EVALUATION OF MODELS FOR LACTATION CURVES FOR BUNAJI, FRIESIAN AND FRIESIAN-BUNAJI CROSSBRED COWS IN NIGERIA

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CERTIFICATION

This thesis entitled "EVALUATION OF MODELS FOR LACTATION CURVES FOR BUNAJI, FRIESIAN AND FRIESIAN-BUNAJI CROSSBRED COWS IN NIGERIA" by STEVE AJAYI SHADE OLORUNJU, meets the regulations governing the degree of DOCTOR OF PHILOSOPHY of Ahmadu Bello University, Zaria, and is approved for its contribution to scientific knowledge and literary presentation.

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DECLARATION

I hereby declare that this thesis has been written by me and that it is a record of my own research work. It has not been presented in any previous application for higher degree.

All quotations are indicated and the sources of information are specifically acknowledged by means of reference.

30/12/91

S. A. S. OLORUNJU

DEDICATION

This thesis is dedicated to the families of OLORUNJUS and LUKELES for without a happy marriage, success cannot be achieved easily in life.

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ABSTRACT

This study investigated the suitability of the available models in representing **the** pattern of **milk** production of Bunaji, Friesian and Friesian-Bunaji **crossbred cows in Nigeria. The models evaluated were Gamma, Modified Gamma and** the Inverse Polynomial functions.

Five hundred and eighty-four lactations were used. These comprised of 205, 111 and 268 records from Bunaji, Friesian and Friesian-Bunaji crossbreds. The lactation records covered **a** period of 18 years and the records were from cows in the first five parities. Each lactation was fitted to each of the models. The curve and production indicators namely initial week average daily production **(initprd),** peak week **(pwk),** peak production **(Mxprod)**, persistency (s) **and** total production per lactation **(Tprod)** were obtained for each model. These parameters were subjected to least squares analysis considering parity, lactation length, season and year of calving as factors. A combined analysis was also undertaken for the breeds incorporated as additional factor to evaluate the effects of the curve and production parameters.

Multiplicative factors were developed for estimating 44 week (305-day) production for each breed.

Results showed the average lactation lengths for Bunaji, Friesian and Friesian-Bunaji crossbreds were 32, 50 and 36 **weeks, respectively. The average milk production per**

lactation varied between 928-1010 kg for Bunaji, 3800-4300 kg for Friesians and 1860-2000 kg for Friesian-Bunaji crossbreds. The average initial week daily productions were 4.69, 8.39 and 8.69 kg while the corresponding peak productions were 6.4, 18.9 and 11.4 kg, respectively.

The observation showed that Gamma function was the most suitable when compared to other functions. The function had the least deviations comparing the observed with the estimated for each breed. Also, the function estimated the production parameters with a higher precision compared to others. The Co-efficient of determination (R^2) was highest under the Gamma function. The values were 84% for Bunaji, 74% for Friesian-Bunaji and 68% for Friesian cows. The values obtained using the Inverse polynomial functions were 70% for Bunaji, 61% for Friesian-Bunaji and 52% for Friesians. Values under the Modified Gamma function were relatively closer to those of Gamma function. Multiplicative factors obtained using the Gamma function were found to be more precise than those based on the other two functions.

Bunaji and Friesian-Bunaji crossbred cows had significantly ($P<0.05$) higher persistency than the Friesian cows. This is due to the higher adaptability to the environment by the two relatively more indegenous breeds.

Some factors were found to have effects on the production pattern of the cattle in Nigeria. These included breed, parity, lactation length,season and year of calving of the cows. Furthermore, all the factors enumerated above had

effects on the persistency of milk production.

Prom this study, the phenotypic correlation between the curve and the production parameters showed that the initial week average daily production and the peak production correlated very highly ($P<0.001$) with the total production. This therefore could be a useful and readily available tool to be used in culling low milk producing animal from the herd.

Finally, as a result of the relatively short lactation length observed in Bunaji and Friesian-Bunaji crossbred cows, it is possible and practicable to embark on early re-breeding of these breeds of cattle to boost the milk production as well as increasing the herd size provided there is a corresponding improvement in the management.

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CHAPTER 1

INTRODUCTION

The study of milk production and the pattern of production has been of great interest to many people particularly the animal production specialists or scientist as well as dairy farmers. Several efforts have been made towards studying production pattern in ruminants especially cows and this entailed representing the pattern of milk production using some mathematical formulae (Brody et al (1923), Wood (1967) and Yadav et al (1977))

Models can be defined in different ways. To the Mathematician, a model is defined as simply the representation of some phenomenon using mathematical equations. The factors in the phenomenon or process are represented in the equations. A model could also be defined as a formular that can be used in obtaining the value of some quantity given that some known values are to be used in the calculation. For example, given the age and the weight of an animal from birth to puberty taken at monthly intervals, one might want to estimate the relationship between the weight and the age. Such a mathematical representation of the relationship between the weight of an animal and the age will be regarded as a model. Furthermore, a Scientist or a farmer may want to know the change in the amount of milk produced by a cow as the days in milk increased. A mathematical way of representing such a relationship is generally referred to as modelling.

The rate of milk production of a cow has been observed to follow some pattern. For instance, Sturtevant (1886) observed that the fall in milk yield with time decreased from month to month. Generally, once a cow's milk yield starts, it quickly attains an optimum and then diminishes gradually as the lactation progresses. The pattern of milk flow is also unique to each cow. In other words no two cows have the same pattern of milk production in their lactation. There is usually some element of individuality in the production pattern as well as between parity. Because of this individual differences observed in the pattern of production, efforts have been made to obtain a mathematical expression that can be used to express the relationship of milk production with time for different situations that the cows may be subjected to, for example changes in management. This mathematical expression has been found to be a valuable tool in both nutritional, breeding as well as physiological studies. For example, it has been possible to compare the pattern of production before the application of a given treatment with the pattern of production after the application of same treatment. Under such experiment, the animal becomes its own control implying that any difference noticed in the pattern of production can comfortably be attributed to the effect of the treatments imposed on the animal.

Models can also be used to predict the production for partial or entire lactations. The principal uses of extended

records are to rank all cows in a herd on the estimated producing ability by placing all lactations on a common basis of 305-day production. They are useful in the evaluation of sires by all daughters that started a lactation.This helps to quicken the genetic evaluation of the breeding animals. Generally, extended incomplete records can be used to project what a cow will produce in a lactation while that lactation is still in progress. Early information would facilitate selection prior to the completion of a lactation. Presently, selection of a bull on the performance of his offspring is delayed until several of his daughters have completed at least one lactation. Projections of records still in progress could reduce the time needed to prove a sire. Examples of use of part lactations for development of multiplication factors to estimate full lactation yield includes the works of Madden (1955), Wood (1969, 1974), Kellog et al (1977), Schaeffer et al (1977), Keown and Van Vleck (1973) and Abubakar and Buvanendran (1981).

Wood (1968) successfully used the curve parameters to compare the sire-daughter groups for persistency. The use of lactation models for extension in dairy management has become of great value in well established dairy industries. For example, the Milk Marketing Board of Great Britain used a modified version of Wood (1969) method of extension. Their technique used a curve resulting from predetermined parameter estimates to compute the total production for the cows after correcting for seasonality of production. Furthermore, Wood

(1974) suggested a technique using the Gamma curve to estimate total production from a single days yield after obtaining some predetermined parameters for the function. The parameters from the model, have been found to have some biological interpretations. Wood (1969) gave the full interpretation of how the persistency is calculated from the curve parameter, evaluation of peak production and the week at which the peak is attained. He explained that, the first parameter "a" measured the general level of production whereas the other parameters of the Gamma function measure the rate of rise to the peak b, and rate of decline from the peak c of the curve.

PURPOSE OF STUDY

The objectives of this study are:

i. The evaluation of the available models using the milk production records for the indigenous breeds of cattle (Bunaji), exotic breed (Friesian) and the Friesian-Bunaji crosses in order to assess the suitability of the models on daily milk yield and other productivity parameters such as; initial week average daily production, peak week which is an indicator of peak production and peak production.

ii. Estimate total milk yield from part records (early lactation) by development of factors for each breed.

iii. Determine the most suitable model that can be used for the indigenous cattle for milk production prediction

using one day's yield taken at weekly, monthly intervals and bi-monthly .

iv. Determine the factors that affect the curve characteristics and production indicator viz, initial week production per day, peak production, total production per lactation for the three categories of cattle.

CHAPTER 2

2.1 *LITERATURE*

The study of the pattern of milk production in cattle is as old as the dairy research itself. Interest and research on the subject was first recorded by Sturtevant(1886). He expressed the falling of the milk yield with time as a percentage decrease from month to month. His work and results became the foundation for more ideas in the study of milk production pattern.

2.11 **Grady (1917) and Mclandish (1924)** used this idea but introduced a modification. They considered the first month production as the standard. They went further to express the succeeding months yield as a percentage difference from the first as the lactation progressed.

2.12 Sanders (1923) however used the ratio of the total lactation yield to maximum daily yield. Correcting for the differences in month of calving, he got what he called "shape figure" and defined it as the pattern of production. This was considered as the first representation of milk production graphically or pictorially. The advantage of this approach was that it made it possible to describe each lactation by a simple mathematical expression which was found to be high if the yield was maintained near the maximum and low when the yield dropped rapidly.

2.13 **Ellinger (1923)** used the ratio between gross production in the second week to that in the first 10 weeks sections of the lactation period.

2.14 **Brody et al. (1923 a,b)** are generally considered as the first to describe the pattern of production mathematically using an exponential equation given by :-

$$M_t = M_o \text{ Exp } [-kt]$$

where M_t is the production during any month t and M_o is considered as the theoretical value of the milk flow at time of parturition. k was defined as persistency. Brody and his colleagues applied this equation to average yield records obtained from several animals and for several breeds to obtain a representation for the herd. This model had several criticism, the first of which was that it did not take into consideration the inclining and declining phases as observed in milk production. This made the biological interpretation of the parameters difficult to explain.

2.15 **Brody et al. (1924)** suggested a modification to their earlier model as a result of the criticisms. The modified model was;

$$Y_t = A \exp [k_1 t] - B \exp [-k_2 t]$$

Where A, B, K_1, K_2 are parameters to be evaluated and y_t is the yield at time t. The modified model now has the inclining as well as the declining phases represented by the parameters k_1 and k_2 respectively while A-B measured the

production at time of parturition. Despite the modification, not much has been done with the model using real data.

2.16 Turner (1926) proposed an exponential model similar to that described by Brody et al (1923, a,b). He described the rate of decline in production as a percentage of the preceeding months in production. Not much was done further using the idea because no model was given.

2.17 Gooch (1934) suggested another exponential model given by: $Y_t = a \exp [bt]$

where Y_t is the milk production at time t, parameter 'a' was considered as the initial production at parturition (theoretical), whereas exp [b] is a rate factor measuring persistency which is a measure of the maintenance of the peak production. The larger the value of b, the higher the persistency. Not many people seemed to have used Gooch's model because of similar criticisms as for Brody's models discussed above.

2.18 Robb (1940) introduced another model which is a modification of Gooch (1934) by the introduction of term that is quadratic in time t to give;

$Y_t = A \exp [Bt + Ct^2]$

Where Y_t is the yield at time t and A is the yield at time of parturition while B and C are parameters indicating the inclining and declining phases of the model. Not much was done with the model until the re-introduction of the model by

Sikka in 1950. The model is referred to as "Parabolic" exponential model. The model too has not been used extensively and perhaps may be because there is no biological interpretation for the parameters to be estimated.

2.19 Vujic and Bacic (1961) proposed another exponential model defined as

$$Y_t = tn^{-a} \exp[-nt]$$

Where y_t is yield at time t and with parameters n and a. n is a function of initial production while a measures rate of change. A major short coming of the model is that at any particular time t, the estimates of n and a are required to be evaluated thus making the evaluation more cumbersome and unreliable and hence made it less attrative than the ealier proposed models.

2.20 **Nelder (1966)** decided to deviate from the exponential families by proposing a useful group of multifactor response functions this time from the polynomial family. The quadratic form of the model has been applied to lactation data. This model is called Inverse polynomial and is defined as;

$$Y_t = t[B_0 + B_1 t + B_2 t^2]^{-1}$$

Where the parameters are B_0, B_1 and B_2 and Y_t is the production in time period t. The parameters B_0 describes the constants for the rising phase, B_1 as the average slope of the curve and B_2 describes the declining extremes. This model

has been used more extensively by researchers than other models. The week of peak production was computed as $[B_0/B_2]^{1/2}$ while the production at that week was estimated as $[2(B_0 B_2)^{1/2} + B_1]^{-1}$.

Singh (1973), Yadav et al. (1977) used the model to compare lactation production of different classes of animals. Yadav et al. used the inverse polynomials to compare the lacation curves of Harianna and its Friesian crosses. They defined Both found that Nelder's inverse polynomial model was superior to Wood(1967) in the R^2 values.

2.21 Wood (1967) proposed a model from the exponential family generally referred to as Gamma distribution. The model is defined as;

$$Y_t = A\ t^B\ Exp\ [-ct]$$

where,

A, B and C are parameters and Y_t is the yield in the t^{th} week. At parturition, the milk production is theoretically A while B and C measure the rate of rise and decline from the peak,respectively. He further proposed that the total yield is represented by

$$Y = AC^{-(B+1)}\ T(b+1)$$

and the yield to week t is given by

$Y_t = A\ S_0^t\ t^B \exp[-ct]\ dt$ which can be evaluated where S is an intergral for t between zero and infinity using the tables of incomplete Gamma function. He also provided biological interpretaion to the parameters. This

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included: the week of peak production which was defined as the ratio of the two parameters given by

t_{peak} = [B/C] while the maximum production at that week was defined as

$$y_{peak} = A\,[B/C]^{B} \exp[-B]$$

From this model he obtained another parameter which he called "persistency" S which he defined as the extent to which the peak is maintained. The parameter is represented by

$$S = -(b+1)\log_e C.$$

For simplicity, the proposed model can be transformed by logarithmic transformation into a form represented by

$$\log_e (Y_t) = \log_e (A) + \log_e (t) - ct$$

The form makes it possible to perform a straight forward multiple regression analysis. The estimates of the parameters were obtained by least squares procedure which is another important feature of the model. Furthermore, Wood (1977) gave details of the model's capability for biological Interpretation. The model has been used with other models to fit lactation curves in different breeds of cattle (Kellog et al, 1977; Cobby and Le Du, 1978; Rao and Sundaresan, 1979; Abubakar and Buvanendran, 1981, Rowlands et al, 1982 and Mechana and Ruiz (1987). Madsen (1975) used the model's computational procedure for measuring persistency so that he could compare with other methods of measuring persistency of milk production. He found that the other methods compared

favourably with that of Wood.

2.22 **Kuck et al. (1976)** proposed another model which was a modification of Wood (1967). The difference is that the new model had taken account of the effect of season on lactation curves.

The new model was defined as,

$$\log_e (Y_t) = \text{Log}_e (A) + B \log_e (t) + ct + D$$

The parameters A,B and C represent same parameters as for 2.21 where $D = U \text{ Sin } (x) + V \text{ Cos } (x)$ and Sin (x) and Cos (x) are trigonometric functions to account for the cylic effects of season. The day of the year expressed in radians is denoted by x. Not many researchers have used the model: The general comment about the model is that there may be no differences between Kuck's and Wood's models.

2.23 **Schaeffer et al. (1977),** proposed another non-linear model which requires the estimation of six parameters.The model is defined as

$$Y_{ij} = A \exp(-b_1(i-t_0))\,[1 - \exp(-B(i-t_0))] / B \exp(E_{ij})$$

The parameters are A, B, b_1, t_0

Where Y_{ij} is the amount of milk given on the i^{th} day of the lactation of the j^{th} cow. A is associated with general production. B is the slope of the lactation curve during the increasing production state. b_1 is the slope during the decline in production after peak, t_0 is a "lag time" parameter and may indicate when a cow's udder begins to

lactate prior to calving. E_{ij} is a residual effect which is defined as exp (ri Sin (ip)) where r represent the amount of periodic effect in a particular set of records. i Sin (ip) is a periodic effect observed in the initial analyses and also by Kuck et al(1976) and corresponded biologically to a seasonal effect in the curve. The p is 2n divided by the length of the period which could differ among lactations groups.

The above model was applied to Holstein and Jersey cows in Canada. The range of the R^2 was observed to be 62-99% for animals with greater than 3 lactations. The conclusion from the study showed that the non-linear model is as good as the Wood's or Kuck's model. The only difficulty in the wide acceptability of the model was that there were two many parameters required for estimation. Furthermore, in an environment where the facilities for computation are lacking, it might be difficult to use. That perhaps might be the explanation why many researchers have not used it.

2.24 Cobby and Le Du (1978) introduced another model defined as;

$$Y_t = A\,(1-Exp(-kt)) - Bt$$

where

Y_t is the yield at time t. The yield at parturition is A (theoretical). They used the model and compared it with two other models which were variants of Wood (1967) model. They argued that Wood's model gave unsatisfactory estimates

of the parameters. They further recommended a weighted least squares estimation of the parameters. Their study showed that their model was as good as Wood (1967). They attempted giving the equivalent curve characteristics to the model. The peak was estimated as:

$t_p = -\log_e (B/Ak)/k$ and the production tended to be a straight line $Y_t = A - Bt$ after peak, giving B kg/week at the rate of decline of milk yield and A/B weeks as the length of the lactation. They also observed that their estimate of peak week was consistently less than that from Wood (1967).

2.25 Dhanoa and Le Du (1982) made a break away from exponential models for a new model which has been an idea suggested earlier by Grady (1917). Grady stated that milk yield at a given stage of lactation is largely determined by the yield in the preceeding stage. The authors built up on the idea to suggest a time series model which was given as

$$Y_t = n (M_0 - M_1 t) + (1-n) Y_{t-1} \quad t \geq 1, \text{ and } 0 \leq n \leq 1$$

where Y_t and Y_{t-1} are the current and preceeding milk yield in kg/week and the constant n estimates the fraction by which the milk yield adjusts to the level at the next stage. The fraction (1-n) by which the yield persists at the preceeding level was used to define the measure of persistency which was given as;

$$P = (1-n) M_0/M_1$$

where M_1 is the rate of decline in kg/week and M_0 is a constant. Dhanoa and Le Du (1982) compared the time series

model with Wood (1967) and Cobby and Le Du (1978) models. They used the model for the representation of milk production and to evaluate the liveweight changes and dry matter intake of lactating cows as Wood (1979). Their result had a very good agreement in the coefficient of determination (R^2).

