fit for parities 2-4 of non mastitic cow's lactation.

Keywords: Friesian x Bunaji, lactation curve, mastitic cows, goodness of fit mathematical models.

INTRODUCTION

The milk yield potential of a cow and its reproductive efficiency are important factors for a profitable dairy industry. Lactation curve have been used as the main tools for understanding and evaluating the genetic potential for production by a herd or breed of cow (Osorio and Segura, 2005). It is also important for health monitoring, feed and economic management decisions (Bouallegue *et al.,* 2013). Many functions have been used to model lactation curve of dairy cows (Beever *et al.*, 1991), but they vary in their suitability across different breed and systems of production. The objective of this study was to evaluate the fitness of three mathematical models to describe the lactation curve of Friesian x Bunaji cows using data from passed lactation records.

MATERIALS AND METHODS

This was a cross-sectional study that used passive lactation records of cows from 2000 to 2015 from the Dairy Research Programme, National Animal Production Research Institute (NAPRI) Shika, Zaria. The data consisted of 56,636 daily milk records, 446 lactations from 155 cows that had mean lactation number of 2.88 and a range of 1-7th lactations (parities). Cows were hand-milked twice daily and dried up after 305 days in milk. Daily milk yield records were organized into mastitic and non-mastitic lactations (defined as a lactation with or without an occurrence of clinical mastitis within the lactating period respectively), and into 5 parity groups namely 1-4 (group 4 comprised of parities 4 and above since there were records of animals in parities 5th- 7th). Averages of weekly milk yields of the mastitic and the non mastitic cows were then computed for each parity over a 305-day in milk (actual milk yield). Model equations used were those used by Vadillo *et al.* (2012) and estimation of fitness were done using Proc NLIN procedures in SAS 9.0 version 8 (2010). The lactation curves were optimized in MATLAB (2015) Computational Software to minimize the sum of square deviation until convergence was attained. Goodness-of-fit for each model's prediction was assessed using the adjusted Coefficient of determination (R^2_{Adj}) and the Root Mean Square Error (RMSE).

RESULTS AND DISCUSSION

The result of the study shows that Lactation curve prediction by Wood and Dijkstra models were characterized by an increase in milk production in the early lactation, peak production attained between 4-8 weeks post calving, and a gradual decline in production until the cow is dried up. Wilmink model had its peak milk yield at the beginning of lactation which gave its lactation curve a different shape from the regular curve of lactation.

The parameters and estimated goodness-of-fit criteria (coefficient of determination "R^2_{adj}", root mean square error "RMSE") for mastitic and non-mastitic cows from all the models are presented in tables 1 and 2. The best fit model was determined by highest R^2_{adj} and lowest RMSE. The non-mastitic Friesian x Bunaji cows in parities 1, 2 and 3 showed good fit values for the three model, but the best fitted model for parity 1 cows was Dijkstra model, while for parities 2, 3, and 4, it was Wilmink model, though the shape of the lactation curve by Wilmink model was not a typical lactation curve shape. Parity 4 R^2_{adj} and RMSE were low for all the models (Table 1). Dijkstra model fitted best for mastitic cows of parities 1-4 (Table 2). Studies have shown that high milk yielding cows are more prone to mastitis (Oltenacu and Broom, 2010). Cunha *et al* (2010) reported that for pure Holstein and Holstein-Zebu crosses Dijkstra model best fits lactation curve for high milk yielding cows, while Wilmink and Wood models fits best for low and medium milk yielding cows. The result of this study shows that the mastitc cows could have been higher milk yielding cows than the non-mastitic cows, which explains why Dijkstra model was the best fitted model than the Wilmilk model which was best fitting for lactation curve of non-mastitc cows. Wilmink and Dijkstra gave better fit than Wood model probabaly because of the extra parameters present in those models, which might have given them better prediction power. The initial milk yields obtained from the models were higher than the actual values of initial milk yield.

