Lactation curves and persistency of White Fulani and Sokoto Gudali lactating cows

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Abstract

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The aim of this study was to determine the lactation curve traits of White Fulani (WF) and Sokoto Gudali (SG) lactating cows. Wood's gamma and Wilmink's curve parameters were employed to identify the lactation curve types and values for the parameters beginning yield (a), coefficient of rising (b), coefficient of decreasing (c) t = time and e = is the exponential. The k parameter assumed a fixed value derived from a preliminary analysis and is associated with the time at peak yield were used to determine the shape and type of lactation curve. All parameters in a typical lactation curves were positive, and in the event of one parameter being negative, the curve was considered to be an atypical lactation curve. Lactation records from WF ($n = 96$) and SG ($n = 130$) cows were recorded in the study area between year 2016 - 2017. Cows were hand-milked twice per day in the morning and evening from the 5th day post partum till the end of the lactation period (260-270days). Prediction equation of milk yield showed R^2 values ranging from (32.00) in the SG to (35.00) in the WF. It was observed that the Wood's model curves were typical while Wilmink's model curves were atypical respectively. For typical lactation curves, a , b , c , persistency (S), time after parturition until the peak yield occurs (T_{max}), maximum daily peak yield (Y_{max}), and coefficient of determination (R^2) were - 0.25 ± 0.13 , 1.08 ± 0.07 , 0.23 ± 0.19 , 2.34, 51.00, 2.62 and 97 for WF lactating cows and - 0.23 ± 0.14 , 1.13 ± 0.08 , 0.07 ± 0.03 , 2.33, 51.26, 2.58 and 96 for SG Lactating cows respectively. Parameters predicted by the Wood's model have the potential of being useful for breeding programmes in the SG and WF cows.

Keywords: White Fulani, Sokoto Gudali, Lactation curve, Persistency, Mathematical model.

Introduction

In Nigeria, cattle provides more than 90% of the total annual domestic milk output (Walshe *et al.*, 1991) with the White Fulani or *Bunaji* breed recognized as the principal producer (Adeneye, 1989). The domestic output of about 407,000 metric tonnes of milk (Olaloku, 1999) from an estimated 14 million cattle (RIM, 1992) can hardly satisfy the dairy demands of the ever increasing population of Nigerians (Ibeawuchi *et al.*, 2000). Despite their contribution to the Nigerian economy, these cattle have not been well-defined as most of the breeds are classified as dual purpose. Milk production is one of the main sources

of income for dairy farmers. Thus records of milk yield are of significant importance for dairy herds (Adedibu *et al.*, 2013). The proper estimation of average, total and daily milk production, as well as the effective organization of breeding plans and management systems for dairy herds based on these estimates, depends both on the efficiency of the system used for recording milk production levels and the accuracy of methods for calculating the milk yield of herds. The term, *Lactation curve* refers to a graph illustrating the relationship between milk yield and the period of time after calving (Wood, 1967). In other words, these graphical representations, which

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demonstrate the relationship between milk yield and lactation period, are assumed to indicate the total milk yield of a single lactation. The careful analysis of lactation curve shapes is important, as they might highlight feeding and management-related problems in a dairy herd (Epaphras *et al.*, 2004). Lactation persistence can be defined as the ability of the cow to maintain milk yield (milk, fat, and protein) after achieving the maximum milk production (Wood, 1967). This trait is directly related to the economics of milk yield as it may allow reduction of milk production costs by decreasing both feeding costs and those costs related to health and reproduction of the cows (Tekerli *et al.*, 2000).