2.26 **Rowlands et al. (1982)** used a combination of Cobby and Le Du (1978) and other models with the variants of Wood (1969) models. They used the following four models to compare the milk yield of some cows.

(i) $\log_e (Y_t) = \log_e (A) + B \log_e (t) - Ct$ Transformed Wood(1967)

(ii) $Y_t = A\ t^B\ Exp\ (-Ct)$ - Wood(1967) (Untransformed)

(iii) $Y_t = A\ Exp\ [-pt] - A\ Exp\ [-qt]$ variants of Brody *et al.*(1924)

(iv) $Y_t = A - P^1 t - A\ Exp\ (-q^1 t]$ variant of Cobby and Le Du(1978).

In their study, they concluded that the untransformed model (ii) fitted the data slightly better than models (iii) and (iv) while model (i) was worst than either of the other three listed above. Discussing the advantages of each, they stated that models (i), (ii) and (iv) were found to have under-estimated the peak production while (iii) over-estimated and model (ii) provided the best estimate of the peak week. None of the models provided the best overall estimation of the curve characteristics.

2.27 **Badner and Anderson (1985)** used variants of Wood (1967) and Nelder (1966) models. They compared five different models defined below by Marquardt's method of non-linear regression procedures. The models are

$Y_t = a\ t^b\ exp\ (-ct) + e_t$ - **Wood's**

$Y_t = a\ t^b\ exp\ [-t + dt^{0.5}] + e_t$

$Y_t = a\ t^b\ exp\ [\ -ct + 5ct^{0.5}]$

$Y_t = t/[a+bt + ct^2]$ - **Nelder's**

$Y_t = t/[a+bt + ct^2 + dt^3]$

Where a, b, c and d are parameters that have interpretation as for the original models. Model 1-3 are variants of Wood (1967) model while 4 and 5 are variants of Nelder's (1966) model. No significant improvement was observed over Wood's model from their result.

2.28 **Hayashi et al (1986)** proposed the use of Oscillation models in the representation of lactation curves. They stated that milk production can be compared to the pattern of motion of a particle subjected to a transient acceleration. The proposed model was thus defined as;

$Y_t = b\ [exp(-t/c) - exp\ [-t/ac]$

Where Y_t is the milk production at t and the parameters to be estimated are a, b, c where `a' was defined as the initial rising phase,b is the theoretical production at parturition and 'c' rate of decline from peak. They attempted to compute some of the curve characteristics as Wood did. Days to peak is defined as

t_{peak} = -ac $\log_e$ (a)/(1-a) while the production at the peak was given as $b(1-a)a^{a/(1-a)}$

They obtained a range of coefficient of determination (R^2) of 0.68 - 0.96. Their result was said to have compared favourably with other proposed models, Wood's inclusive. Just like in Schaeffer (1977), not much has been done with this model.

2.29 Kasonta (1988) proposed another model which is a variant of previous exponential models, particularly Wood (1969). This model is also from the exponential family. The model was defined as;

$$Y_t = a\ t^b \exp(-ct) + d \exp[-gt] + B$$

where $B = Z \sin((t+m))/k$

Y_t presents the yield of t^{th} week of lactation, a, b, c, d, g, m, k and z are parameters which are required to be estimated. The first term $a\ t^b \exp(-ct)$ in the model is basically Wood (1967) model. The other two terms d exp (-gt) and Z sin ((t+m)/k) have been introduced to give better fit. The observation made on this model can be compared to that made on the Schaeffer et al. (1977) model. The model requires too many parameters to be estimated. Results showed that there was no significant difference between the R^2 value obtained for this model and the values obtained from Woods model.

2.30 **Deluyker et al (1990)** proposed another Time series model for predicting the milk production for Holstein cows. This model used a running average. Here the newly recorded milk production x_t was compared with the forecast value based on the average of the last few days.

$$X_t^{t-1} = 1/p[\ X_{t-1} + \ldots\ldots\ldots\ldots\ldots + X_{t-p}\ ]$$

Where X_t^{t-1} denotes the forecast of X at time t based on the milk yield values X_{t-1}, X_{t-2}..... The running average model is a Stochastic model belonging to the class of autoregressive integrated, moving average (ARIMA) models described by Box and Jenkins (1976). The model was found to be a suitable stochastic model to forcast milk production which provided a useful alternative to classical linear models for analysis of serially correlated data. It is however doubtful if the parameters can be useful in terms of biological interpretation as observed for previous models.

USE OF FACTORS IN ESTIMATING TOTAL LACTATION FROM PART

One of the objectives is to estimate the total production from part records. In literature, two methods have been prominent in the development of factors for extending lactation records. The two methods prominently used are the Ratio and Regression methods. The ratio method involves the computation of ratio of part production to total production. This ratio when multiplied by actual production equals estimated 305 days production. The other method is to obtain the regression of total production on partial production.

Both Linear and quadratic regression equations have been used widely. Harvey (1966) found that the curvi-linear part of cumulative production did not have significant effect. This implies that the linear equation will provide a satisfactory means of extending part production. Principal uses of the factors are in ranking the producing ability of cows in a herd by planning all lactations on a common basis corrected to a 305 days. Factors can be used to project what a cow will produce in a lactation while the lactation is still in progress. Such early information would facilitate selection prior to the completion of a lactation.

A second use of extended record is that it is a useful tool in the evaluation of sires by all daughters that started a lactation. The use of part record can quicken the genetic evaluation of breeding animals. Until recently, selection of a bull on performance of his offspring was delayed until several of his daughters had completed at least one lactation. By the use of factors, projection of records still in progress could reduce the time needed to prove a sire by up to 9 months if not more. Madsen (1955), Lamb (1960, 61) and Searle (1961) have used the factors to assess the producing ability of in order to carry out performance testing.

The comparison of the two methods by Lamb (1960) showed Ratio method is simple to use although from their data it appeared to under-estimate the total production of low cows and over-estimate that of high producing cows since it takes

into account only the incompleteness of lactations. Furthermore, the use of cummulative records have been found to be more useful and widely applicable. Abubakar and Buvanendran (1981) have also computed multiplicative factors to assess crossbred cows producing ability.

In conclusion, the models enumerated above can be categorised in three broad classes namely; Polynomial, Exponential functions and Time series based models. Most of the work done used models based on the exponential functions while little has been done on lactation curves using Polynomials and Time Series models. This might be as a result of lack of biological interpretation that could be assigned to the coefficients obtained for the Time series models.

CHAPTER 3

3.0 MATERIALS AND METHODS

3.1 Source of data and description of analysis

The National Animal Production Research Institute which was formerly the Shika Research Station was established in 1928 by the then Ministry of Agriculture for the Northern Provinces of Nigeria. Shika Station is located at latitude 11° 15' N, longitude 7° 32' E at an altitude of about 667 M above the sea level and found within the Northern Guinea Savana ecological zone of Nigeria.

The climate is relatively dry, the rains occuring during the months of May to September with an average rainfall ranging between about 736- 1377 mm per year. The dry season commences with a period of dry cool weather called Harmattan lasting from about mid-october to February. This is followed by hot dry weather from March to April. The mean annual minimum and maximum daily temperature ranged between 14°C to 32°C during the Harmattan and from 19°C to 36°C during the hot season. The relative humidity varies between 17 and 35 during the dry season. The corresponding figures for the wet season ranged between 63 - 80. Table 1 is a summary of the average monthly weather conditions in Shika from 1960 - 1978 the period of data collection.

Table 1: Summary of Meteorological data for Shika from 1960-1978

Month	Temperature(°C) Mini	Maxi.	Average Humidity [%]	Average Rainfall mm
January	13.7	29.7	16.8	0.56
February	16.1	32.5	15.2	0.00
March	19.4	35.0	24.2	2.70
April	21.3	35.3	46.8	43.60
May	21.2	33.2	62.7	101.40
June	19.8	30.5	71.3	164.80
July	19.4	28.4	78.9	231.20
August	19.3	27.6	80.5	282.70
September	19.1	29.1	75.8	194.00
October	18.2	31.2	60.3	35.50
November	15.0	30.6	27.3	0.30
December	13.4	29.9	20.5	0.05

One of the major objective of the station was to produce superior Bunaji (White Fulani) bulls to be issued to local livestock men (Guide to Shika 1968-69). In 1962, the Station was transferred from the Ministry of Agriculture to the Ministry of Animal and Forest Resources. In October 1962, it was assigned to Ahmadu Bello University and subsequently became part of the department of Animal Science and Institute for Agricultural Research. It was formally upgraded to a full fledged Institute in 1976.

The Institute has records of milk production for Bunaji (White Fulani) and Bokoloji (Sokoto Gudali) cows dating as far back as 1928. In 1964, the first Friesian was brought to Shika from Vom Station in Jos. This was the beginning of cross-breeding to produce Friesian-Bunaji cows. The Institute therefore has milk production records for Bunaji, Bokoloji, Friesian-Bunaji and Friesian Cows.

This study used some of these records for the period of 1960 to 1978. Records of animals used included only those that were not being subjected to any experiment. Furthermore, animals that were sick during the course of the lactation were excluded from the study.

Also, records beyond 5 lactation were not included. This was because there were very few cows (less than 2%) that had records beyond the fifth lactation because most of the cows beyond the 5th parity were usually disposed off. Below is a brief description of Bunaji breed of cattle.

3.11 Bunaji Cattle

Bunaji cattle is the most common breed in Nigeria and is distributed throughout the Northern States particularly in the Guinea and Sudan savannah of the country within the elevation of about 647m above sea-level. They also inhabit the plateau areas where the ranges are up to 800m above sea levels (Gates, 1952). Gates (1952) reported that the Bunaji is suspected to be from the Hamitic Longhorn cattle from Egypt. They are believed to have migrated south from Egypt and have spread along the North and West coast of Africa sometime in 2000 BC. They are mostly characterised by a skin that is white with black patches though some have black skins with white patches. They are classfied as medium sized because of their even temperament. They are chiefly owned by the nomadic Fulanis and are of medium production in milk yield. The production ranged between 789 - 1069 kg (Knudsen

and Sohael(1970) and Johnson et al.(1984))

3.12 Friesians

These are well documented European breeds of cattle. They are large sized animals and have high production in milk yield. Their production ranged between 2000-4500 kg per lactation Udedibie et al.(1983).

3.13 Friesian-Bunaji Crosses

These are cows obtained by either natural mating or by artificial mating where the male is always the Friesian. Their characteristics include their ability to produce higher milk than the Bunaji which is of bigger size. All their features and production patterns are between the pure Bunaji and Pure Friesian cows.

3.2 Management of Herd

The animals were kept in fenced paddocks during the day except time of grazing when they were out. They were brought into the open sided roofed enclosures at night throughout the period. Cows were milked twice per day. Cows in milk were fed with concetrate rations composed of sorghum and bran, cotton seed, groundnut cake, dried blood, soyabean and palm kernel meals while sweet potatoe vines and tubers, mucuna hay, sunflower and maize silage and dried sorghum leaves were fed as roughage in the dry season.

In the wet season, rotational grazing on sown mucuna pastures supplemented with concentrate rations was provided. Routine treaments were carried out on the animals to ensure the health of the animals. Finally, cows that produced less than 2kg/day were dried off. Milk records were taken daily for each animal. Further information on management and performance of the three breeds of cattle has been documented by Knudsen and Sohael (1970) and Olayiwole et al.(1973).

3.3 Assessment of models

The objectives of this study is to examine in detail the use of three models in describing lactation curves. The three models were compared in terms of their suitability in describing the lactation curves from three breeds of cattle under the tropical environments. The parameters used in assessing the suitability included: the general goodness of fit test of the models. The common yardstick was the coefficient of determinations viz R^2 (Seber, 1977). This measures the amount of variability accounted for by the fitted model. High R^2 values indicate adequacy while low values indicate inadequacy of the model. Generally, an R^2 of about 70% or above is considered to indicate a good measure of fitness.

Another measure is use of the Residuals at each week along the curve. Any observed trend in the residuals along the curve indicates bias and subsequently could be interpreted as inadequacy of the model (Draper and Smith,

1966 and Seber, 1977). Apart from these general measures, the models were also assessed by their ability to correctly predict the location of some vital indicators observed on the actual data. These included:

3.31 Initial Production

Initial production is the initial observed average daily production for first week production after parturition. A good model is expected to have high correlation between the observed and the predicted initial week production.In other words, irrespective of the other factors (parity, season or year of calving of the cow) the difference between the predicted initial production using the model and the observed should be close to zero.

3.32 Peak Week

The peak week is the week at which the production of a cow is highest before it declines in production. The importance of peak week has been established by Wood (1969), Schneeberger (1979) and several others. The ability of a farmer to make accurate prediction as to the week an animal will attain the maximum production will assist him in assessing the performance of an animal in a herd and possibly the general production pattern in the herd. If a farmer is able to predict correctly, he can make forcasts about the profitability of any given management system he may have on his farm. If an animal is found not to be suitable such an

animal can either be culled or disposed of. The model that makes the most accurate prediction closest to the observed will be assessed as the best. In other words, the relationship between the observed peak week and the predicted peak week should be close to unity i.e. (1.0). A bad model will have values close to zero.

3.33 Peak Production

This is considered as the highest production in a week during the entire lactation curve. It is also useful in assessing the performance of an animal. It has been established that there is a positive significant correlation between the initial production and peak production (Rao and Sundaresan;1979). Similarly, the same holds for total production and peak production. Using this parameter and assuming there is the possibility that the performance of an animal can be correctly assessed then those found not meeting up to any cut off point can be culled from the herd. The model that provides a prediction with the least deviation from the observed is considered the most adequate.

3.34 Total Production per Lactation

A dairy farmer's primary consideration is to be able to get high production from his animals. The model that is able to make the most accurate prediction when compared to the actual production will be more reliable. Part records can thus be used to predict the total production of the animal.

A model that will serve this purpose will be an asset to the farmer or researcher. This is because the primary objective of the development of lactation curves is to be able to obtain a tool that will reduce the cost of regular visits to the farmers who at times are difficult to reach. The difficulty arises because the normads are constantly on the move in search of pastures to graze their animals. Other parameters to be used include the persistency which Wood (1969) defined as the extent to which the peak yield is maintained. Comparison of persistency between the models can only be made between Gamma function and Modified Gamma models. Inverse function does not indicate how this persistency is to be evaluated.

3.35 Persistency

This is another measure that has been found to be a useful tool in assessing the productivity of a cow. Persistency, according to Wood (1967), is a measure of how consistent a cow is able to maintain its level of peak production during the entire lactation period. This parameter was estimated for each lactation using the Wood (1967) computational formula of $-(b+1)\log_e c$ which is a function of the rate of rise and decline from the peak.

3.36 Coefficient of Determination (R^2)

In assessing or evaluating any model, it is necessary to know how good the model is. Some measures of degree of

adequacy of a model is achieved with the use of the above named statistic. The statistic measures the amount of variability that the model is able to account for. Draper and Smith (1966) and Seber (1977) described the properties and emphasised the danger in the arbitrary use of the statistic. Rather the adjusted R^2 is recommended since that takes into account the number of terms fitted into the model. Generally, a good model is expected to have an adjusted coefficient of determination closer to (100%). The statistic has been used in this work to evaluate the adequacy of the models for comparison.

After computing the statistics described earlier and corrected for differences in factors (parity, season,lactation length) comparison between the observed and the predicted were made to check for differences. Correlations were also computed between the predicted and observed for each model. These coefficients were compared.

3.4 Choice of model

As reviewed earlier, several models have been proposed. The models were chosen not necessarily on mathematical simplicity. The models were chosen on the basis of their practical applicability. Models chosen must not just provide parameter estimates but must provide estimates that have biological or practical interpretations to the users. The second condition of choice of model is ease of use. For example Seber (1977) stated categorically that there is no

use fitting a model that requires estimation of several parameters when it is possible to fit a model that requires fewer parameters that can equally provide precise measure of fitness. Finally, what is being sought is a model that can be used by Researchers with minimum problems and difficulties in the use of such a tool and such a model must contain the minimum biological interpretation required for field application.

On the basis of these criteria enumerated above, three models given below were chosen from the range of models described earlier. The models chosen are:

3.41 GAMMA FUNCTION

1. Wood (1967) model which is defined as

$$Y_t = A\ t^B\ \exp\ [-ct]$$

which has been tranformed to become

$$\log_e (Y_t) = \log_e (A) + B \log_e (t) - ct$$

3.42 MODIFIED GAMMA FUNCTION

2. Kuck et al (1976) defined as

$$\log_e(Y_t) = \log_e(A) + B \log_e(t) + ct + U\ Sin(x) + V\ Cos(x)$$

The additional parameters U and V are used in conjunction with trigonometric functions to account for the cyclic effect of season while the week of the year expressed in radians is given by x.

denoted s for persistency, **initprd** for initial week production/day; **pwk**, for week of peak production; **Mxprod** for Peak production; **Tprod**, total production/lactation.

3.5 Data collection and analytical procedures

Records of 584 lactations satisfying the conditions stated earlier (i.e sick animals or those under experiments were exempted and not more than 5 lactations) were used. These comprised of 205 lactations from 60 Bunaji cows, 268 lactations from 69 Friesian-Bunaji cows and 111 lactations from 39 Friesian cows.

Milk production was recorded daily while weekly production was computed from the daily production. Average daily production per week for Bunaji, Friesian-Bunaji and Pure Friesian were computed from the weekly total production for the entire lactation period.

The three models were fitted to each of the 584 lactations individually. The estimates of the parameters for each model and predicted curve characteristics were computed using multiple regression analysis. The residuals from each lactation record were tested for lack of fit using the standard procedures described by Draper and Smith (1966). Furthermore, the average curve was computed by obtaining the production of all the lactations at each week and for each breed to obtain the average curve for each breed. The total predicted production was computed from the sum of the predicted daily production per week multiplied by seven for

the entire period of lactation for each cow for each breed. The predicted peak week and peak production were computed as indicated for each model from the literature. The predicted initial production for each of the models was the fitted value at week one. Persistency was computed for Gamma based models according to the relation described in section 3.34.

For each model, correlation coefficients were calculated between predicted and observed curve characteristics - such as total production, week of peak production, peak production and initial week average daily production. Furthermore, the overall percentages of number of times the predicted week of peak production coincided with the observed were computed for each model and compared. This was repeated for each parity to assess the effectiveness of each model within parity.