CONCLUSION

Dijkstra model gave the best fit for lactation curve of mastitic Friesian x Bunaji cows. Wilmink model was best fitted for non mastitic Friesian x Bunaji cows. The shape of the curve was not typical of lactation curve probably because of the value of k parameter (which is related to the moment peak) used. Varying this value might give a better fit and shape of curve.

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Table 1: Non-mastitic cows parameters (a, b and c), goodness of fit criteria estimates for Wood, Wilmink and Dijkstra models.

Functions	a	b	c	R^2_{Adj}	RMSE	Persistency	PW
Parity 1							
Wood	$7.49\pm4.9e^{-2}$	$0.0426\pm1.6e^{-3}$	$0.00118\pm1.5e^{-4}$	0.9447	0.1387	4.760	5
Wilmink	7.01±8.4e-3	0.0360±2.8e-5	0.00087±2.5e-5	0.9975	0.0239		
Dijkstra	$7.46\pm5.1e^{-3}$	$0.0423\pm1.7e^{-4}$	$0.00102\pm1.5e^{-5}$	0.9993	0.0147		
Parity 2							
Wood	$9.06\pm7.9e^{-2}$	$0.1152\pm2.7e^{-3}$	$0.00075\pm2.4e^{-4}$	0.9776	0.2245	4.392	5
Wilmink	$8.28\pm2.4e^{-2}$	$0.1039\pm8.2e^{-4}$	$0.00251\pm7.2e^{-5}$	0.9975	0.0689		
Dijkistra	$9.46\pm2.2e^{-1}$	$0.1391\pm9.4e^{-3}$	$0.00014\pm3.3e^{-4}$	0.9545	0.3169		
Parity 3							
Wood	$8.27\pm2.9e^{-2}$	$0.1141\pm9.8e^{-4}$	$0.00046\pm7.8e^{-5}$	0.9968	0.0826	4.164	6
Wilmink	$7.75\pm2.6e^{-2}$	$0.1066\pm8.8e^{-4}$	$0.0027\pm7.8e^{-5}$	0.9973	0.0744		
Dijkistra	$9.00\pm2.3e^{-1}$	$0.1448\pm9.7e^{-3}$	$0.00016\pm3.4e^{-4}$	0.9535	0.3269		
Parity 4							
Wood	$6.82\pm1.4e^{-1}$	$0.0265\pm5.0e^{-3}$	$0.00029\pm4.4e^{-4}$	0.3781	0.4234	5.281	5
Wilmink	$6.90\pm1.2e^{-1}$	$0.0389\pm3.9e^{-3}$	$0.00252\pm3.5e^{-4}$	0.7777	0.3299		
Dijkistra	$7.30\pm2.6e^{-1}$	$0.0421\pm1.1e^{-2}$	$0.00021\pm3.9e^{-4}$	0.5506	0.3698		

a=Initial milk yield, b=Ascending parameter before peak yield, c= Descending parameter after peak yield, PW=Peak week, RMSE=Root mean square error

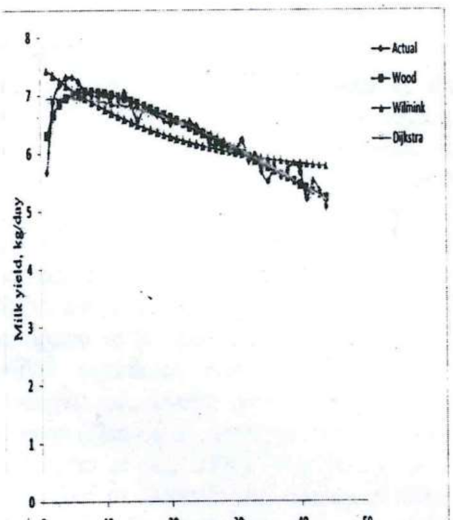

Figure 1 represent parity 1 average actual and predicted (by Wood, Wilmink and Dijkstra Models) non mastitic cow's milk yield of Friesian x Bunaji cows for forty four weeks milk yield (representing 305 days in milk "DIM").