Milk yield and persistency are the only variables of the lactation curves that can be influenced by a variety of factors, although the general shape of the curve remains mostly unchanged (Alphonsus *et al.*, 2011). A number of different empirical models have been developed over three decades to obtain more accurate prediction to explain the shape of lactation curves (Wood, 1976; Gipson and Grossman, 1989). Among these, are the use of analytical time functions which allows partition of the variability of daily milk yield into a regular and continuous component, and a stochastic component (Gipson and Grossman, 1989). Knowledge regarding the shape of lactation curves enables the prediction of total lactation milk yield based on data from a single test day (Wood, 1976) or several test days at the beginning of the lactation period. (Wood, 1967) proposed different mathematical models to obtain more accurate prediction of the shape of the lactation curve and incomplete gamma function to model the lactation curve of milk. A mathematical model to describe lactation curves and persistency should describe and fit all types of curves

especially typical curves which contain parameters that are easy to estimate for every animal with sufficient number of measurements, as well as allow a persistency measure that can be computed for all lactations (Gengler, 1996).

This study intends to determine the lactation curve characteristics of White Fulani and Sokoto Gudali lactating cows by using the Wood' and Wilmink's model.

Materials and methods

Study area

The study was conducted at Guga, Giwa Local Government area of Kaduna State, located within the Northern Guinea Savannah zone of Nigeria. Giwa lies on latitude 11°11' North and longitude 7°38' East at an altitude of 686m above sea level. The coordinates were obtained using the Ovimaps®. The climate is relatively dry, with a mean annual rainfall of 700-1400mm occurring between the months of April-September. The dry Season begins around the middle October with dry cold weather that ends in February. This is followed by relatively hot-dry weather from March to April when rain begins. The minimum and daily temperatures range from 14°C to 24°C during the cool season and from 19°C to 36°C during the hot season. The relative humidity varies between 19 and 35% in dry season and 63 and 80% in wet season (IAR, 2013).

Experimental animals

The animals used for this study were those reared by indigenous small-holder cattle herds in Giwa Local Government Area. The indigenous cattle breeds used were *Bunaji* (White Fulani) and *Sokoto Gudali* (Bokoloji).

Management system

The animals were managed extensively under agro pastoral system of management. The system is mostly traditional with an unrestricted free-range grazing under the

supervision of the herdsmen. The animals are fed during the rainy season on natural pastures and crop residues especially during the dry season with little or no supplementary feeding (Adegbola, 2002).

Data collection

Lactation records from White Fulani (n=96) and Sokoto Gudali (n=130) cows were recorded in the study area between the year 2016 - 2017. Cows were hand-milked twice per day in the morning and evening from the 5th day post-partum till the end of the lactation period which was between (260-270days).

The data was obtained from both breeds of cows in their first, second, third and fourth parity. All cows were milked twice a day.

Daily milk yield

Cows were hand milked twice daily and milk quantity was measured using a measuring cylinder graduated (1000mL) capacity and recorded.

Milk yield characteristics

Initial yield (kg): This was measured as milk yield on the 7th day postpartum

Peak yield (kg): This was measured as optimal test day yield during the lactation period

Peak day (d): This was measured as a day of the highest milk yield within lactation period

Statistical analysis

Data was analysed using Analysis of variance procedure of SAS (2002) and R (2016):

$$Y_{ij} = \mu + \alpha_i + e_{ij}$$

Where, Y_{ij} = response or dependent variables (milk yield, udder and body conformation traits);

μ = overall mean;

α_i = effect of i^{th} factors (breed)

e_{ij} = random error.

The significant means were compared

using Tukey's procedure

Lactation curve analysis

Two mathematical functions were used to fit the lactation curves:

Wood's gamma model (Wood, 1967):

$$Y = at^b e^{-ct}$$

Where: Y = milk yield at time t;

a = general scaling factor representing initial milk yield,

b = is the rate of increase to peak production,

c = is the rate of decline after peak production, and e = is the exponential.

Exponential Wilmink (Wilmink, 1987):

$$Y = a + be^{kt+ct}$$

Where a, b, and c are associated parameters with production level (a); milk production increased previous to peak (b); and decrease after peak (c) daily lactation, t = time and e = is the exponential.