Finally, for each of the three breeds, namely Bunaji, Friesian-Bunaji and Pure Friesian, the curve characteristics were compared looking at the predicting ability of each model. For instance, considering peak week, the comparison was done by computing the proportion of data for which the predicted is equal to the observed, less or greater than the observed. The assessment was done generally and subsequently by parity.

Other comparisons done included paired t-test to compare the predicted with actual observed curve characteristics between models and within breeds. The next stage considered each model and evaluated or assessed the factors affecting the curve characteristics. The factors included for each

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breed were effects of season and year of calving, parity or stage of lactation, lactation length.

The curve characteristics from each model and for each breed were subjected to least squares analysis by considering the factors enumerated above. The Generalised Linear Models subroutine of SAS (1987) package was used for the least square analysis.

Seasons of calving were categorised as follows:

Seasons	Months
Cool Dry Harmattan	December - February
Hot Dry Hamattan	March - May
Wet Season	June - August
Post Raining Season	September- November

Similarly, the lacation length were classified into four categories. These are:

1. Below 26 weeks duration
2. 26-35 weeks
3. 36-45 weeks
4. Over 45 weeks.

The data included all parities up to the 5th and years considered were from 1960 - 1978.

To assess the factors affecting the parameters of the lactation curve under each model, an individual breed least squares analysis was carried out. This was done by subjecting the estimates of the predicted lactation curve parameters obtained from fitting regression analysis to each lactation record for each model. The same was repeated for

the production characteristics evaluated earlier (viz, the predicted initial week production/day, peak week, peak production, total production as well as the coefficient of determination R^2).

3.51 Statistical Model:

$$Y_{ijklm} = u + S_i + L_j + P_k + Q_l + e_{ijklm}$$

Y_{ijklm} = predicted lactation curve or production parameters on the m^{th} animal of the l^{th} year in the k^{th} parity in the j^{th} lactation class and i^{th} season.

u = Overal mean

S_i = effect of the i^{th} season where i = 1,2,3,4

L_j = effect of the j^{th} lactation length where j=1,2,3,4

P_k = effect of the k^{th} parity where k = 1 to 5

Q_l = effect of the l^{th} year where l = 1 n_i (varied).

e_{ijklm} = random error assumed normally distributed with mean 0 and variance 0^2.

Where Y_{ijklm} is the curve characteristics (the parameters for each model and the predicted curve characteristics from models). This model was fitted for each data set, i.e. Bunaji, Friesian-Bunaji and Friesian data. Each was evaluated separately to assess factors affecting the curve and production indicators.

3.52 Multiplicative factors

Multiplicative factors were developed for each model using the method of Abubakar and Buvanendran (1981). They

used the ratio method. This ratio was computed from the fitted model. The factor MF was computed as:

$$MF = \frac{\text{Estimated Total Yield}}{\text{Estimated part yield during n weeks}}$$

From the curve parameters, data was generated to develop some multiplicative factors (MF) for estimating total yields from actual part yields during the first 4, 6, 8, ... 44 weeks of lactations for each of the models. Furthermore, the deviations between the predicted using the factors and the observed yield were computed for the three models. The values for different models were compared with the actual data for each breed of cattle to assess the adequacy.

Finally, a joint least squares analysis was carried out in oder to assess the effects of breeds and other factors on the curve characteristics notably the various parameters from each curve. This was done by pulling the curve characteristics together for all breeds. The model used was same as before except that the breed effect was incorporated into the model. Also, the year effect was categorised into four production periods of Pre 1966, 1966 - 1970, 1971 - 1975 and post 1975.

CHAPTER 4

4.0 RESULTS

4.1 Evaluation of the models using Bunaji Data

Two hundred and five lactation records were analysed and the summary for the parameters for Bunaji data is given in table 2 below.

Table 2: Observed average productivity parameters for Bunaji data

Parameter	N	Mean	S.E
Initprd/day (kg)	205	4.69	0.130
pwk(week)	205	4.84	0.255
Mxprod/day (kg)	205	6.39	0.815
Tprod/lact. (kg)	205	928.38	15.687
Lact length (week)	205	32.10	0.720
Daily production (kg)	205	4.13	0.282

Note
Initprd=Initial week average daily production
pwk- peak week
Mxprod- peak production/day at peak week
Tprod-total production/lactation

The results from the table indicated that the average total production/lactation for a Bunaji cow varied from 913 - 1007kg per lactation. The corresponding lactation length - averaged 32.10 weeks with an average initial week production/day of about 4.69 kg. The peak was attained after about 4.84 weeks of parturition. This implied that the Bunaji cow peaked between 4 - 6 weeks after parturition and the production during that week is about 6.39kg/day.

The results for the observed production data with respect to the total production and lactation length agreed with the findings of Foster (1960), Knudsen and Sohael (1970)

and recently the findings of Johnson et al (1984) who, in a study to examine the production of Bunaji cows, found that the production of Bunaji cows vary between 789 and 1060kg while the lactation length varies between 31-36 weeks in production.

The average daily production of about 4.13kg per day agrees with that of Johnson et al (1984). However, this did not agree with the study of Knudsen and Sohael (1970) who obtained a value of 2.29 kg/for Bunaji cattle.

Results from table 3 below showed that two models, Gamma and Modified Gamma have significantly higher adjusted coefficient of determination (R^2) than Inverse function. Considering each of the curve characteristics it is observed that the predicted average initial week production per day for the Gamma and Modified Gamma models were closer to the observed than the corresponding value from the Inverse function (4.69 Vs 4.58 and 4.59 as against 4.69 Vs 3.90).

The two model's (Gamma and Modified Gamma) under-estimated the initial week production/day for Bunaji Cattle. This under estimation was also observed to a larger extent in Inverse function. The under-estimation was about 17% for Inverse function against 2% recorded for Gamma function or Modified Gamma model.

For peak week, the prediction from Gamma function and Modified Gamma models over-estimated the actual average from table 2 while Inverse under-estimated. The corresponding deviations from the actual average are for Gamma function,

Modified Gamma and Inverse function, respectively.

Table 3: Predicted average curve and production characteristics by functions

Curve Characteristics	GAMMA Mean	GAMMA S.E.	MODIFIED GAMMA Mean	MODIFIED GAMMA S.E.	INVERSE Mean	INVERSE S.E.
Initprd/day (kg)	4.58	0.14	4.59	0.13	3.90	0.12
pwk (week)	5.42	0.19	5.41	0.20	4.31	0.12
Mxprod/day (kg)	6.11	0.14	6.56	0.13	9.03	0.41
Tprod/lact(kg)	933.17	28.98	930.00	28.92	1006.29	35.67
Persistency (s)	2.93	0.036	3.66	0.05	N/A	N/A
Adjusted R^2	0.839	0.009	0.840	0.009	0.70	0.013
[a/b_1]	2.900	0.029	2.3000	0.033	-0.00174	±0.003
[b/b_0]	0.3902	0.016	0.3879	0.016	0.1520	0.0131
[c/b_2]	0.0729	0.002	0.0726	0.002	0.00862	0.0005

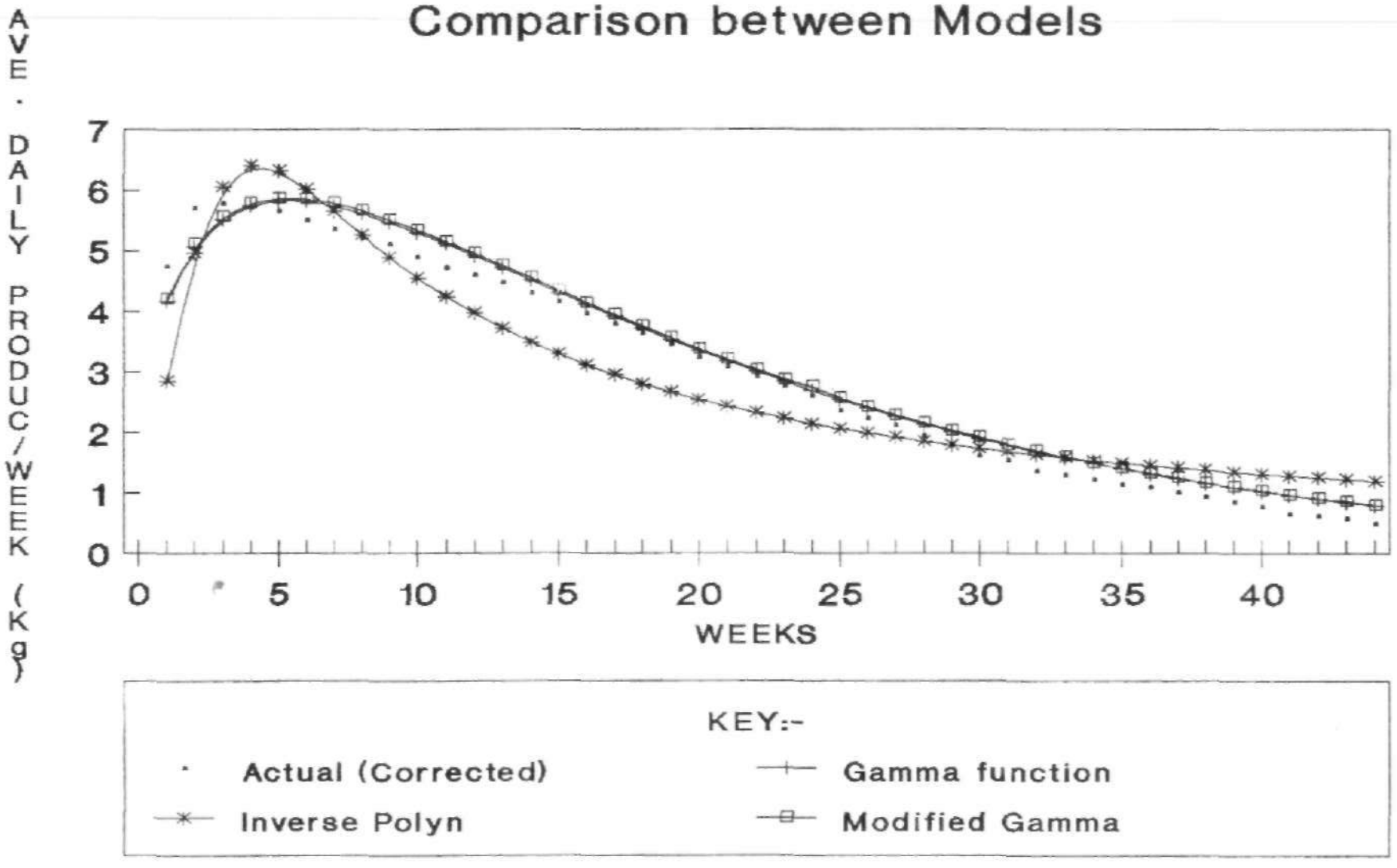
Note

Initprd=Initial week average daily production
pwk- peak week
Mxprod- peak production/day at peak week
Tprod-total production/lactation
a-general level of production under Gamma basedfuntions.
b-rate of rise to the peak under Gamma based functions.
c-rate of decline from the peak under Gamma based functions.
b_1 , b_0 and b_2 are the corresponding parameters under the Inverse functions parameters.

Figure 1 is the graph of the observed and the fitted for the models, after correcting for the differences due to the effects of parity, lactation length, season and year

figure 1

fig.1 Bunaji cow Lactation Curves
Comparison between Models



of calvings for the Bunaji data. General level of production for the observed was under-estimated by all the models. A close look at the graph showed that between 4th and 16th week, there is an obvious over-estimation of the actual by Gamma and Modified Gamma models. The percentage over-estimation between these two periods varied from 3.1-8.4 (table 3). This was highest between 7th and 12th weeks for Gamma and Modified Gamma. The variation dropped between 16th and 24th weeks to about 3% on average and then increased rapidly from 8% to almost 61% in the 44th week. Recall that the average number of weeks in production per lactation was about 32 weeks for Bunaji data (table 2). Beyond the 33rd week, the animals in milk constituted the exceptionally good ones that could be considered as top 5% producers in the Bunaji group. For the Inverse function, the pattern was different as can be seen from figure 1. The figure revealed that there was an over-estimation between 3rd and 8th week (region of peak for all curves) and then an under-estimation between weeks 9 and 31.

TABLE 4:Observed daily, fitted and deviations of models from observed for Bunaji data

WEEK	OBSERVED	GAMMA FITTED	% DEVIATION FROM OBSERVED	MODIFIED GAMMA FITTED	% DEVIATION FROM OBSERVED	INVERSE FITTED	% DEVIATION FROM OBSERVED
1	4.74	4.163	12.2	4.206	11.3	2.854	39.8
2	5.71	5.072	11.2	5.118	10.4	4.956	13.2
3	5.78	5.523	4.4	5.570	3.6	6.064	-4.9
4	5.73	5.745	-4.4	5.791	-1.2	6.411	-12.1
5	5.69	5.827	-3.1	5.873	-3.9	6.319	-11.8
6	5.51	5.816	-5.6	5.862	-6.4	6.021	-9.3
7	5.36	5.742	-7.1	5.787	-8.0	5.646	-5.3
8	5.21	5.624	-7.9	5.668	-8.8	5.260	-1.0
9	5.11	5.474	-7.1	5.517	-8.0	4.890	4.3
10	4.90	5.303	-8.2	5.345	-9.1	4.550	7.1
11	4.72	5.116	-8.4	5.157	-9.3	4.242	10.1
12	4.60	4.921	-7.0	4.961	-7.8	3.965	13.8
13	4.47	4.720	-5.6	4.759	-6.5	3.717	16.8
14	4.31	4.517	-4.8	4.555	-5.7	3.494	18.9
15	4.16	4.313	-3.7	4.350	-4.6	3.293	20.8
16	3.96	4.112	-3.8	4.148	-4.7	3.113	21.4
17	3.79	3.915	-3.3	3.949	-4.2	2.950	22.2
18	3.63	3.721	-2.5	3.755	-3.4	2.802	22.8
19	3.45	3.533	-2.4	3.566	-3.4	2.667	22.7
20	3.24	3.351	-3.4	3.383	-4.4	2.544	21.5
21	3.08	3.125	-3.1	3.206	-4.1	2.431	21.1
22	2.92	3.006	-2.9	3.036	-4.0	2.328	20.3
23	2.76	2.844	-3.0	2.872	-4.1	2.232	19.1
24	2.60	2.688	-3.4	2.716	-4.5	2.144	17.5
25	2.36	2.539	-7.6	2.566	-8.7	2.063	12.6
26	2.23	2.397	-7.5	2.423	-8.7	1.987	10.9
27	2.11	2.261	-7.2	2.286	-8.3	1.916	9.2
28	1.94	2.132	-9.9	2.156	-11.1	1.851	4.6
29	1.79	2.010	-12.3	2.033	-13.6	1.789	0.1
30	1.61	1.893	-17.6	1.915	-18.9	1.731	-7.5
31	1.54	1.783	-15.8	1.804	-17.1	1.677	-8.9
32	1.36	1.678	-23.4	1.698	-24.9	1.626	-19.6
33	1.30	1.579	-21.5	1.598	-22.9	1.578	-21.4
34	1.22	1.485	-21.7	1.504	-23.3	1.533	-25.7
35	1.14	1.396	-22.5	1.414	-24.0	1.490	-30.7
36	1.09	1.312	-20.4	1.330	-22.0	1.450	-33.0
37	1.01	1.233	-22.1	1.250	-23.8	1.411	-37.7
38	0.93	1.158	-24.5	1.174	-26.2	1.375	-47.8
39	0.85	1.088	-28.0	1.103	-29.8	1.340	-57.6
40	0.78	1.021	-30.9	1.036	-32.8	1.307	-67.6
41	0.65	0.959	-47.5	0.973	-49.2	1.276	-96.3
42	0.62	0.900	-45.2	0.913	-47.3	1.246	-100.0
43	0.57	0.844	-48.1	0.857	-50.4	1.218	-113.6
44	0.49	0.792	-61.6	0.804	-64.1	1.190	-142.9

Within this period the under-estimation was highest between 16th and 20th week with a deviation of about 21% compared to about 3% over-estimation for Gamma and Modified Gamma models. This was followed by a gradual drop in deviation until the 30th week when there was a general over-estimation of the actual. Beyond 34th week of lactation, Nelder's over-estimation was significantly higher than the corresponding deviations for Gamma or Modified Gamma. From figure 1, there is the indication to prefer Gamma, or Modified Gamma model to the Inverse function . This is further enhanced when we consider the rate at which the peak is maintained. In other words, by measure of persistency, Gamma and Modified Gamma have higher level combined with higher value of adjusted coefficient determination of about 0.84.

