
Short Communication

Lactation curves in West African Dwarf and Red Sokoto goats

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Abstract

Four mathematical functions (incomplete gamma, non linear regression, mixed log, and polynomial regression) were fitted to 202 weekly lactations of 8 West African Dwarf and 9 Red Sokoto goats to ascertain the accuracy of prediction of individual's milk production. The accuracy was assessed by the magnitude of R^2 and the proportion of individual lactations well predicted. All the functions tested generally gave good fit to the observed data with slight tendency to consistently underestimate daily milk yield. The pooled R^2 estimates for all models, exceeded 70%. Both breeds showed similar peak yields ($P > 0.05$) averaging 420.65 ml during first week of lactation. The proportion of individual lactations accurately predicted most of the models (incomplete gamma, mixed log and polynomial regression) were moderate (66.67%) for Red Sokoto breed to high (87.5%) for West African Dwarf breed. R^2 values generated from the fit of non-linear regression model however showed significant ($P < 0.05$) breed difference with indication that more West African Dwarf goats (87.5%) had better fit ($R^2 = 0.863$) than Red Sokoto goats (44.44%) with R^2 estimated at 0.693. The apparently reasonable trends in goodness of fit shown by the models, despite the limitation in number of records, points to the fact that predictive equations could be developed with increase in data size to predict future yields from incomplete lactation records.

Keywords: Lactation curves, goat

Introduction

Mathematical models have been used to predict total milk yield of goat (Ehoche and Buvanendran, 1983; Review by Gipson and Grossman, 1990) and dairy cows as reviewed by

Sudarwati *et al.* (1995) and Olori *et al.* (1999). The information has been utilized in breeding and selection programmes to improve both milk yield and fat content (Gipson and Grossman, 1990; Carta *et al.*, 1995), provide information for implementation of optimum management and

feeding strategies for dams and their offsprings, leading to more efficient feeding trials (Ehoche and Buvanendran, 1983; Sudarwati *et al.*, 1995; Cardellino and Benson, 2002) and to identify sick animals that need special attention, such as those with decreased milk production from sub-clinical mastitis. Standard models have been developed to describe the variation in milk yield during the course of lactation (Wood, 1967; Yadav *et al.*, 1977; Cobby and Le Du, 1978; Ali and Schaeffer, 1987; Wilmink, 1987; Sudarwati *et al.*, 1995) with more emphasis on cattle than other livestock species. Daily milk yield rises to the peak within the first 2 weeks in Red Sokoto goats (Ehoche and Buvanendran, 1983; James, 2000), and within 3 weeks in West African Dwarf (James, 2000) while Bemji *et al.* (2007) recorded peak yields for both breeds during the first week of lactation. Several models fitted by Olori *et al.* (1999) predicted the pattern of mean herd lactation well, with little difference in fit. Wahome *et al.* (1994) noted that the lactation curve in goats is similar to that of cows, having an initial rise to a peak followed by a gradual decline in yield to a drying off. The Wood's function was however found to be most suitable for Red Sokoto goat (Ehoche and Buvanendran, 1983) in which the equation explained nearly 98% of the variation in milk yield. The shape of the lactation curve in goats has been shown to vary between breeds and between individuals within breed (Devendra and Burns, 1983). This study investigates the fit of 4 different lactation curve models to individual weekly lactations in order to establish the proportion of animals for which the models give appreciable fit.

Materials and Methods

Two hundred and two weekly estimates of daily milk yield were obtained from a total of 17 lactating does (8 West African Dwarf and 9 Red Sokoto) intensively managed by the College of Animal Science and Livestock Production Farm of University of Agriculture, Abeokuta situated within the sub-humid zone of South-western Nigeria. Goats were hand-milked on weekly basis for 12 weeks during which kids are weaned from their dams. Details on management of the flock and hand-milking procedure as well as data collection have been reported (Bemji *et al.*, 2007). The data were subjected to least squares analysis of variance with a linear model which included breed as a fixed effect factor with 2 levels, week of lactation with 12 levels, parity of doe with 3 levels and litter size with 2 levels. Least squares estimates for lactation week were obtained and used as the standard curve to which 4 empirical models of lactation curve were fitted (Table 1). Three records of does with incomplete lactations due to loss of kids were excluded from the analysis.

For all models, Y_t is the daily milk yield (ml) in lactation week, t and a , b , c , d and e are parameters. Each model was fitted in turn to weekly records of individual does using Systat program, release 5.02 (Systat, 1992), following which parameter estimates were pooled. Evaluation of the models was based on corrected coefficient of determination (R^2) which equals the percentage of the variance of daily yields explained by the model.

Table 1. Functions used to model the lactation curve

Description of model	Model	Author
Incomplete gamma (IG)	$Y_t = a t^b \text{Exp}^{-ct}$	Wood (1967)
Non-linear regression (NR)	$Y_t = a - bt - a \text{Exp}^{-ct}$	Sudarwati <i>et al.</i> (1995)
Mixed log (ML)	$Y_t = a - bt^{0.5} + c \log t$	Review by Olori <i>et al.</i> (1999)
Polynomial regression (PR)	$Y_t = a + bt + ct^2 + d \log t + e(\log t)^2$	Ali and Schaefer (1987)

Results

Estimated parameters for the 4 functions used in describing variation in daily milk yield of West African Dwarf and Red Sokoto goats are presented in Table 2. Observed mean daily milk yields for both breeds were similar ($P > 0.05$), peaking at 420.65 ml during the first week of lactation and gradually declining to about 168.87 ml by the 12th week of lactation (Fig. 1) when kids are weaned from their dams. The predictions of both time (week of lactation) and peak yield using pooled curve parameters were close to the observed data (Fig. 1). Mean daily milk yield was adequately predicted by all models ($R^2 > 0.700$) with slight tendency to consistently underestimate yields. The actual and predicted

lactation curves did not present a typical first phase (ascending).