The k parameter assumes a fixed value derived from a preliminary analysis and is associated with the time at peak yield (Wilmink, 1987).

Total yield was estimated using the following model, $y = a(b+1)/c^{b+1}$.

Where y = estimated milk yield,

a = variation in yield,

b = parameter less than unity, implying that (b+1) is close to unity and

c = decrease after peak daily lactation.

Persistency, S was evaluated using the following model = $c^{-(b+1)}$

b = parameter less than unity, implying that (b+1) is close to unity and c = decrease after peak daily lactation.

Calculated Milk yield per day (MYD), peak time (PT), peak yield (PY) and persistency (S), were estimated for each model using the mathematical functions.

Goodness of fit between models

Goodness of fit was determined using the

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following models; (Pollott and Gootwine2000).

1. The adjusted coefficient of determination (R^2_A) to the number of parameters on each model was estimated as goodness of fit according to formula Wasike *et al.* (2011):

$$R^2_A = 1 - (n-1/n-k) \times (1-R^2)$$

Where:

R^2_A = Adjusted coefficients of determination

N = No. of records

K = No. of predictors or independent variables

R^2 = Coefficient of determination

2. The residuals mean squares of prediction (RMSE) was calculated individually for each lactation and then averaged for each of the models using the following equation:

$$RMSE = \sqrt{\frac{RSS}{n-p-1}}$$

Where: RSS = residual (difference between absolute values of observed milk production and estimated), n = number of observations and p = number of parameters from each model.

3. The Akaike's information criteria (AIC).

This was calculated using the following

equation (Burnham and Anderson, 2002).

$$AIC = n \times \ln(RSS) + 2p$$

Where; n= number of observation

RSS= residual sum of square; P= number of prediction

4. Bayesian Information Criterion (BIC)

The Bayesian Information Criterion (BIC) proposed by Schwarz (1978) has the same form of the AIC with the exception that the log-likelihood is penalized by log n instead of 2, where n is the sample size. The BIC criterion selects the model that minimizes:

$$BIC(\cdot) = -2L + \log(n) \times p = n \times \log(RSS(\cdot)/n) + \log(n) \times p$$

Where: L = maximum log-likelihood, (RSS (·)) for particular value of and p is the model complexity in a linear model correspond to the number of predictors).

Results and discussion

Estimation of curve parameters in the White Fulani and Sokoto Gudali cows

The SokotoGudali cows shows that estimated lactation curve parameters of Sokoto Gudali cows using Woods model were -0.23, 1.13 and 0.07 which are, a; production level, b; milk production before lactation, c; peak day respectively with coefficient of determination of $R^2 = 96\%$ (Table 1).

Table 1: The parameters and goodness of fit measurements for predicted lactation curve models of Sokoto Gudali lactating cows

Model	Wood	Wilmink
a± s-a	-0.23±0.14	-0.18±0.03
b± s-b	1.13±0.08	1.15±0.17
c± s-c	0.07±0.03	0.01±0.001
K	0.00	0.50
Adj R ²	0.96	0.87
RSD	0.14	0.27
S	2.33	2.35
Peak yield (kg/day)	2.58	2.48
Peak time (day)	51.26	51.24

a =intercept, b =inclining slope, c= declining slope, k = constant, s= persistency, Adj R² = Adjusted coefficient of determination, RSD= Residual standard deviations and kg =kilogram

In Figure 1, estimated lactation peak yield (PY) were 2.58 kg at Peak Time (PT) day (51.26 day) of lactation period with persistency of 2.58% for Wood models. In Wilmink model, the curve parameters were -0.18, 1.15, 0.01 and 0.50 for a; production

level, b; milk production before lactation, c; peak day and k; peak day of peak milk yield respectively with coefficient of determination of $R^2 = 87\%$. Estimated PY was 2.48 kg at PT day (51.24 day) of lactation period with persistency of 2.48% for Wood's model.