Table 5 gives the summary for the Observed, predicted cumulative production, and the multiplicative factors for computing total production from part records for each of the models as well as the percentage deviations of the predicted from the actual Observed cumulative production. From the table, columns 6,7 and 8 give the percentage deviations of the predicted from the Observed. Negative values indicated that the predicted was greater than the observed indicating over-estimation other wise, there was under-estimation. Pattern of deviations of the models have

TABLE 5: Observed and predicted cummulative production, % deviation and multiplicative factors for functions

	PREDICTED PRODUCTION				% DEVIATION FROM OBSERVED AVE. PRODUCTION			MULTIPLICATIVE FACTORS FOR PREDICTING		
	PART YIELD		MODIFIED			MODIFIED			MODIFIED	
WEEK	OBSERVED	GAMMA	GAMMA	INVERSE	GAMMA	GAMMA	INVERSE	GAMMA	GAMMA	INVERSE
4	153.01	143.52	144.80	142.00	-6.20	-5.40	-7.20	6.764	6.767	6.209
6	230.81	225.02	226.94	228.38	-2.50	-1.70	-1.05	4.314	4.318	3.860
8	304.55	304.58	307.13	304.71	-0.01	-0.80	-0.05	3.187	3.191	2.893
10	374.35	380.02	383.16	370.80	-1.51	-2.40	0.95	2.555	2.557	2.378
12	439.38	450.28	453.99	428.25	-2.48	-3.33	2.53	2.156	2.158	2.059
14	500.64	514.94	519.18	478.72	-2.86	-3.70	4.38	1.885	1.887	1.842
16	557.27	573.92	578.66	523.57	-2.99	-3.84	6.05	1.691	1.693	1.684
18	609.01	627.37	632.59	563.83	-3.01	-3.87	7.42	1.547	1.549	1.564
20	655.70	675.56	681.23	600.31	-3.03	-3.89	8.45	1.437	1.438	1.469
22	697.55	718.82	724.93	633.61	-3.05	-3.93	9.17	1.351	1.352	1.391
24	734.89	757.55	764.04	664.25	-3.08	-3.97	9.61	1.281	1.286	1.327
26	766.95	792.10	798.97	692.60	-3.28	-4.17	9.69	1.226	1.226	1.273
28	795.23	822.85	830.06	718.97	-3.47	-4.38	9.59	1.180	1.181	1.226
30	819.00	850.17	857.70	743.61	-3.81	-4.73	9.21	1.142	1.142	1.186
32	839.23	874.40	882.21	766.74	-4.19	-5.12	8.64	1.110	1.111	1.150
34	856.83	895.85	903.92	788.52	-4.55	-5.50	7.97	1.084	1.084	1.118
36	872.38	914.80	923.13	809.10	-4.86	-5.82	7.25	1.061	1.061	1.090
38	885.92	931.54	940.10	828.60	-5.15	-6.12	6.47	1.042	1.042	1.064
40	897.24	946.30	955.07	847.13	-5.47	-6.45	5.58	1.026	1.026	1.041
42	906.13	959.32	968.28	864.77	-5.87	-6.86	4.56	1.012	1.012	1.019
44	916.79	970.77	979.90	881.64	-5.89	-6.88	3.83	1.000	1.000	1.000

- Over-prediction of the observed production by model
+ Under-prediction of the observed production by model

already been described above for weekly average daily production. For the cummulative production, results showed that there was an over-prediction of the first 4 week production with the values of 6.2, 5.4 and 7.2 respectively for Gamma, Modified Gamma and Inverse, respectively. The level of over-prediction dropped to almost a constant level of about 3% for Gamma and Modified Gamma up to 32nd week of production and then a gradual increase, to a maximum of 6% and 7% respectively. For Inverse function, the pattern was different. This was because, there were some degree of under-prediction of the observed. The range increased steadily from 1% in the 10th week to about 10% in the 28th week and gradually dropped again. Generally, between the 12th week and 36th, the cummulative predicted for Gamma and Modified Gamma significantly ($P < 0.01$) differed from that obtained for Inverse. Factors on table 5 have been used to compute predicted part yield. Table 6 gives the corresponding predicted cumulative production for these periods. Furthermore, the correlation analyses have been computed between observed and predicted.

TABLE 6: Observed, predicted cumulative production and deviations from factors

PART WEEK	OBSERVED	GAMMA	MODIFIED GAMMA	INVERSE	DEVIATION(%) GAMMA	MODIFIED GAMMA	INVERSE
4	153.01	135.54	135.45	147.63	11.4	11.5	3.5
6	230.81	212.52	212.31	237.51	7.9	8.0	-2.9
8	304.55	287.63	287.35	316.89	5.5	5.6	-4.1
10	374.35	385.89	358.47	385.56	4.1	4.2	-3.0
12	439.38	425.25	424.79	445.34	3.2	3.3	-1.4
14	500.64	486.29	485.73	497.84	2.9	3.0	0.0
16	557.27	542.01	541.38	544.46	2.7	2.9	2.3
18	609.01	592.48	591.85	586.33	2.7	2.8	3.7
20	655.70	637.98	637.35	624.26	2.7	2.8	4.8
22	697.55	678.86	678.23	658.91	2.7	2.8	5.5
24	734.89	715.40	714.84	690.76	2.7	2.7	6.0
26	766.95	748.02	747.53	720.23	2.5	2.5	6.1
28	795.23	777.07	776.58	747.67	2.3	2.3	6.0
30	819.00	802.90	802.48	773.29	2.0	2.0	5.6
32	839.23	825.79	825.37	797.30	1.6	1.7	5.0
34	856.83	846.02	845.74	819.98	1.3	1.3	4.3
36	872.38	863.94	863.66	841.33	1.0	1.0	3.6
38	885.92	879.76	879.55	863.63	0.7	0.7	2.5
40	897.24	893.69	893.55	880.88	0.4	0.4	1.8
42	906.13	905.94	905.94	899.29	0.0	0.0	0.8

From Table 6, results showed that values obtained using the factors developed had high significant correlation coefficient between the observed and the predicted. The coefficients ranged between 0.999 and 1.000 for Gamma and Modified Gamma and 0.993 - 0.996 for Inverse. The percentage deviation between the Observed and the predicted varied between 11.5 at 4th week part yield to almost 18 at 40th week part yield. In other words, the accuracy of the factor increased as there were more records for part yield for both Gamma and Modified Gamma. For Modified Gamma there were some over-estimation of the observed between 6th and 12th week part yield then there was a gradual increase in the percentage deviation as the more records became available for the part yield. This suggested that the factor became less accurate as more records became available for part yield. This further confirmed the earlier observations about the apparent inadequacies of the Inverse function when fitted to Bunaji data.

At peak production, the observed was 6.39 kg as against 6.11, 6.56 and 9.08 kg per day for Gamma function, Modified Gamma and Inverse functions, respectively. The predictions from the first two models had closer agreement with the observed. The percentage deviations were 4 and 3% for Gamma function and Modified Gamma and -42% for Inverse. Inverse over-estimated the average peak production per day by about 42% and Modified Gamma over-estimated by about 3% while

Gamma under-estimated by about 4% over all the lactations.

For total production over all the lactations, the corresponding values for Gamma function, Modified Gamma and Inverse were 933.17, 930.00 and 1006.29 kg, giving rise to an over-estimation of about 4.79, 1.62 and 7.791 kg for Gamma function, Modified Gamma and Inverse, respectively. The corresponding percentage of over-estimations were 0.5, 0.2 and 8.4, respectively.

For persistency, Modified Gamma model generally provided a better estimate with a value of 3.66 as against 2.93 observed for Gamma function over lactations.

The last three rows give the parameters of the curve for each of the model. The general level of production differed significantly ($P < 0.01$) between Gamma function and Modified Gamma whereas the rate of rise or fall in the milk which gives the inclining and declining phases were not significantly ($P > 0.05$) different for Gamma function or Modified Gamma.

4.2 FACTORS AFFECTING CURVE AND PRODUCTION CHARACTERISTICS UNDER GAMMA FUNCTION

Table 7 showed factors affecting the Bunaji data curve characteristics and table 8 showed the least squares means and standard errors for the factors. All the curve and production characteristics were significantly ($P<0.05$) affected by parity while the effect of the lactation length affected the rate of decline ($P<0.001$), the coefficient of determination ($P<0.05$), persistency ($P<0.001$), the week of peak production ($P<0.001$) although the level of significance differred for each parameter. Season of calving affected the general level of production ($P<0.05$), the rate of rise ($P<0.05$) while the level for persistency, week of peak production and initial week average production per day were significant at 1%.

The effect of year of calving was significant for only the adjusted coefficient of determination($P<0.01$) as far as this model was concerned.

The detailed observation of the least squares means for the curve characteristics under Gamma function showed that the general level of production was lowest in the first parity. This gradually increased to a maximum in the third parity and was followed by a gradual drop as the parity increased. This implied that the general level of production was affected by the parity, in Bunaji cows. Thus suggesting that first calvers had lower level of production than cows

that were already in production. This observation could have been affected by a number of factors like the age the cow calved which has direct relationship with the physiological developments of the animal. Also the body conditions at the time of calving. This result agreed with the findings of Abubakar and Buvanendran (1981) who worked with crossbred cattle in the same location.

However, it was observed that the general level of production a, was not affected by the lactation length of the cows for Bunaji. This perhaps might be explained by the fact that majority of Bunaji cows (about 64%) had lactation length less than 36 weeks. The result indicated that the season of calving significantly affected the general level of production. Cows calving in the months of December to February were found to have the lowest general level of production while those calving during September to November months had the highest general level of production. All cows calving between March to August had intermediate general production levels. These figures may be explained by the availability of feeds in the period of gestation. Generally, animals calving between September and November had enough feed in the period of gestation and particularly at the critical periods notably the second and third trimester to enhance the general level of production.

Table 8: Least square means and standard errors for curve characteristics under Gamma function for Bunaji Cows.

Source		b		c		a		R^2		s		pwk		Mxprod		Initprd		Tprod	
PARITY	N	Mean	S.E.	Mean	S.E.	Mean	S.E.	Mean	S.E.	Mean	S.E.	Mean	S.E.	Mean	S.E.	Mean	S.E	Mean	S.E.
1	53	0.404	0.05	0.054	0.006	2.017[d]	0.08	0.73[d]	0.024	3.22[a]	0.080	6.93[a]	0.43	5.47[d]	0.3	3.84	0.33	1071.71	43.17
2	54	0.338	0.05	0.067	0.006	2.427[a]	0.08	0.81[a]	0.024	3.00[d]	0.080	5.08[d]	0.42	6.98[a]	0.3	5.14	0.32	1077.61	42.94
3	51	0.343	0.05	0.071	0.006	2.545[a]	0.08	0.81[a]	0.024	3.00[d]	0.080	4.99[d]	0.44	7.20[a]	0.3	5.67	0.33	1132.84	43.59
4	29	0.286	0.06	0.059	0.007	2.516[f]	0.09	0.83[a,f]	0.028	3.08[d]	0.095	5.06[d]	0.53	6.25[d]	0.4	5.62	0.38	1101.45	51.00
5	18	0.380	0.07	0.082	0.009	2.492[a,f]	0.13	0.85[f]	0.038	2.84[d]	0.125	4.76[d]	0.66	6.94[d]	0.5	5.38	0.51	1122.60	67.97
LACTATION LENGTH																			
<26 wks	59	0.403	0.04	0.099[f]	0.0050	2.361	0.07	0.82[a]	0.021	2.63[d]	0.069	3.75[d]	0.37	6.00	0.3	4.86	0.28	626.54	37.24
26-35	70	0.395	0.04	0.078[f]	0.0050	2.374	0.07	0.83[a]	0.021	2.83[a]	0.069	4.85[a]	0.36	6.53	0.3	5.07	0.28	938.89	37.36
36-45	49	0.307	0.05	0.051[a]	0.0056	2.471	0.08	0.83[a]	0.024	3.23[f]	0.078	5.73[f]	0.41	6.79	0.3	5.39	0.32	1276.82	42.30
>45	27	0.297	0.06	0.038[d]	0.0076	2.391	0.10	0.75[d]	0.032	3.43[a]	0.105	7.12[a]	0.57	6.79	0.4	5.20	0.43	1562.71	56.85
SEASON OF CALVING																			
Dec. - Feb.	61	0.432	0.04	0.067	0.0050	2.241[d]	0.07	0.78[d]	0.021	3.09[d,a]	0.069	5.31[f]	0.38	6.37	0.3	4.42	0.28	1077.45	37.32
Mar. - May	64	0.379	0.04	0.073	0.0053	2.402[a]	0.07	0.82[a]	0.022	2.88[d]	0.074	5.36[a]	0.39	6.72	0.3	5.14	0.30	1123.46	39.86
June - Aug.	35	0.307	0.05	0.068	0.0065	2.499[a]	0.09	0.84[f]	0.027	3.00[d,a]	0.090	4.61[d]	0.48	6.73	0.4	5.57	0.37	1119.08	48.92
Sept - Nov.	45	0.284	0.05	0.058	0.0057	2.455[a]	0.08	0.79[d]	0.024	3.15[a]	0.079	5.18[a]	0.43	6.30	0.3	5.39	0.32	1084.98	42.82

Note

a=general level of production under Gamma funtions.
b=rate of rise to the peak under Gamma functions.
c=rate of decline from the peak under Gamma functions.
s=persistency
Initprd=Initial week average daily production
pwk= peak week
Mxprod= peak production/day at peak week
Tprod=total production/lactation

Least squares means connected by the same letter within a subclass are not significantly different from each other (P<=0.05)

However, those calving between December and February had lower feed supply as there were no more crop residue and hay thus resulting in the lower level of general production when compared to other seasons. Furthermore, whatever reserve the animal had will not be released for milk production.

Considering the inclining phases of the curve, table 7 showed that only the parity and season had significant effects on the inclining phases($P<0.01$). The effects of lactation length and years did not affect the inclining phase of milk production of Bunaji cows significantly.

In Gamma function, the result showed that parity and lactation length significantly affected the rate of decline in production at 5% and 0.1% levels, respectively. Results indicated that rates of decline was highest for animals in the fifth parity and lowest for first parity. No significant difference was observed in the rate of decline for cows in second and third parities. For lactation length, the rate of decline was highest for first calvers and lowest for fifth calvers.

For persistency, it was observed that under Gamma function, there was significant ($P<0.05$) effects of parity, of lactation length ($P<0.001$) and season of calving ($P<0.01$). Highest persistency was recorded in the first parity and lowest for fifth parity. However, there was no significant difference between the persistency for second, third, fourth and fifth parities. For lactation length, the highest persistency was found in the categories with greater

than 45 weeks in production. Only less than 15% of the records fall into this category. Results showed that the lowest rate of decline was recorded for this category of lactation class length. Persistency of milk production by season of calving showed that the lowest persistency occurred among cows that calved in the March - May season and highest for those calving in the September - November seasons. Although the persistency here is not significantly different from those that calved in December - February or June - August seasons. A reason that could be advanced for low persistency between March-May could be as a result of the bad condition the animal passed through during the last trimester of pregnancy, and would require building up body condition before milk could be improved.

With respect to the week of peak production, the results showed that this parameter is affected by parity ($P<0.05$), Lactation length ($P<0.001$) and season of calving ($P<0.01$). For parity, first calvers took longest time to attain their peak with a value of about 7 weeks after parturition, while the peak production was attained much earlier in the later parities, though there was no significant difference between parities with respect to the peak week. Generally, the result showed that for parity greater than one, the peak production was attained between 4-5 weeks after calving for Bunaji cows.

In the case of lactation length, the week of peak production increased as the lactation length increased. From

table 8, the peak week was about 4 weeks after calving for category of less than 26 weeks in production while the peak for those in over 45 weeks lactation length had the peak at about 7 weeks after calving. Considering the effect due to season, results indicated that animals that calved in the dry months of the year tended to stay longer before attaining their peak production as demonstrated by values for December - February and March - May compared to those of June - August and September- November. Animals that calved at the peak of the rains attained their peak significantly ($P<0.05$) earlier than those that calved between December - February. The result also showed that there was no significant ($P>0.05$) difference in the peak week between March - May and September - November calvers.

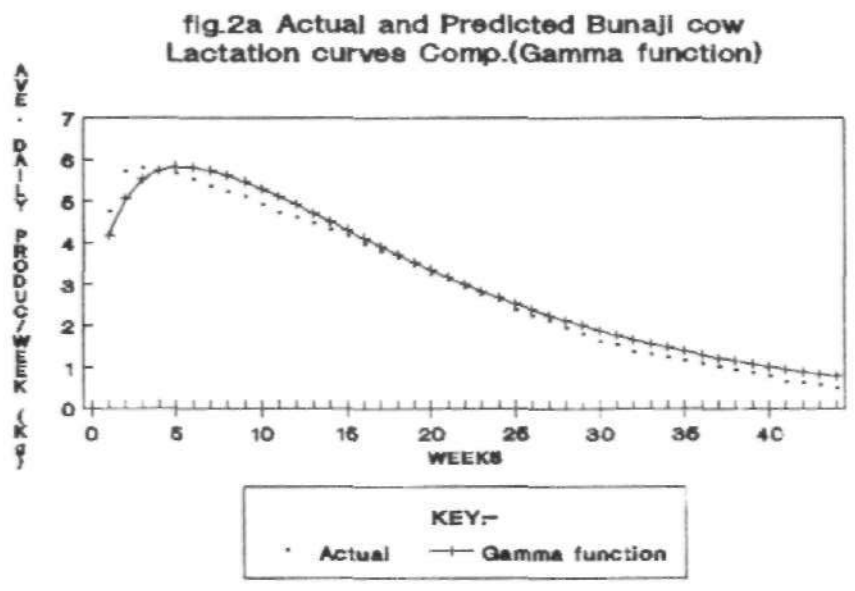
For peak production, the results showed that the parameter was only affected by parity of the animal as indicated by a significant effect of parity on the peak production of Bunaji cows. The highest peak production of 7.20kg/day $\pm$ 0.33 was recorded in the third parity while the lowest of 5.47 $\pm$ 032 occurred in the first parity. These values were attained at about fifth and seventh weeks, respectively.

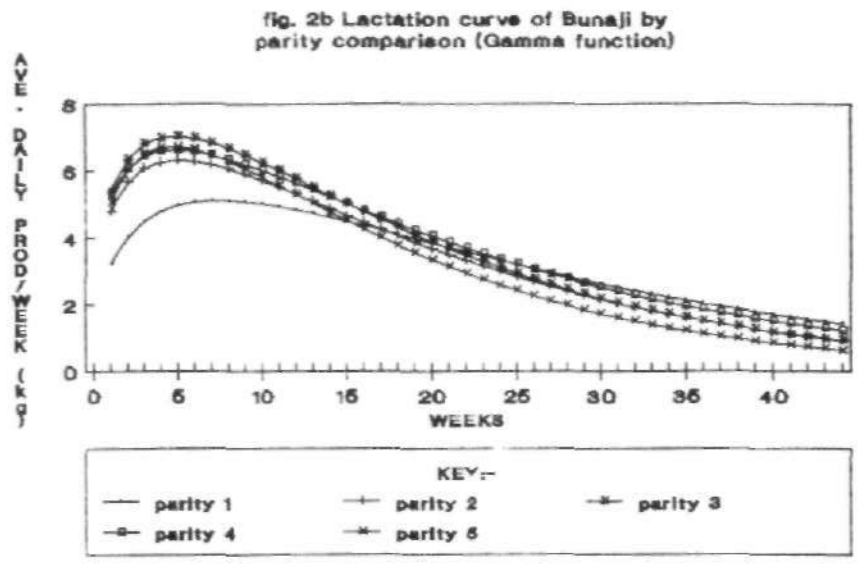
For the adjusted coefficient of determination R^2 which measures the adequacy of the model in describing the curve, results showed significant ($P<0.05$) effects at parity and lactation length ($P<0.05$). The best fit was recorded in the fifth parity with a value of 0.85 and the lowest was recorded

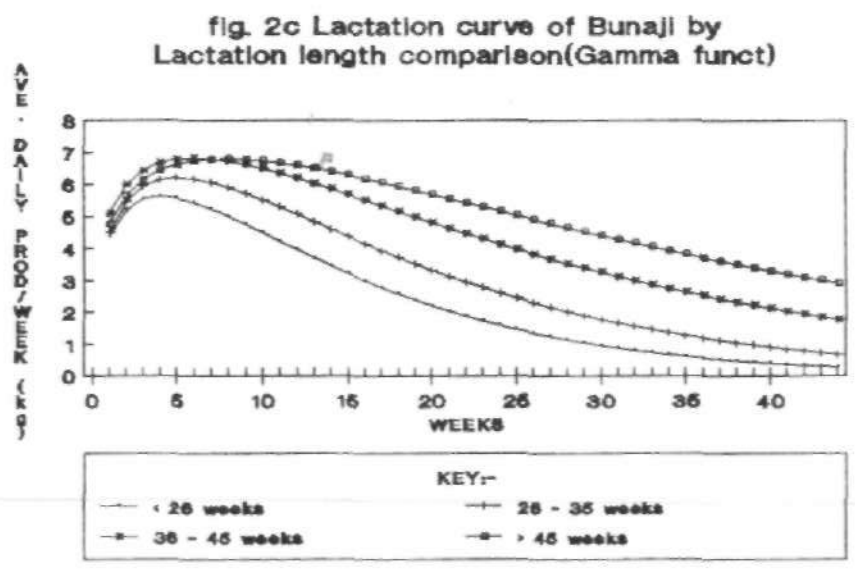
in the first parity with a value of 0.73. The values observed for second, third, and fourth parities did not differ significantly ($P > 0.05$). For lactation length, the fitness was worst for the category with greater than 45 weeks in milk. Very few cows were in this category anyway and that perhaps explains the low R^2 value. Figures 2 (a,b,c,d) gives the pattern of production for the fitted and actual, the production by parity, lactation length and season of calving under gamma function.