The proportion of individual lactations accurately predicted by the incomplete gamma, mixed log and polynomial regression models were moderate (66.67%) for Red Sokoto breed to high (87.5%) for West African Dwarf goats. R^2 values generated from the fit of non-linear regression model however showed significant ($P < 0.05$) breed difference with indication that more West African Dwarf goats (87.5%) had better fit ($R^2 = 0.863$) than Red Sokoto goats (44.44%) with R^2 estimated at 0.693. The range in goodness of fit of the models to individual lactations was generally moderate ($R^2 = 0.428$ to 0.995), with only one individual (Red Sokoto) having the least R^2 estimate from the non-linear regression model. While most parameter estimates from other functions were not affected by breed, parity and litter size, the effect of breed on some parameter estimates generated from polynomial regression function was significant ($P < 0.05$).

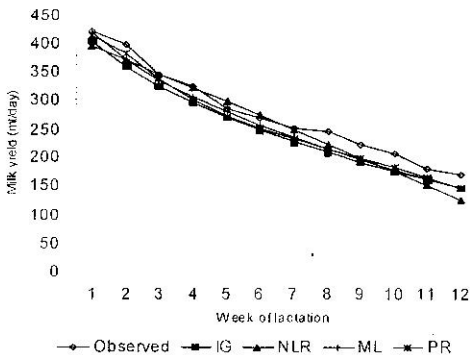


Fig. 1. Observed and predicted values of mean milk yield for each model

Discussion

It is evident from this study that all the models gave good fit to the observed data with pooled R^2 estimates exceeding 70%. The five-parameter curve gave slightly better fit than the three

Table 2. Estimates of parameters and coefficients of determination (R^2) for functions used to model the lactation curves

Model	Breed	Parameters					R^2	% with $R^2 \geq 0.700$
		a	B	c	d	e		
IG	WAD	496.753	0.124	0.156			0.904	87.50
	RS	434.555	-0.120	0.074			0.812	66.67
	Pooled	436.100	-0.051	0.080			0.851	82.35
NR	WAD	437.060	26.981	219.347			0.863 ^a	87.50
	RS	400.262	22.511	19.006			0.693 ^b	44.44
	Pooled	419.109	24.419	112.515			0.771	70.59
ML	WAD	579.247	-143.219	18.725			0.895	87.50
	RS	464.557	-60.006	-40.859			0.812	66.67
	Pooled	521.056	-103.701	-6.224			0.846	82.35
PR	WAD	448.376 ^a	-26.459 ^d	1.697 ^a	41.794 ^a	-53.531	0.937	87.50
	RS	98.504 ^b	313.920 ^a	-8.642 ^b	-275.522 ^b	-291.776	0.865	88.89
	Pooled	270.589	144.267	-3.547	-116.881	-170.975	0.892	91.11

a, b, c, d and e are curve parameters; WAD = West African Dwarf; RS = Red Sokoto

Estimates within the same column having different superscripts differ significantly ($P < 0.05$)

IG = Incomplete gamma, NR = Non linear regression, ML = mixed log, PR = Polynomial regression

parameter curves. Olori *et al.* (1999) reported that the goodness of fit of each model to each lactation is classified as 'good' if $R^2 \geq 70\%$, 'fair' if $70\% > R^2 \geq 40\%$ and 'poor' if $R^2 < 40\%$. The level of accuracy obtained with incomplete gamma was equally high ($R^2 = 81.2\%$) for Red Sokoto goat, even though lower than 98% earlier reported by Echoche and Buvanendran (1983), the disparity being mainly attributed to differences in data size. This preliminary investigation is providing evidence that other models besides incomplete gamma could explain the variation in milk yield of the Red Sokoto as well as West African Dwarf goat which is being investigated for the first time. That actual and predicted lactation curves did not present a typical first phase (ascending) could be attributed to about 59% of the lactating does that peaked during the

first week of lactation, while 41% had peak yields occurring during the second week of lactation. This was equally distributed between the breeds. The non-significant effect of breed on parameter estimates was expected since the breeds under study are low-yielding and had similar yields.

The range in goodness of fit of the models to individual lactations was narrow; Observed variations were mainly attributed to differences between individual goats rather than between models. About 33.33% of Red Sokoto lactations were less accurately predicted ($R^2 < 70\%$) across three of the models with the exception of polynomial regression function. Olori *et al.* (1999), working with Holstein-Friesian cows, suggested that the suitability of empirical models of lactation curve does not depend on the

mathematical form of the lactation function alone but rather more on the biological nature of the lactation itself which varies randomly between individuals.

Conclusion

All four models gave good fit to the lactations of the flock. On individual basis, only the non-linear regression model did not fit lactations of Red Sokoto breed adequately. The apparently reasonable trends in goodness of fit shown by the models, despite the limitation in number of records, point to the fact that predictive equations could be developed with increase in data size to predict future yields from incomplete lactation records.

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