Figure 1: Lactation curve for Sokoto Gudali cows

The estimated lactation curve parameters of White Fulani cows were -0.25, 1.08 and 0.23 which are, a; production level, b; milk

production before lactation, c; peak day respectively with coefficient of determination of $R^2 = 97\%$ (Table 2).

Table 2: The parameters and goodness of fit measurements for predicted lactation curve models of White Fulani Lactating cows

Model	Wood	Wilmink
a± s-a	-0.25±0.13	-0.16±0.03
b± s-b	1.08±0.07	1.05±0.07
c± s-c	0.23±0.19	0.10±0.09
K	0.00	0.50
Adj R2	0.97	0.96
RSD	0.11	0.12
S	2.34	2.36
Peak yield (kg/day)	2.62	2.50
Peak time (day)	51.00	51.02

a =intercept, b =inclining slope, c= declining slope, k =constant, s= persistency, Adj R² = Adjusted coefficient of determination, RSD= Residual standard deviations and kg =kilogram

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Estimated lactation PY was 2.62 kg at PT(51.00 day) of lactation period with persistency of 2.34% for Wood models. In Wilmink model, the curve parameters were -0.16, 1.05, 0.10 and 0.50 for a; production level, b; milk production before lactation,

c; peak day and k; peak day of peak milk yield respectively with coefficient of determination of $R^2 = 96\%$. Estimated lactation PY was 2.50 kg at PT day (51.02 day) of lactation period with persistency of 2.36% for Wood's model (Figure 2).

Figure 2: Lactation curves for White Fulani cows

Estimation of curve characteristics for milk yield

The lactation curve of both WF and SG were steeper with a low persistency which indicated that they produce less milk in relation to the quantity of feed consumed (Macciotta *et al.*, 2005). This is because a cow with a flat lactation curve that can be described as persistent and can make better use of less quantities of forage as well as less stress due to an elevated lactation peak (Dekkers *et al.*, 1998). The WF and SG could also be more susceptible to metabolic and reproductive disorders (Dekkers *et al.*, 1998) because of the lactation curves in this study. This could be linked to the fact that this population of WF and SG had not been genetically selected as dairy breed. Lactation curves and persistency are highly influenced by genetic makeup of dairy

cows as reported by several authors (Ponce and Bell, 1986; Ossa *et al.* (1997; Tekerli *et al.* (2000); Val-Arreola *et al.* (2004); Macciotta *et al.* (2005); Lemus-Ramírez *et al.* (2008).

The coefficients of determination R^2 indicated that the independent variables (production level, milk production before lactation, peak day) accounted for 97 percent of the total milk yield of the SG which is an indication of the model's fit to the structure of the available data (Akinsola, 2017). A large coefficient of determination indicates the ability of the independent variable and the model to describe the dependent variable. In this study, the mean coefficients of determination values were in agreement with the value of 99.1% reported by Kumar *et al.* (1992).

Such values allow for observing the dispersion and range of points (data from

milk production) with individual records around the average lactation curve for each model (Cruz *et al.*, 2009). This lends credence to the assertion by some authors why Wood model is flexible under high and low production systems (Wood, 1967; Akpa *et al.*, 2007). Both models were free of convergence problems as indicated by Sahin *et al.* (2014) in Anatolian Buffalo. Regarding the features of the different equations in this study, all equations showed systematic deviation from actual milk yield in accordance with Gipson and Grossman (1989) and Vargas *et al.* (2000), especially at the beginning of lactation and peak yield. So, these results showed that Wilmink model had some disadvantages such as standardization of production level in predicting lactation curve features and under the conditions of the present study. The tested growth functions showed Wood model is a potential candidate for the lactation equation.

Conclusions

The Wood model was more efficient than the Wilmink model in predicting the trajectory of milk yield in White Fulani and Sokoto Gudali cattle. The Wood model would be a more suitable tool in dairy breeding program targeted towards genetic improvement for milk yield in these two breeds.

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