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figure 2.







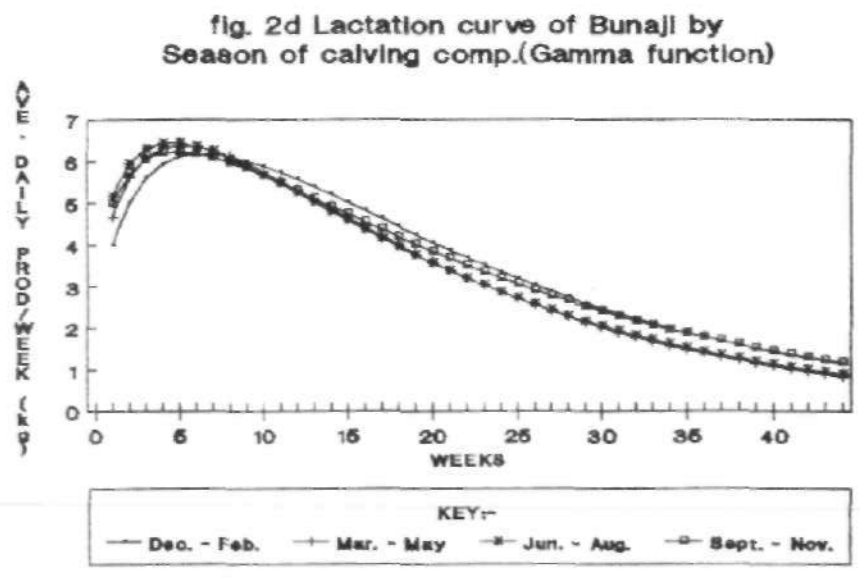


Figure 2. Production pattern of Bunaji using Gamma function

4.3 FACTORS AFFECTING LACTATION CURVE AND PRODUCTION CHARACTERISTICS UNDER MODIFIED GAMMA FUNCTION

Table 9 gives the summary of the least squares analysis of variance showing the significance of the factors for Modified Gamma model fitted to Bunaji data for various curve and production characteristics. Table 10 gives the least squares means and the standard error for the various factors under consideration.

Evaluating the factors affecting the curve characteristics for Bunaji data under Modified Gamma showed that, parity had significant ($P<0.001$) effect on all the curve characteristics except the parameter measuring the inclining phase of the curve. The effect of lactation length was significant for the declining phase of the curve (c) $P<0.001$, persistency ($P<0.001$), peak week ($P<0.001$) and peak production ($P<0.05$). The effect of season was found to be significant for all the parameters except for the inclining phase of the curve. Significant year effect was observed for adjusted coefficient of determination (R^2) ($P<0.05$) and persistency ($P<0.001$).

TABLE 10: Least squares means and standard errors for curve and production parameters under Modified Gamma function for Bunaji cows

Source		b		c		a		R^2		s		pwk		Mxprod		Initprd		Tprod	
PARITY	N	Mean	S.E.	Mean	S.E.	Mean	S.E.	Mean	S.E.	Mean	S.E.	Mean	S.E	Mean	S.E.	Mean	S.E	Mean	S.E.
1	53	0.3726	0.05	0.052[d]	0.006	2.019[d]	0.09	0.75[d]	0.02	4.16[e]	0.10	6.6[e]	0.4	6.8	0.9	4.0[d]	0.3	1062.1	42.9
2	54	0.3406	0.05	0.066[e]	0.006	2.449[e]	0.09	0.81[e]	0.02	3.50[d]	0.10	5.2[d]	0.4	6.8	0.9	5.1[e]	0.3	1081.1	42.9
3	51	0.3491	0.06	0.072[d,e]	0.006	2.521[e]	0.09	0.81[e]	0.02	3.49[d]	0.10	4.8[d]	0.5	6.8	1.0	5.5[e]	0.3	1144.3	43.0
4	28	0.3015	0.06	0.061[d,e]	0.007	2.475[e]	0.11	0.82[e]	0.03	3.49[d]	0.12	5.0[d]	0.5	5.8	1.1	5.5[e]	0.4	1099.0	51.4
5	18	0.3921	0.07	0.079[f]	0.009	2.510[e]	0.14	0.86[e]	0.04	3.49[d]	0.15	4.8[d]	0.7	7.2	1.5	5.5[e]	0.5	1129.3	64.9
Lactation Length																			
<26	59	0.4115	0.04	0.099[f]	0.005	2.353	0.08	0.83[e]	0.020	3.05[d]	0.08	3.5[e]	0.4	5.2[d]	0.8	4.9	0.3	623.2[d]	37.0
26-35	70	0.3871	0.04	0.077[f]	0.005	2.369	0.08	0.84[e]	0.020	3.54[e]	0.08	4.9[e]	0.4	6.8[d,e]	0.8	5.1	0.3	944.1[e]	37.0
36-45	49	0.3060	0.04	0.051[e]	0.006	2.500	0.09	0.82[e]	0.023	3.83[e,f]	0.09	5.7[f]	0.4	8.5[e]	0.9	5.3	0.3	1275.9[f]	41.8
>45	27	0.3002	0.06	0.037[d]	0.008	2.357	0.12	0.74[d]	0.031	4.05[f]	0.13	6.9[e]	0.6	6.2[d]	1.2	5.9	0.4	1569.4[e]	56.6
Season of Calving																			
Dec. - Feb.	61	0.4357[e]	0.04	0.066	0.005	2.232	0.08	0.77[d]	0.020	3.82[e]	0.08	6.3[e]	0.4	5.6[d]	0.8	4.3[d]	0.3	1085.3	36.9
March- May	64	0.3779[e]	0.04	0.073	0.005	2.430	0.08	0.83[e]	0.021	3.60[d]	0.09	5.2[d]	0.4	5.8[d]	0.9	5.2[d,e]	0.3	1113.7	39.0
June - Aug.	36	0.3087[d]	0.05	0.068	0.007	2.468	0.10	0.84[e]	0.027	3.50[d]	0.11	4.5[d]	0.5	8.9[e]	1.1	5.4[e]	0.4	1129.9	49.4
Sept - Nov.	45	0.2825[d]	0.05	0.057	0.006	2.450	0.09	0.79[d]	0.023	3.55[d]	0.10	5.0[d]	0.4	6.4[d]	0.9	5.4[e]	0.3	1083.7	42.5

Note

a=general level of production under Gamma funtions.
b=rate of rise to the peak under Gamma functions.
c=rate of decline from the peak under Gamma functions.
s= persistency
Initprd=Initial week average daily production
pwk= peak week
Mxprod= peak production/day at peak week
Tprod=total production/lactation

Least squares means connected by the same letter within a subclass are not significantly different from each other (P<=0.05)

Under Modified Gamma model, it was found that the general level of production, a was affected only by parity. Results showed that the lowest level of general production was recorded for the 1st parity while the highest was recorded for the 3rd parity. The production for 4th parity did not differ significantly (P>0.05) from that recorded for the 5th parity. This suggests that the general level of production increases gradually to attain an optimum about the 3rd parity and this gradually dropped though not significantly at about the 5th parity for Bunaji. The general level of production was not affected by the effects of either lactation length or season of calving.

For the inclining phase of the curve, this was affected significantly (P<0.05) by the effect of season only. Results showed that cows that calved between December-February had highest rate of increase while those that calved between June-August have lowest rate of increase. This may be as a result of the fact that animals fed on crop residue and hay with higher supplementation during December - February months would perform better compared to the period of June - August when the animals were usually grazed on the pastures. The grazing may not be enough thus leading to lower rate of rise to the peak.

For the declining phase, parity and lactation length have significant (P<0.001) effects, but there was no significant (P>0.05) seasonal effect. The declining phase was

highest for parity 5 and lowest for the first parity.

For persistency, significant effects of parity ($P<0.001$), lactation length ($P<.001$), season of calving ($P<0.05$) and year of calving ($P<0.01$) were observed. For parity, cows in the 1st parity had significantly($P<0.001$) higher persistency than the other parities. Results also showed positive and significant ($P<0.01$) relationship between persistency and the inclining phase of the curve. For higher parities results showed that the persistency was almost constant since there was no significant difference between the values. Observation on the persistency for the lactation length showed that, animals that were in milk for less than 26 weeks had the least persistency, they had the largest inclining phase as well as the highest rate of decline. Animals that were in milk for greater that 45 weeks had better persistency.

With respect to seasonal effect, results showed animals that calved in the months of December-February had significantly ($P<0.01$) higher persistency than those of other periods. This perhaps might be explained that there were shorter periods for the on-set of rains than those other categories that require longer period of dry spell before the availability of pasture in the field. Also, it might be that those animals were well fed and had better body condition

With respect to initial production result, table 9 showed that parity and season had significant ($P<0.01$) effects on the parameter. Table 10 showed the corresponding

least squares means for each of these factors. Initial week daily prodution for 1st parity was the lowest and this significantly ($P<0.01$) differed from the corresponding values for parities greater than 1. The pattern appeared gradual but got to a maximum at the third parity. Subsequently, no difference was observed in the values in parity 3,4 and 5 . For seasonality, result indicated that cows calving in the months of June-November had significantly ($P<0.05$) higher initial week average daily production when compared to those in other seasons, particularly those calving in the months of December-February when the pasture was not available. This might be that the feed conserved during the rainy season sustained the relatively higher initial milk production.

For Peak week, that is, the week the maximum milk was attained in production, it was found that lactation length ($P<0.001$) and season of calving ($P<0.01$) had significant effects (Table 9). From table 10, it could be observed that the largest production was obtained for parity 1 with a least squares means of about 7 weeks after calving under Modified Gamma model. The lowest estimate was obtained for parity 4 with a value of about 6 weeks.

Under lactation length, results showed that there was some relationship between the time the peak was attained and the lactation length. In other words, the shorter the lactation length, the earlier the peak was attained. For the effect of seasons, results indicated that animals that calved in the months of December-February had significantly

($P<0.05$) larger values than those calving in other months.

With respect to Peak production, only lactation class length and effect of season affected the parameters. Under Modified Gamma model results showed that animals that calved in the months between June-August had significantly higher prodution with an average of about 8.88 kg/day compared to those that calved in December-February with an average daily production of about 5.62 kg/day. The discrepancy in these values could be attributed to the differences in the availability of feeds for the animals within these periods. From table 10, animals that calved in December-February took about 6.30 weeks to attain a maximum of about 5.62 kg from an initial average of 4.33 kg. This amounted to an average of about 0.21 kg/day as compared to about 0.77 kg/day for animals that calved between June-August when there was abundance of pasture. The corresponding rate of production for March-May and September-November were 0.132 and 0.196 kg/day, respectively. Looking at the adequancy of the model for each of the factors, the adjusted coefficient of determination R^2 showed that all the factors had significant effects on the parameter. For parity, the results showed that the fitness in first parity was significantly lower than those of higher parities with that of fifth parity having the best and the highest R^2. For lactation length, it appeared that the model had significantly better fit for classes of less than 45 weeks in milk. As for season, the model fitted significantly ($P<0.05$) better for periods of rainy season

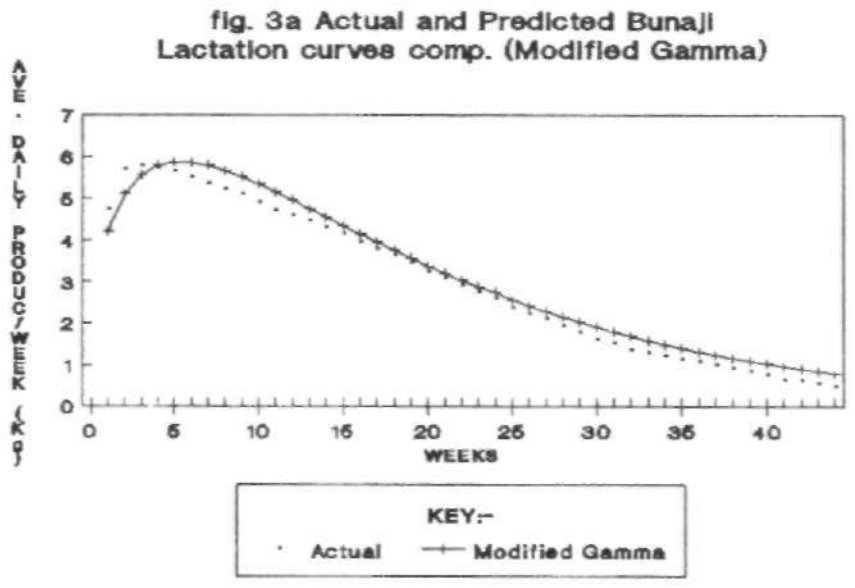
(March-August) than the dry periods (September-February). Figure 3 (a,b,c,d) gives the production patterns for Bunaji using the Modified Gamma function under various factors.

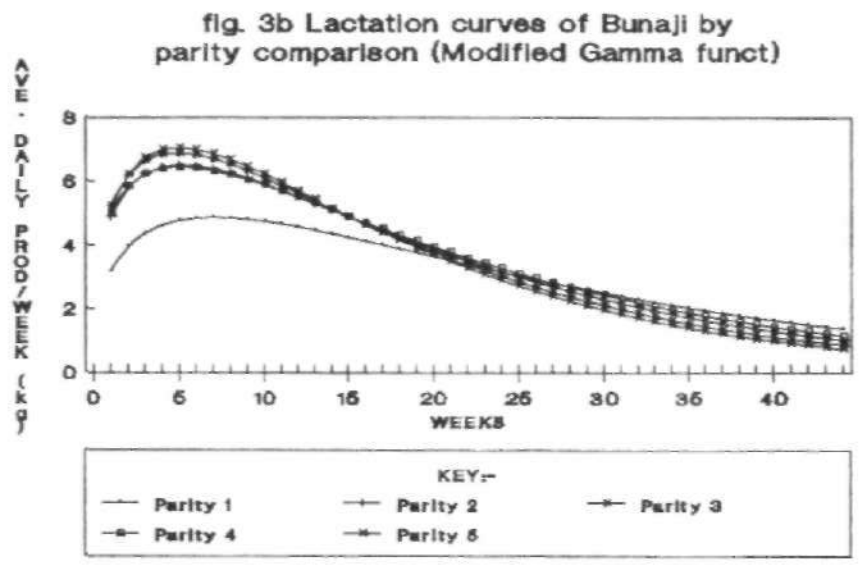
4.4 FACTORS AFFECTING CURVE AND PRODUCTION CHARACTERISTICS UNDER INVERSE POLYNOMIAL FUNCTION

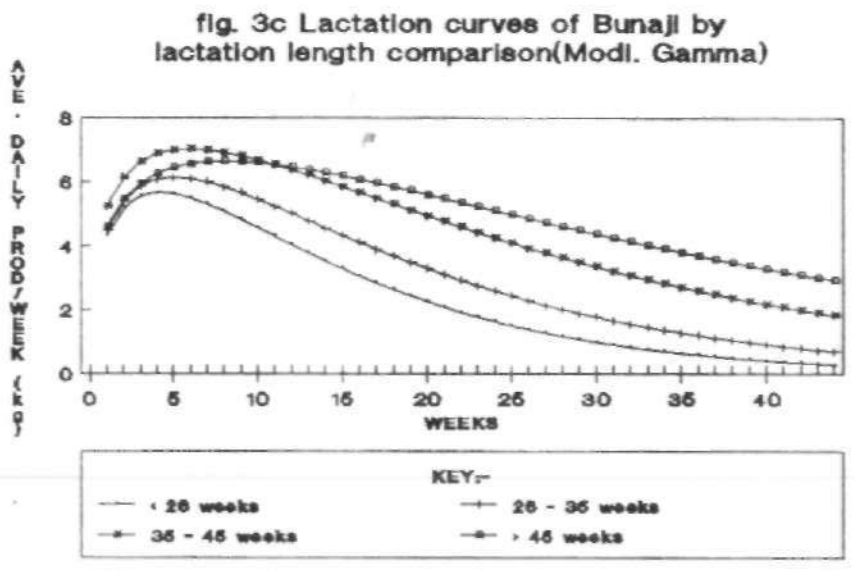
On fitting the Inverse function to Bunaji data (Table 11) the following factors were found to have influence on the curve characteristics. Effect of parity was observed to have significantly affected the following characteristics: Rising Phase(b_0) ($P<0.05$), Average slope (b_1) ($P<0.001$) Rate of decline(b_2) ($P<0.001$), pwk ($P<0.001$), Mxprod ($P<0.05$) and Initprd ($P<0.01$). Effect of lactation length was observed to be significant for the declining phase ($P<0.01$) of the curve, Peak week ($P<0.001$) and Peak production ($P<0.05$). However, effect of season of calving affected only the peak production ($P<0.05$) while the effect of year of calving was observed to be significant ($P<0.05$) for the coefficient of determination (R^2).