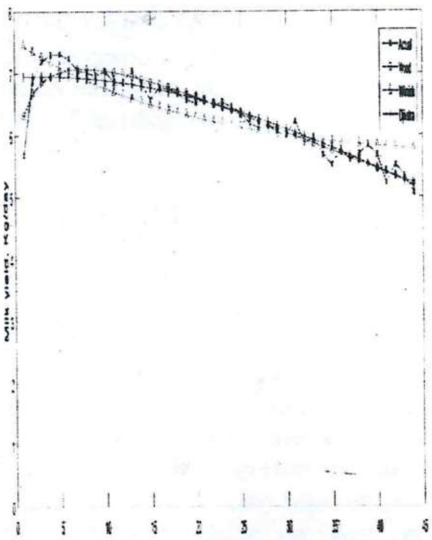

Figure 2 represent parity 1 average actual and predicted (by Wood, Wilmink and Dijkstra Models) mastitic cow's milk yield of Friesian x Bunaji cows for forty four weeks milk yield (representing 305 days in milk "DIM").

Table 2: Mastitic cows parameters (a, b and c) and goodness of fit criteria estimates for Wood, Wilmink and Dijkstra models.

Functions	a	b	c	R^2_{Adj}	RMSE	Persistency	PW
Parity 1							
Wood	$6.10{\pm}7.2e^{-3}$	$0.00088{\pm}2.0e^{-4}$	$0.00022{\pm}2.0e^{-5}$	0.7255	0.0207	4.357	6
Wilmink	$5.83{\pm}2.2e^{-3}$	$0.0032{\pm}9.0e^{-5}$	$0.00083{\pm}3.2e^{-6}$	0.9994	0.0031		
Dijikistra	$6.06{\pm}1.5e^{-5}$	$0.0006{\pm}6.6e^{-7}$	$0.00012{\pm}2.3e^{-8}$	0.9999	0.00002		
Parity 2							
Wood	$7.52{\pm}3.4e^{-2}$	$0.0789{\pm}1.1e^{-3}$	$0.00029{\pm}1.0e^{-4}$	0.9907	0.0979	4.206	8
Wilmink	$6.87{\pm}4.7e^{-3}$	$0.0643{\pm}2.0e^{-4}$	$0.0018{\pm}6.9e^{-6}$	0.9999	0.0066		
Dijkistra	$7.35{\pm}1.4e^{-3}$	$0.0768{\pm}4.6e^{-5}$	$0.00052{\pm}4.1e^{-6}$	0.9999	0.0039		
Parity 3							
Wood	$9.06{\pm}7.9e^{-2}$	$0.1152{\pm}2.7e^{-3}$	$0.00075{\pm}2.4e^{-4}$	0.9776	0.2245	4.075	4
Wilmink	$8.28{\pm}2.4e^{-2}$	$0.1040{\pm}8.2e^{-4}$	$0.00251{\pm}7.2e^{-5}$	0.9975	0.0690		
Dijikistra	$9.06{\pm}1.6e^{-3}$	$0.1172{\pm}6.8e^{-5}$	$0.00048{\pm}2.4e^{-6}$	0.9999	0.0023		
Parity 4							
Wood	$8.27{\pm}2.9e^{-2}$	$0.1141{\pm}9.8e^{-4}$	$0.00045{\pm}8.7e^{-5}$	0.9968	0.0828	3.898	6
Wilmink	$7.56{\pm}3.4e^{-3}$	$0.0980{\pm}1.4e^{-4}$	$0.00266{\pm}5.1e^{-6}$	0.9999	0.0048		
Dijkistra	$8.07{\pm}4.5e^{-4}$	$0.1094{\pm}1.9e^{-4}$	$0.0011{\pm}6.7e^{-7}$	1	0.0006		

a=Initial milk yield, b=Ascending parameter before peak yield, c= Descending parameter after peak yield, PW=Peak week, RMSE=Root mean square error