Considering the effect of these factors in details for each curve characteristics, it was observed that for the rising extremes (b_0), only parity had significant effects ($P<0.05$). Table 12 showed that the third parity had the lowest value while the fifth parity had the highest (b_0). However, there are no significant differences in the rising phases for first and fifth parity on the one hand, and second, third and fourth parities on the other. No significant effect of season or lactation length was observed. For the average slope, only parity effect was significant. This was highest for 1st parity and lowest for 5th parity whereas the values for parity 2, 3 and 4 did not differ significantly from one another for the declining

figure 3







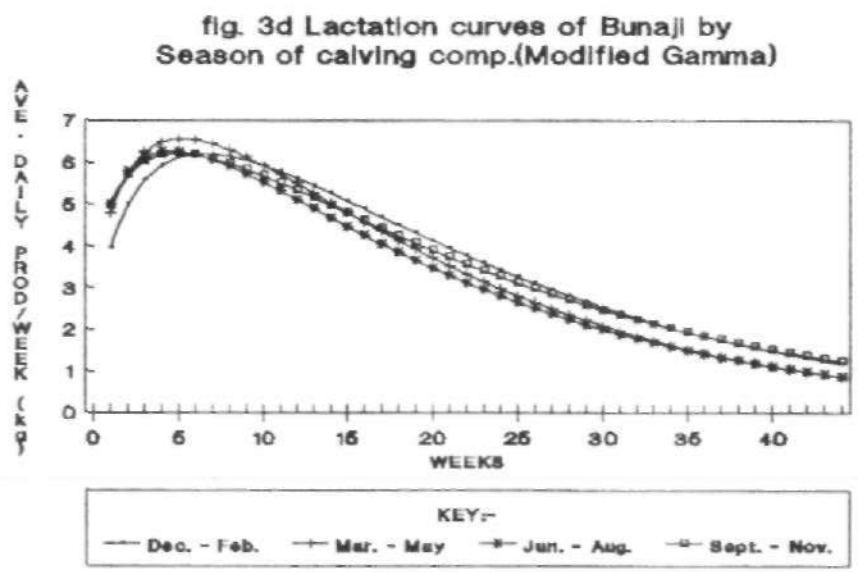


Figure 3. Lactation pattern of Bunaji using Modified Gamma function

TABLE 12: Least Squares means and standard errors for curve and production parameters under Inverse function for Bunaji data

VARIABLE	N	b_0		b_1		b_2		R^2		pwk		Mxprod		Initprd		Tprod	
PARITY		MEAN	S.E	MEAN	S.E	MEAN	S.E	MEAN	S.E	MEAN	S.E	MEAN	S.E	MEAN	S.E	MEANS	S.E
1	53	0.170[a]	0.04	0.0398[c]	0.020	0.0047[a]	0.002	0.61	0.04	5.5[b]	0.3	6.6[a]	1.1	3.5[a]	0.3	1139.9	63.3
2	54	0.103[a,b]	0.04	0.0289[b]	0.019	0.0072[a,b]	0.002	0.65	0.03	4.2[a]	0.3	8.7[a]	1.1	4.3[b]	0.3	1182.7	63.2
3	51	0.057[a]	0.04	0.0194[b]	0.020	0.0074[a,b]	0.002	0.70	0.04	3.7[a]	0.3	10.95[a,b]	1.1	4.7[c]	0.3	1283.5	65.4
4	28	0.069[a]	0.04	0.0219[b]	0.023	0.0076[a,b]	0.002	0.71	0.04	3.6[a]	0.3	8.71[a]	1.3	4.9[c]	0.4	1157.6	74.6
5	18	0.200[b]	0.06	0.0905[a]	0.031	0.0157[c]	0.002	0.73	0.05	3.6[a]	0.4	11.40[b]	1.7	4.2[b]	0.5	1252.2	103.2
LACTATION LENGTH																	
< 26 Weeks	59	0.122	0.03	0.0047	0.017	0.0114[b]	0.001	0.71	0.03	3.1[a]	0.2	7.30[a]	0.92	4.4	0.3	629.1	54.8
26-35 Weeks	70	0.168	0.03	-0.022	0.017	0.0107[b]	0.001	0.71	0.03	3.7[b]	0.2	9.63[b]	0.94	4.3	0.3	1014.0	55.1
36-45 Weeks	49	0.101	0.03	0.0144	0.019	0.0069[a]	0.001	0.70	0.03	4.3[c]	0.3	11.08[c]	1.00	4.4	0.3	1399.7	60.8
>45 Weeks	27	0.096	0.05	0.0186	0.026	0.0050[a]	0.002	0.60	0.05	5.3[d]	0.4	9.16[d]	1.44	4.2	0.4	1769.8	83.0
SEASON OF CALVING																	
DEC - FEB	61	0.143	0.03	-0.0071	0.017	0.0094	0.001	0.65[a]	0.03	4.6	0.2	7.71[a]	0.93	3.9	0.3	1172.8	54.7
MARCH - MAY	64	0.144	0.03	-0.0055	0.018	0.0086	0.001	0.66[a]	0.03	4.0	0.2	10.52[b]	0.98	4.3	0.3	1224.9	57.8
JUNE - AUG.	35	0.112	0.04	0.0064	0.002	0.0084	0.002	0.70[b]	0.04	3.9	0.3	10.39[b]	1.20	4.4	0.4	1263.6	71.8
SEPT - NOV	45	0.087	0.03	0.0213	0.019	0.0076	0.001	0.69[b]	0.03	4.0	0.3	8.55[a]	1.04	4.8	0.3	1151.3	61.6

Note

b_0=rate of rise under Inverse funtions.
b_1=average slope of the under Inverse function.
b_2=rate of decline from the peak Inverse functions.
Initprd=Initial week average daily production
pwk= peak week
Mxprod= peak production/day at peak week
Tprod=total production/lactation

Least squares means connected by the same letter within a subclass are not significantly different from each other (P<=0.05)

extremes. Fifth Parity had significantly (P<0.01) higher values than other parities while first parity had the lowest. Values for parities second, third and fourth 4 did not differ significantly from each other. For lactation length, results indicated that the declining phases could be effectively categorised into two. These were for lactation length less than 35 weeks and the other category of class greater than 35 weeks in milk.

On the evaluation of initial week average daily production, the model showed significant diferences(P<0.001) between parities. Table 12 showed that first parity had significantly (P<0.05) lower average initial week production/day when compared to other parities. By this model, the highest was recorded for fourth parity which did not differ significantly from the value for third parity.

For the peak week, results showed that first calvers took significantly (P<0.05) longer period to attain the peak than those animals in higher parities. In the case of lacation length, the results gave an indication that there was a positive relationship between the peak week and the lactation length. Results showed that animals with short lactation length attained peak earlier than those with longer lactation length. No significant effect of season was noted as far as this parameter is concerned. Using the estimates from the Inverse model, the Peak production was highest in fifth parity though this value of 11.40kg did not differ significantly from the third parity value of about 10.95

kg/day. With respect to lactation length, results indicated that animals in the 36-45 lactation length had significantly ($P<0.01$) higher peak production/day than animals in the other categories. For effect of seasons, results also indicated that animals that calved in the rainy season (March-August) had significantly ($P<0.05$) higher peak production than those that calved in others. This is due to feed availability because pasture was in abundance coupled with the fact that the animals still had good reserve.

The average daily rate of increase to the peak production from initial by season was highest for cows that calved in the periods between March and August. The value for various seasons December-February, March-May, June-August and September-November are 0.82, 1.55, 1.54 and 0.94 kg/day, respectively.

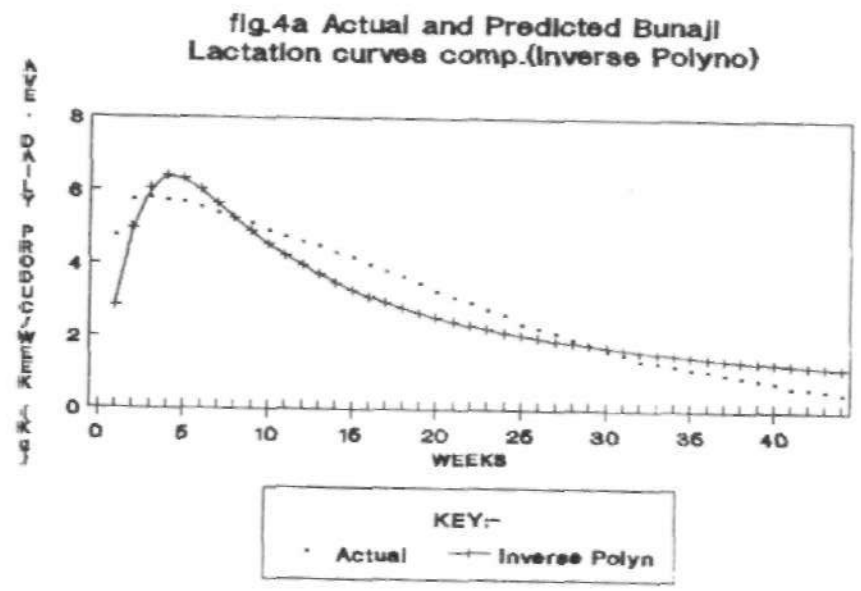
For the adjusted coefficient of determination (R^2) results showed that there were no significant effect of factors on the R^2 except for effect of year of calving. The highest R^2 value of 0.70 was recorded in the cool-wet season namely, June-August season. This value did not differ significantly from the other values of those animals that calved in September-November season or other seasons. The lowest R^2 value was recorded for animals that calved in December-February periods.

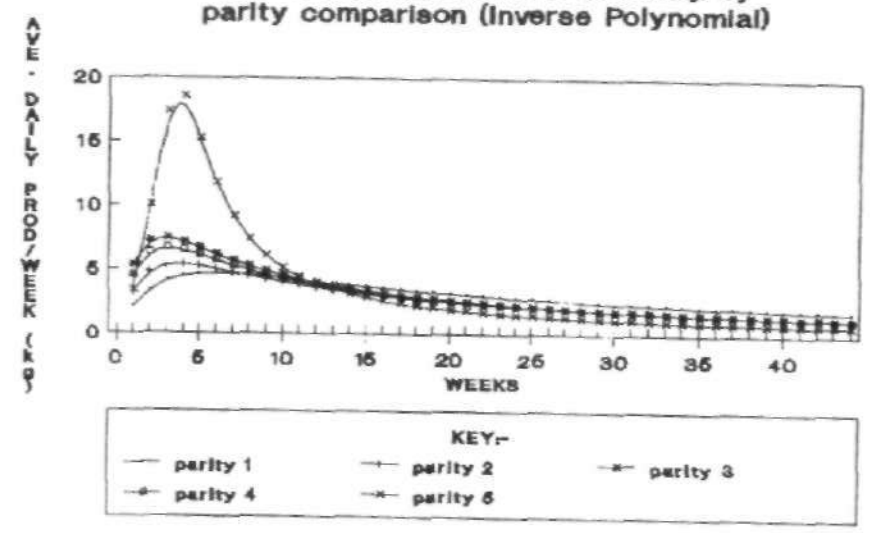
From tables 7, 9, and 11 (Appendix A), showing the least squares analysis of variance for Gamma function, Modified Gamma and Inverse models, parity was consistently found to

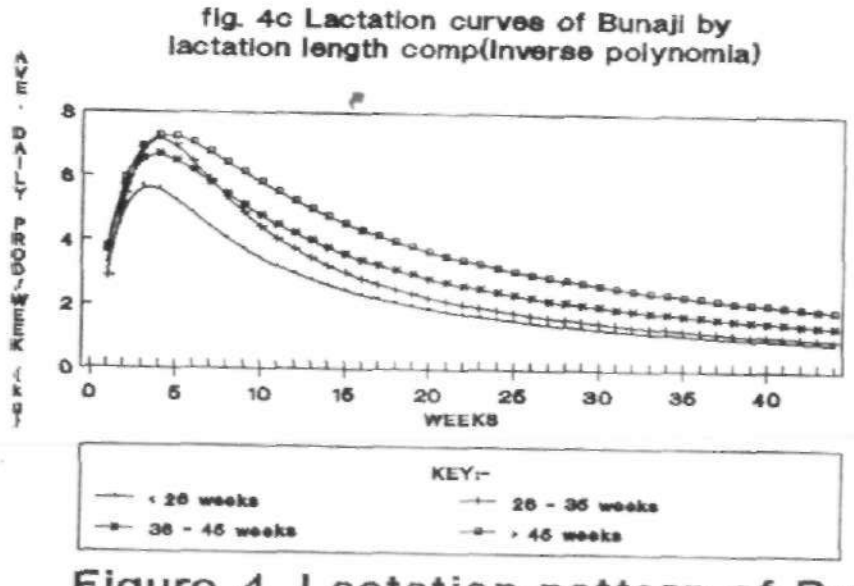
have serious influence on all the curve parameters with the exception of the inclining phase for Gamma function and Modified Gamma function.

Figures 2b, 3b,4b are graphs of production by parity for Gamma function, Modified Gamma and Inverse models. From figure 2b, production curve for parity 1 showed the lowest general level of prodution when compared to other parities. This parity also had the lowest of peak production, however, the result showed that, the persistency was highest for this parity (Table 8). This observation agreed with the findings of Abubakar and Buvanendran (1981) though their study was on Friesian-Bunaji cows and for Gamma function model. This obseration was the same for the other model (Modified Gamma and Inverse models given in figures 3b & 4b). Results further showed that the highest production (Peak prodution) was recorded in the third parity as against fourth and fifth parities recorded in Modified Gamma and Inverse models, respectively. Inverse model consistently over-estimated the peak production compared to others. Figures 2d, 3d, 4d are productions curves by season for each of the three models. The pattern of production is similar. Figures 2c, 3c and 4c are the production curves by lactation length for the three models.

FIGURE 4







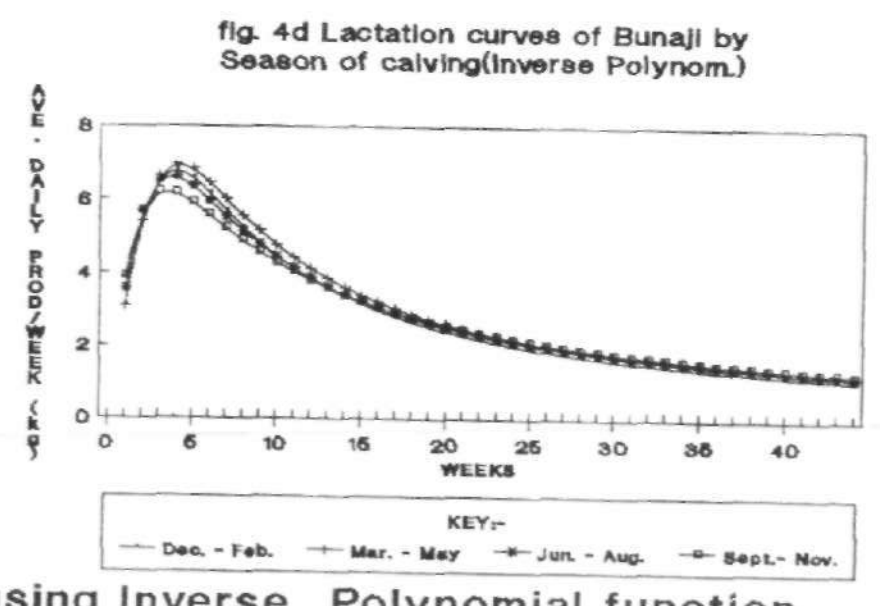


Figure 4. Lactation pattern of Bunaji using Inverse Polynomial function

Considering the effect of season of calving on the curve showed that the highest peak was recorded for animals calving between March-May in both Modified Gamma and Inverse while June-August of calving lead to the highest in Gamma function model. In terms of the maintenance of the peak production, animals that calved in December-February had better persistency for Modified Gamma functions while animals that calved in September-November had the highest persistency in Gamma function model. Results showed that there were no significant differences between cows that calved between December-February and those that calved between September-November under Gamma function model (table 8). Under Gamma function model, the findings agreed with Abubakar and Buvanendran (1981). They recorded highest persistency for animals that calved between September-November although there was no significant effect of season of calving on persistency which is not true in this study. Persistency was found to have been significantly ($P<0.01$) affected by season of calving in Bunaji cows under Gamma function.

Finally, under the lactation length, figures 2c, 3c and 4c, results showed that animals that were in milk for between 36-45 weeks had better persistency when compared to other classification. The results also showed that the pattern of production for Gamma function did not differ significantly from that of Modified Gamma comparing the pattern for the 3 models. They only differed between 3rd and 8th weeks in

production which coinsided with the time the peak was attained and differed from model to model.

As indicated earlier, it was found that parity was one of the factors that significantly ($P<0.05$) affected the curve characteristics for all the models. This section compared the predictions for the models by parity for the production characteristics.

4.5 MODEL COMPARISONS FOR BUNAJI DATA

4.5.1 Initial Week Production

Table 13 gives the observed average initial week production per day compared to the predicted for each of the models. Modified Gamma and Gamma function model generally over-estimated the average initial week production per day while the contrary was the case for Inverse when compared with the observed.

Table 13: Observed and predicted average initial week production/day by parity for Bunaji data

PARITY	N	OBSERVED MEAN	GAMMA MEAN	MODIFIED GAMMA MEAN	INVERSE MEAN
1	52	3.434	3.84	3.86	3.50
2	52	5.129	5.14	5.06	4.30
3	50	5.174	5.67	5.47	4.70
4	28	5.000	5.62	5.47	4.90
5	18	4.753	5.38	5.47	4.20
Correlation with the observed			r=0.942*	r=0.919*	r=0.879^{ns}

* P<0.05
n.s Not significant

The observed average varied between 3.43 - 5.17 kg for Bunaji cow. The predictions over the lactation followed the same pattern of the observed in that, there was a gradual increase from first parity to a maximum which was attained in the third parity and then a gradual decrease subsequently in

parities 4 and 5. Comparing the predicted for each model with the observed, it was noted that Gamma function and Modified Gamma functions significantly (P<0.001) over-estimated the actual or Observed initial week production per day while Inverse model significantly (P<0.05) under-estimated the observed value. Furthermore, the result also indicated that there was no difference between the predicted values from Gamma function and Modified Gamma functions while significant (P<0.01) differences existed between either Gamma function or Modified Gamma and Inverse predictions. Results showed a closer agreement between the predicted and the observed values for the three models in the first parity. However, as the parity increased, the differences between the predicted and the observed for the three models increased. For Gamma function model, the lowest deviation was recorded in the second parity and the largest recorded in fifth parity. The deviation under Gamma function model were -0.41, -0.01, -0.50, -062 and -0.63 kg for first to fifth parities, respectively. The corresponding values for Modified Gamma functions were -0.43, -0.07, -0.3 -0.47 and -0.72 kg while Inverse were 0.07, 0.83, 0.47, -0.1 and -0.55 kg, respectively for the parities. Positive values showed under-estimation while negative values values indicated that there was over-estimation compared to the observed. Generally, over all lactations, results showed the average deviations of -0.434, -0.398 and 0.144kg for Gamma, Modified Gamma and Inverse fucntions, respectively. The correlation

between the observed and the predicted for each model are 0.942, 0.919 and 0.879 for Gamma function, Modified Gamma and Inverse function, respectively. These coefficients were only significant for Gamma based functions

4.5.2 Peak Week

Defined earlier as the week at which maximum production was attained. Table 14 gives the summary for the models with respect to the observed peak week and the corresponding least squares means of predicted values for the different model. The result showed that the peak week for the actual data occurred between 4-7 weeks after parturition in the Bunaji cattle. For first calvings, the peak was attained about the seventh week and this dropped to about the fourth week subsequently for cows in higher parity.

Table 14: Observed and predicted peak week by parity for Bunaji cows

PARITY	OBSERVED MEAN	GAMMA MEAN	S.E.	MODIFIED GAMMA MEAN	S.E.	INVERSE MEAN	S.E.
1	6.78	6.93	0.43	6.58	0.45	5.46	0.26
2	4.42	5.08	0.42	5.15	0.44	4.23	0.26
3	4.02	4.99	0.44	4.78	0.45	3.67	0.27
4	3.81	5.06	0.53	4.97	0.54	3.56	0.32
5	4.44	4.76	0.66	4.82	0.69	3.63	0.42
Overall	4.84	5.41	0.18	5.42	0.51	4.32	0.31
Correlation coefficients between observed and predicted		0.949*		0.965*		0.961*	

* = P < 0.05

Considering the figures from different models, Gamma function values ranged from 5 - 7 weeks, Modified Gamma ranged from 5 to 7 while Inverse ranged from 4 to 6 weeks, respectively . For parities greater than 1, the predictions from Inverse appeared closer to the observed and under-estimation when compared to the actual observed average data. Gamma function values showed that there was a general over-prediction. Comparing the predicted values between models revealed that significant differences existed (P<0.01) between the observed and the predicted for Gamma function, Modified Gamma and Inverse function.

Also, no significant differences existed between the values for Gamma function and Modified Gamma while there was significant difference (P< 0.05) between Gamma based functions and Inverse. The over-prediction was highest for both Gamma function and Modified Gamma in the second, third

and fourth parities. For Gamma function, the deviations were 0.66, 0.97 and 1.25. For Modified Gamma function, the values were 0.73, 0.76 and 1.16 while the corresponding deviations in Inverse model for the same periods were 0.19, 0.35 and 0.25, respectively. Comparatively, Inverse prediction had lower deviations in the said parities when compared to the observed values.

By correlation, the coefficients for Gamma function, Modified Gamma and Inverse were 0.949, 0.965 and 0.962, respectively. These values were all significant at 5%. The coefficients did not differ significantly from each other although, Inverse coefficients was highest. Averaged over all parities, Gamma function and Modified Gamma predictions were significantly closer to the observed than the predictions from Inverse function. This would therefore appear to be more reliable though, one might perhaps prefer Inverse prediction in some of the parities.

Further analysis of the peak week was done to assess the frequency of the co-incidence of the predicted with observed for each of the three models.

Table 15 : Assessment of model prediction co-inciding with observed peak week by parity for Bunaji data

	GAMMA			MODIFIED GAMMA			INVERSE		
PARITY	A	B	C	A	B	C	A	B	C
1	3	10	13	4	9	14	4	12	9
2	4	9	15	4	9	15	4	10	13
3	6	6	12	7	6	12	5	8	12
4	2	3	7	2	3	8	4	4	6
5	2	3	4	3	3	3	2	4	4
Overall	17	31	51	19	30	51	18	38	43

Key: A = % Predicted peak week coincides with actual peak (coincidence)
B = % Predicted < Actual peak week (under-prediction)
C = % Predicted > Actual peak week (Over-prediction)

Table 15 showed the assessment of each model in percentage of occurences that the model correctly predicted the observed. The number of cases when the predicted was less than the observed and vice versa were recorded for each model. It was found that in 18% of the cases, Gamma function predicted the peak correctly, 31% the predicted was less than the observed while in 51% the predicted was higher than the observed. The corresponding percentages values for Modified Gamma and Inverse were (19, 31, 51), and (18, 38, 43), respectively. Generally, it was observed that the three models over-estimated the actual week of peak production. Results showed that the degree of over-prediction was higher for Gamma function and Modified gamma. Over all parities, Inverse and Modified Gamma provided higher correct assessment of the peak week, while Modified Gamma function gave the lowest under-estimation although no significant difference was established between models with respect to correct assessment of models.

For the first category, correct assessment [A], no significant difference existed between models however, significant differences existed between parities. Result showed that adequency of each model was affected by the parity. For instance, the degree of co-incidence under Inverse model was higher in all other parities except the

third where Gamma function and Modified Gamma had high rate. For the second category [B], the result indicated that there were significant ($P<0.01$) differences between models and between parities. There was a lower score in the Gamma function and Modified Gamma functions compared to Inverse. The contrary was observed for category [C]. No significant differences between models but differences existed between scores recorded for parities. This suggested that the degree of co-incidence was not the same over parities. (table 15). For all models, the degree of incorrect assessment for the three models was higher for lower parities (first, second, third) than fourth and fifth parities for the three models. With respect to the rate of co-incidence of the actual peak with the observed, there was no significant differences between models. With respect to under-prediction Modified Gamma and Gamma function had lower percentage leading to their preference although the same model also recorded higher cases of over estimation.

4.5.3 Peak Production

The results of peak production for the observed and the predicted for each of the models by parity are presented on table 16. The observed showed a gradual increase from the first parity peak production of about 5.38 kg per day to a maximum of about 7.03 kg/day in the third parity. A decline in fourth and fifth parities was observed with a peak production level of about 6.38 and 6.35kg/day, respectively.

On Gamma function model the estimated peak production for first parity was about 5.47 kg/day which differed from the actual data by about 2% in over prediction. The production under Gamma function model also increased gradually to a maximum at the third parity with a peak production of about 7.20 kg/day compared to the actual of 7.03 kg/day which was an over-estimation of about the same size observed in the first parity. Subsequently, the peak declined in the fourth and fifth parities, respectively to about 6.25 and 6.94 kg/day compared to the actual observed production of 6.38 and 6.35 kg/day, respectively.

TABLE 16: Observed and predicted peak production per day by parity for Bunaji cows

PARITY	OBSERVED MEANS		GAMMA MEANS	S.E.	MODIFIED GAMMA MEANS	S.E.	INVERSE MEANS	S.E.
1	5.38	0.20	5.47	0.32	6.89	0.92	6.64	1.06
2	6.78	0.19	6.77	0.31	6.76	0.93	8.75	1.06
3	7.03	0.25	7.20	0.33	6.77	0.95	10.95	1.11
4	6.38	0.31	6.25	0.39	5.78	1.13	8.71	1.27
5	6.35	0.35	6.94	0.50	7.17	1.46	9.17	1.73
Overall	6.39	0.26	6.11	0.32	6.56	0.55	9.070	1.25
Correlation coefficient between observed and predicted			0.949*		0.965*		0.961^{ns}	

* = P <0.05 ns = non significance.

Under Modified Gamma function, the predicted peak production was higher than the observed with an over-esimation of about 28% and a gradual decrease in the

peak production until the fourth parity which was followed by a sudden increase at the fifth parity with a production of about 7.17 kg/day which was the maximum production. The production at the fifth parity under Modified Gamma was an over-esimation of the observed fifth parity peak by about 6.35 kg/day. The over-estimation was about 13%.

For Inverse, there was generally an over-estimation of the actual data. However, the pattern of production was similar to the actual data and prediction by Gamma function model in that the peak was attained in the third parity. The first parity peak production was about 6.64 kg/day an over-estimation of about 23% compared to the actual first parity production. The third parity peak production was about 10.95 kg/day. This was also an over-estimation of about 56%. The peak production for the fourth and fifth parities were 8.71 and 9.17 kg/day, respectively. Generally over parities, the result showed that Gamma function underestimated the actual peak production by about 4% while Modified Gamma and Inverse over-estimated by about 3% and 42%, respectively.

The comparision between predicted and observed showed that significant differences existed between Gamma function predictions and Observed ($P<0.001$), Modified Gamma prediction and observed ($P<0.01$), Inverse predictions and observed. However no significant difference existed between Gamma function and Modified Gamma function. Comparison between Gamma function, Modified Gamma and Inverse showed that there were significant (P0.05) differences between Gamma function,

Modified Gamma and Inverse while no difference was observed between Gamma function and Modified Gamma function.

The correlation between the predicted and the observed are 0.999, 0.965 and 0.961 for Gamma function, Modified Gamma and Inverse, respecively. All the coefficients were significant at 5% with respect to all the parameters considered. It is obvious that over all lactations, Modified Gamma and Gamma function model would be preferred to Inverse as far as the adequancy of the model is concerned in correctly predicting the actual peak production per day for Bunaji cows.

4.5.4 Total Production/lactation

This parameter has been the most important yardstick for measuring the productivity of a cow by both farmer and the Breeder or scientists. This is considered as an economic trait and of high importance. A model that can adequately be used to predict the productivity of an animal will obviously go a long way towards evaluating a cow before the completion of the lactation interval. Table 17. gives the summary of the observed and the predicted total production for each of the models by parity.

The observed results showed that Bunaji seemed to have attained the peak production in the second parity with a production varying between 993 to 1111 kg. The production gradually declined to between 761.25 $\pm$ 86. kg in the fifth parity. On the basis of the data, it was observed that Gamma function and Modified Gamma under-estimated generally except

for the first and fourth parity for Gamma function model. Inverse model on the other hand was found to have over-estimated the total production for Bunaji cow.

TABLE 17: Observed and Predicted Total production by parity for Bunaji data

PARITY	OBSERVED MEAN	OBSERVED S.E.	GAMMA MEAN	GAMMA S.E.	MODIFIED GAMMA MEAN	MODIFIED GAMMA S.E.	INVERSE MEAN	INVERSE S.E.
1	922.40	60.00	929.9	62.56	914.0	59.77	947.8	67.84
2	1052.88	59.37	1036.4	57.93	1026.8	61.11	1118.2	66.85
3	939.51	49.78	932.1	49.33	933.8	49.32	1021.4	63.05
4	782.83	62.19	786.7	61.23	778.9	61.88	810.3	69.66
5	761.25	86.01	785.5	85.86	760.7	85.85	781.5	111.07
Overall	928.4	28.48	933.0	28.41	930.2	28.51	1006.3	33.26
Correlation between observed and Predicted			0.998*		0.999*		0.991*	

* = P < 0.05

Considering the rate of under or over-estimation, it was observed that Inverse deviations ranged from 3 to 9 percent over-estimation. This was highest in the third parity. Averaged over all parities, Inverse model was found to have significantly over-estimated the actual production by about 8% while the correponding figures for Gamma function and Modified Gamma were 0.5% and 0.2%, respectively.

Comparison of the observed and the predicted from Gamma function, Modified Gamma and Inverse showed that there were significant ($P<0.05$) differences. However, no significant differences existed between the observed, Gamma function and Modified Gamma predictions. Results further indicated that there were significant differences in the total production between parities in confirmation of the least squares analysis on tables 7 , 9 and 11 given earlier.

The correlation co-efficients between the observed and the predicted for each of the models were 0.998, 0.999 and 0.991 respectively for Gamma function, Modified Gamma and Inverse. No significant differences existed between the coefficients of Gamma function and Modified Gamma function, however there were significant differences between Inverse coefficients and others (Gamma function and Modified Gamma function). The results from the predicted total production showed that Gamma function and Modified Gamma function had closer relationship with the observed than the predictions from Inverse function and hence more reliable with respect to total production.

4.5.5 Co-efficient of determination

This statistic is considered as the most useful tool for assessing the adequacy of a model. The higher the R^2 value, the better the model. The table showed that the value obtained using Gamma function and Modified Gamma were not significantly different. Results also showed that generally, Modified Gamma and Gamma function models provided higher R^2 over all the parities. These findings suggested that these two models provided better fitness when used for modelling the production pattern for Bunaji cows.

TABLE 18: Comparison of R^2 between function by parity for Bunaji data.

PARITY	GAMMA MEAN	GAMMA S.E.	MODIFIED GAMMA MEAN	MODIFIED GAMMA S.E.	INVERSE MEAN	INVERSE S.E.
1	0.73	0.024	0.75	0.023	0.61	0.035
2	0.81	0.023	0.81	0.023	0.65	0.034
3	0.81	0.024	0.81	0.023	0.70	0.036
4	0.83	0.028	0.82	0.028	0.71	0.041
5	0.85	0.037	0.86	0.035	0.73	0.054
Overall	0.84	0.32	0.04	0.033	0.71	0.013

R^2 = Coefficient of determination.

Generally, the coefficient of determination increased with parity number. Furthermore, the fitness recorded under Inverse model was found to be consistently lower than the corresponding values in Gamma function and Modified Gamma functions. The explanation for this may be obtained from the various discrepancies in the parameter for the curve characteristics earlier discussed. Notable among these are the initial week production, peak week, peak production, inclining and declining phases of the curve.

4.5.6 Persistency

This, as earlier defined, is the rate at which the peak production is maintained. This particular parameter was measurable only on the Gamma function and Modified Gamma functions. The parameter is considered useful particularly after the observations that over the models, Gamma function and Modified Gamma were found to be better with respect to virtually all the parameters used in assessing the suitability and adequacy of model.

Table 19 below gives the summary of the least squares means measure of persistency over parity for Gamma function and Modified Gamma functions. From the table below, it appeared obvious that Modified Gamma function provided a significantly higher ($p<0.01$) measure of persistency than Gamma function model. On the basis of the results, Modified Gamma function was found to provide a better fitness when compared to the Gamma function model.

TABLE 19: Comparison of persistency by parity for Gamma and Modified Gamma for Bunaji data

	GAMMA		MODIFIED GAMMA	
PARITY	MEAN	S.E.	MEAN	S.E.
1	3.22	0.08	4.16	0.10
2	3.00	0.08	3.50	0.10
3	3.00	0.08	3.49	0.10
4	3.08	0.10	3.49	0.12
5	2.84	0.13	3.44	0.15
Overall	2.93	0.04	3.66	0.05

4.5.7 Correlation

The correlation coefficients between the curve and production characteristics for each of the model were computed. The coefficients are given in tables 20, 21 and 22 for Gamma function, Modified Gamma and Inverse models.

Table 20 Correlation between curve and production parameters for under Gamma function for Bunaji data

		a	b	c	pwk	s	Initprd	Mxprod	Tprod
1.	a	1.000							
2.	b	-0.644***	1.000						
3.	c	-0.182**	0.667***	1.000					
4.	pwk	-0.617***	0.537***	-0.164*	1.000				
5.	s	0.188**	-0.601**	-0.870***	0.180**	1.000			
6.	Initprd	0.938***	-0.649***	-0.260**	-0.587***	0.272***	1.000		
7.	Mxprod	0.663***	-0.090	-0.002	-0.110	0.037	0.645***	1.000	
8.	Tprod	0.244***	-0.152*	-0.466***	0.412***	0.442***	0.248***	0.499***	1.000

Table 21 Correlations between curve and production parameters under Modified Gamma function for Bunaji data

		a	b	c	pwk	s	Initprd	Mxprod	Tprod
1.	a	1.000							
2.	b	-0.578***	1.000						
3.	c	-0.168*	0.679***	1.000					
4.	pwk	-0.517***	0.493***	-0.195**	1.000				
5.	s	-0.381***	0.200**	-0.399***	0.811***	1.000			
6.	Initprd	0.856***	-0.634***	-0.244**	-0.348***	-0.348***	1.000		
7.	Mxprod	0.260***	-0.090	0.069	-0.050	0.045	0.262***	1.000	
8.	Tprod	0.250***	-0.146*	-0.453***	0.393***	0.521***	0.245***	0.265***	1.000

Significance of correlation coefficients is given by
* P < 0.05 ** P< 0.01 *** P < 0.001

a=general level of production
b= rate of rise to the peak
c= rate of decline from the peak
s= persistency
Initprd=initial week average daily production,
pwk= peak week
Mxprod= peak production
Tprod = predicted total production)

From table 20, most of the curve parameters i.e the inclining and the declining phases from the peak as well as the persistency were found to have significant correlations with some of the production indicators.

Considering the coefficients for Gamma function model, the results showed that there was a significant and positive correlation between the general level of production and curve parameters. Results however showed a significant negative correlation with the peak week and the rate of rise and decline of the curves. Considering the rate of rise to the peak, results showed a nagative but significant correlation between initial production, predicted total production and general level of production while it is positively correlated with rate of decline peak. It had no significant correlation with the peak production. With the rate of decline from peak results indicated a significant but negative correlation coefficients with the production characteristics.

The results also showed that persistency was negatively correlated with the rate of rise to the peak and rate of decline from the peak but was positively correlated with the general level of production. This tended to suggest that the higher the general level of production possibly the higher the persistency.

For Modified Gamma function, (table 21) the pattern of the results was similar to what was observed for Gamma function with the exception of some cases. Notable among these was the correlation between persistency and peak week.

In Gamma function model, results indicated a lower correlation coefficient of 0.180 as against a coefficient of 0.811 observed under Modified Gamma function. Under Modified Gamma, the correlation coefficient between persistency and the rate of rise to the peak, rate of decline from the peak and the general level of production were 0.200, -0.399 and -0.381, respectively. The corresponding coefficients under the Gamma function models were -0.601, -0.870 and 0.188, respectively. This observation appeared therefore to be conflicting particularly for the coefficients between persistency and the rate of rise to the peak and the general level of production.

For both functions, the correlation between the initial production and peak week was negative and significant ($P<0.001$) implying that the higher the initial production, the lower the peak week. This is expected in practice. Similarly, it was observed that the correlation between the peak production and peak week were negative but not significant for both models. Table 22 gives the coefficients for the correlation between curve parameters for the Inverse function. Considering the relationship between the curve parameters viz; the rising phase (b_0) and declining phase (b_2) and the slope[b_1], and the production characteristics of the curve (initial production, peak week, peak production and predicted total production) the following were observed.

TABLE 22 : Correlation coefficients between curve and production parameters under Inverse function for Bunaji data

	b_0	b_1	b_2	pwk	Initprd.	Mxprod.	Tprod.
b_0	1.000						
b_1	-0.647***	1.000					
b_2	0.625***	-0.794***	1.000				
pwk	0.440***	0.035	-0.234**	1.000			
Initprd	-0.599***	0.139*	-0.173**	-0.593***	1.000		
Mxprod	-0.066	-0.556***	-0.044	-0.083	0.282***	1.000	
Tprod	-0.064	-0.247**	-0.414***	0.329***	0.089	0.619***	1.000

Significance of correlation coefficients is given by
* P<0.05 ** P<0.01 *** P<0.001

parameters viz;
b_0 = the rising phase; b_2 = declining phase
b_1 = the general slope
Initprd=initial week average daily production,
pwk= peak week,
Mxprod= peak production
Tprod = predicted total production)

The rising phase of the curve was positively and significantly ($P<0.001$) correlated with only the peak week but negatively and significantly ($P<0.001$) correlated with the initial production. It was also observed that the parameter or variable was negatively correlated with peak production and the predicted total production though not significantly. Using the "slope" of the curve, it was found to be negatively and significantly ($P<0.001$) correlated with predicted peak production and predicted total production but positively and significantly ($P<0.05$) correlated with the predicted initial production. For the declining phase, it was negatively and significantly ($P<0.001$) correlated with the predicted total production, predicted initial production and predicted peak week. These observations were found to be of practical importance in that, the lower the rate of fall in the curve, the higher are the possible predicted values of total production and peak week.

4.6 EVALUATION OF THE MODELS USING FRIESIAN-BUNAJI CROSSBRED DATA

Two hundred and sixty-seven lactations over five Parities were analysed. Summary of the actual data is given in table 23. Results showed that the Friesian-Bunaji cow had an average production of about 1862.04 kg/lactation with a standard error of about 44.08 kg over an average lactation length of about 36.22 weeks. This gives an average daily production of about 7.35kg for the crossbred cow. The actual average initial week production/day was 8.69kg while the peak production was about 11.77 kg/day at the peak week. The peak was attained about 4.82 weeks after parturition. This implied that the observed rate of increase per day from the initial to the peak for the Friesian-Bunaji cow was about 0.64 kg.

Table 23. Summary of production characteristics for Friesian-Bunaji data.

VARIABLE	N	MEAN	S.E
Initprd/day	267	8.69	0.185
Pwk(week)	267	4.82	0.248
Mxprod/day(kg)	267	11.77	0.401
Tprod/lact. (kg)	267	1862.04	44.08
Av.Lact.length(weeks)	267	36.22	0.62

parameters viz;
Initprd=initial week average daily production,
pwk= peak week,
Mxprod= peak production
Tprod = Total production/lactation

Table 24 gives the summary of the performance of each of the models' fitting the Friesian-Bunaji data. Considering the overall assessment of the adequacy by way of the coefficient of determination (R^2) for the models.The results showed that Gamma and Modified Gamma models had the same R^2 of about 74%

while the the corresponding value for Inverse function was 61%. This value differed significantly (P<0.05) from Gamma based models. This observation suggests that the two models(Gamma & Modified Gamma) fitted the Friesian-Bunaji data significantly (P<0.05) better that the Inverse function.

Closer evaluation and comparison of the models were made using the curve characteristics. Considering the initial week average production/day, the actual value (table 23) was 8.69 kg, and the corresponding estimated least squares values for Gamma, Modified Gamma and Inverse functions were 9.06, 8.94 and 7.71 kg, respectively. The findings indicated that Gamma and Modified Gamma models over-estimated the observed by about 4.3 and 2.9 percent, respectively while Inverse function under-estimated the observed by about 11.3 percent. The under-estimation was significantly (P<0.01) different from the values for Gamma and Modified Gamma estimation.

For the peak week, it was observed that Gamma and Modified Gamma models over-estimated the observed by 12 and 14 percent while Inverse function under-estimated by about 12 percent. In absolute terms, one might argue that these figures did not differ significantly from one another. They, infact, were in the range of 4 - 6 weeks reported by Abubakar and Buvanendran (1981) after parturition.

With regard to the peak production, results indicated that the observed was 11.27 kg/day at peak whereas 11.10, 10.99 and 12.95 kg/day were estimated from Gamma, Modified Gamma and Inverse functions, respectively.

Table:24 Predicted average curve and production parameters for Friesian-Bunaji data by functions

CHARACTERISTICS	GAMMA MEAN	GAMMA S.E	MODIFIED GAMMA MEAN	MODIFIED GAMMA S.E	INVERSE POLYNOMIAL MEAN	INVERSE POLYNOMIAL S.E
Initprd (kg)	9.06	0.17	8.94	0.20	7.71	0.19
pwk (week)	5.40	0.18	5.50	0.16	4.24	0.11
Mxprod/day(kg)	11.10	0.31	10.99	0.26	12.95	0.36
Tprod	1860.30	27.50	1867.93	27.78	1947.73	33.16
Persistency s	3.41	0.038	3.90	0.026	N/A	
Adjusted R^2	0.74	0.20	0.74	0.20	0.61	0.12
Curve Parameters						
General level of Production [a /b_0] [A]	2.974	0.020	2.954	0.022	0.0132	0.003
Rate of Rise [b /b_1] [B]	0.292	0.012	0.293	0.012	0.0637	0.004
Rate of Decline [c /b_2] [C]	0.0516	0.002	0.0528	0.003	0.0039	0.0002

Note

Initprd=Initial week average daily production
pwk= peak week
Mxprod= peak production/day at peak week
Tprod=total production/lactation
a=general level of production under Gamma basedfuntions.
b=rate of rise to the peak under Gamma based functions.
c=rate of decline from the peak under Gamma based functions.
b_0 , b_2 are the corresponding equivalents for b and c under Inverse function, b_1 is the general slope

From table 24, Inverse function over-estimated the peak production/day while the values from Gamma and Modified Gamma models were lower than the observed. The under-estimations were 0.67, 0.78 kg/day for Gamma and Modified Gamma while the over-estimation from Inverse function was 1.18kg/day. Considering the rate of rise to the peak/day, the actual data showed an average of 0.64 kg while the corresponding figures for Gamma, Modified Gamma and Inverse function were 0.38, 0.37 and 1.24kg, respectively. Inverse function had grossly over-estimated the rate by about 94%

The Total production/lactation showed no significant (P>0.05) differences between the observed production of about 1862.04 kg and the values of 1860.03 kg and 1867.93 kg estimated for Gamma and Modfied Gamma. The value from Inverse function was 1947.73 kg leading to an over-estimation of about 5% when compared to the actual production from data.

On general evaluation of the three models from various criteria, results showed that Inverse function appeared least adequate for representing the production pattern in Friesian-Bunaji data. The Persistency s, which is another important measure of comparing models was computed for Gamma based functions. Persistency was earlier defined as the rate at which the peak production is maintained. The higher this statistic is the better. Results indicated a higher persistency for Modified Gamma model (3.90) compared to 3.41 recorded for Gamma model.

Table 25. Observed Daily, Predicted and % Deviations of Models for Friesian-Bunaji data

Week	Observed	Gamma	%Dev	Modified Gamma	%Dev.	Inverse	%Dev
1	8.72	8.43	3.4	8.3	5.3	5.6	35.6
2	10.43	9.80	6.1	9.6	8.1	8.6	17.6
3	10.45	10.47	-0.2	10.3	1.9	9.9	5.6
4	10.23	10.82	-5.8	10.6	-3.4	10.2	0.4
5	9.96	10.96	-10.1	10.7	-7.6	10.0	-0.8
6	9.62	10.98	-14.2	10.7	-11.4	9.7	-0.5
7	9.44	10.91	-15.5	10.6	-12.6	9.2	2.5
8	9.17	10.77	-17.4	10.5	-14.3	8.7	4.8
9	8.93	10.59	-18.7	10.3	-15.4	8.3	7.5
10	8.93	10.37	-16.1	10.1	-12.8	7.8	12.6
11	8.49	10.12	-19.2	9.8	-15.8	7.4	12.8
12	8.31	9.86	-18.6	9.6	-15.0	7.0	15.7
13	8.13	9.59	-17.9	9.3	-14.2	6.7	18.1
14	7.92	9.30	-17.5	9.0	-13.7	6.3	20.0
15	7.66	9.01	-17.6	8.7	-13.8	6.0	21.3
16	7.40	8.72	-17.8	8.4	-13.9	5.8	22.2
17	7.19	8.43	-17.3	8.1	-13.2	5.5	23.4
18	6.98	8.14	-16.7	7.9	-12.5	5.3	24.5
19	6.76	7.86	-16.2	7.6	-11.8	5.1	25.2
20	6.74	7.57	-12.3	7.3	-8.0	4.9	27.9
21	6.43	7.30	-13.5	7.0	-9.0	4.7	27.4
22	6.26	7.02	-12.1	6.7	-7.6	4.5	28.2
23	6.00	6.76	-12.6	6.5	-8.0	4.3	27.7
24	5.83	6.50	-11.5	6.2	-6.7	4.2	28.2
25	5.59	6.24	-11.7	6.0	-6.9	4.1	27.5
26	5.42	6.00	-10.6	5.7	-5.6	3.9	27.7
27	5.20	5.76	-10.7	5.5	-5.7	3.8	27.0
28	4.91	5.53	-12.7	5.3	-7.4	3.7	25.0
29	4.73	5.30	-12.1	5.1	-6.9	3.6	24.5
30	4.53	5.09	-12.3	4.8	-6.8	3.5	23.5
31	4.09	4.88	-19.3	4.6	-13.2	3.4	17.6
32	3.81	4.68	-22.8	4.4	-16.5	3.3	14.0
33	3.45	4.48	-29.8	4.3	-23.2	3.2	7.6
34	3.10	4.29	-38.2	4.0	-30.8	3.1	-0.2
35	2.86	4.11	-43.5	3.9	-35.8	3.0	-5.8
36	2.63	3.94	-49.7	3.7	-41.3	3.0	-12.1
37	2.40	3.77	-56.9	3.6	-48.2	2.9	-19.9
38	2.20	3.61	-64.2	3.4	-54.6	2.8	-27.8
39	2.03	3.45	-70.3	3.3	-60.4	2.8	-35.8
40	1.84	3.30	-79.3	3.1	-69.0	2.7	-46.2
41	1.63	3.16	-94.1	3.0	-82.4	2.6	-61.6
42	1.38	3.02	-118.2	2.8	-104.5	2.6	-85.7
43	1.18	2.89	-144.3	2.7	-129.0	2.5	-113.0
44	1.01	2.76	-172.3	2.6	-155.5	2.5	-142.7

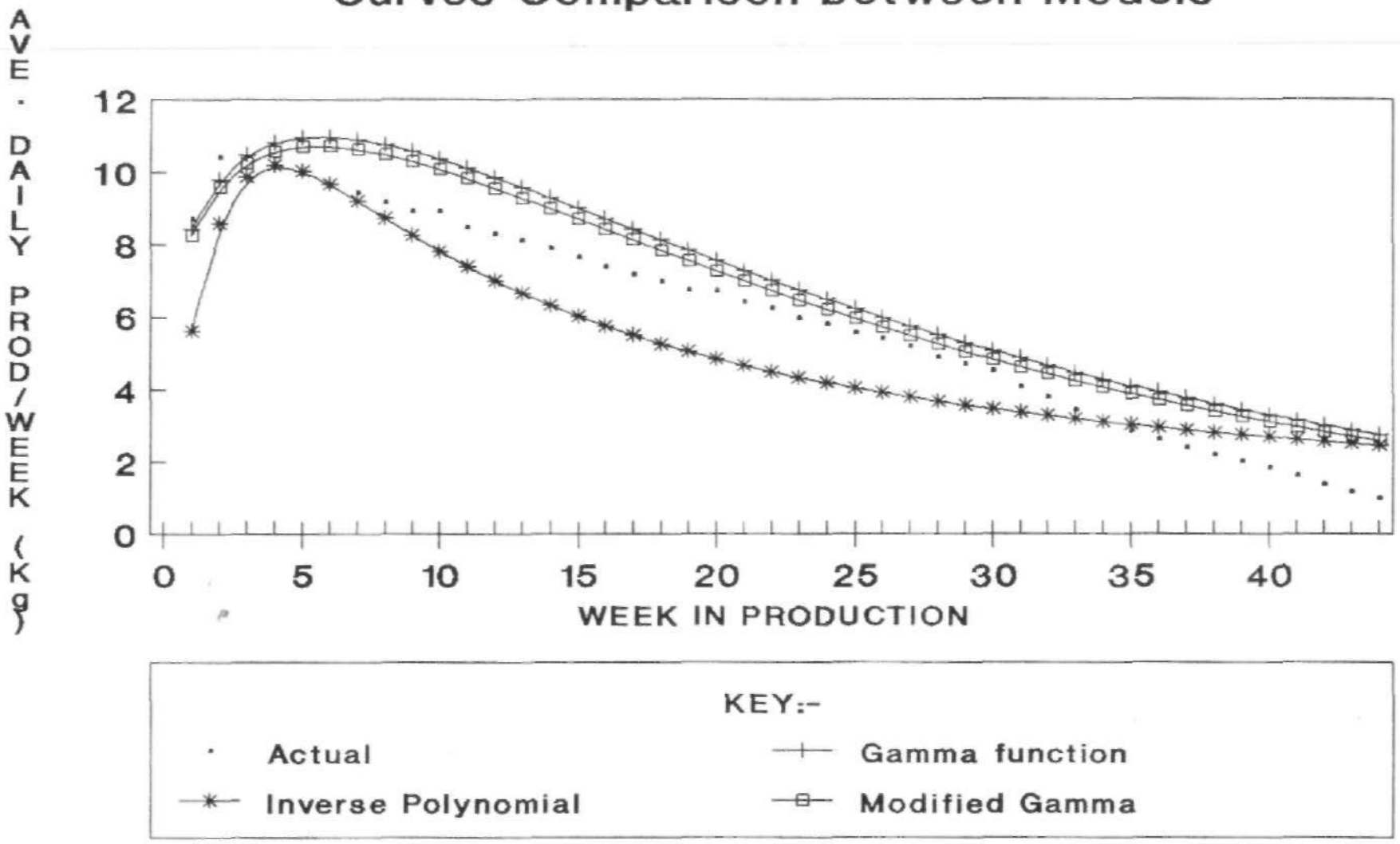
-ve deviations indicate over-estimation
+ve deviations indicate under-estimation

The other parameters in table 20 are the curve characteristics obtained from least squares analysis after correcting for environmental factors like parity at calving, lactation class length, season and year of calving. These parameters have been used in generating figure 5. This figure showed the pattern of production of actual data and prediction from the three models under evaluation. The parameter [A] provides the general level of production for Gamma and Modified Gamma models. Under the Inverse function, the parameter is referred to as the average slope which is also an indicator of the general level of production. Inverse function was found to have under estimated the actual general level of production. Parameter [B] is an indicator that shows the rate of rise to the peak while [C] measured the rate of decline from the peak.

figure 5

figure 5

fig. 5 Friesian-Bunaji cow production
Curves Comparison between Models



PARAMETERS FROM LEAST SQUARES ANALYSIS

Observation from figure 5 showed some close agreement between the observed and fitted values obtained from Gamma and Modified Gamma functions in the first three weeks while the estimated values obtained from Inverse function was significantly ($P<0.05$) different during the same period. From this graph and table 25, it was found that over the entire period, the estimated values from Gamma and Modified Gamma functions consistently over-estimated the actual values from the 3rd week after parturition. The degree of over-estimation by Gamma model varied from 5.8% at the 4th week to a maximum of about 19.2% and a gradual drop to about 12.3% in the 20th week. The rate of change stabilized relatively until about the 31st week when there was a sudden change in the rate of over-estimation from about 12% to about 19%. This gradually increased as the lactation length increased. This could perhaps be explained using the fact that the average lactation length for Friesian-Bunaji cow was 36 weeks. Beyond the 31st week, most of the cows in milk were about the top 5% of the group with higher producing ability when compared to the others of the same breed. Comparing the predictions from Gamma and Modified Gamma functions, the pattern of production was similar. The difference was only in the degree of over-estimation. This was found lower in Modified Gamma than Gamma.

For Inverse function, there was a general under-estimation of the observed average daily production with the exception of the prediction between the 4th and 6th

weeks and beyond the 34th weeks, respectively. Beyond the 34th week, the degree of over-estimation was significantly lower ($P<0.01$) than the corresponding values from Gamma and Modified Gamma predictions. It would thus appear that Inverse function was better in adequacy beyond the 34 weeks. This might not be true as the discrepancy between the observed and the predicted became larger beyond the 38th week.

Table 26 is the summary of the cummulative production data for the observed and predicted from Gamma, Modified Gamma and Inverse functions with the deviations from the observed expressed in percentage as well multiplicative factors for predicting total yield from part productions for each model. Considering the deviations, columns 6,7 and 8, the pattern of variation showed that there was a general over prediction beyond the 6th week for Gamma and Modified Gamma. The rate of over prediction was however lower for the Modified Gamma function. The amount of deviations from Gamma prediction varied between 3.5 and 17.9 percent over 44 weeks or 305 day period. The corresponding figures for Modified Gamma were 1.1 and 13.6 percent, respectively. For both Gamma and Modified Gamma, there were some degree of consistency in the over-prediction between 14th and 34th week cummulative production as the percentage deviation was almost constant (12-13) for Gamma and about 9 for Modified Gamma model.

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TABLE 26. Observed, Predicted Cummulative Production, % Deviations and Multiplicative Factors

WEEK	OBSERVED YIELD	PREDICTED PRODUCTION FOR MODEL: GAMMA	MODIFIED GAMMA	INVERSE	PERCENTAGE DEVIATIONS FROM OBSERVED AVERAGE PRODUCTION: GAMMA	MODIFIED GAMMA	INVERSE	MULTIPLICATIVE FACTORS FOR PREDICTING PART YIELD: GAMMA	MODIFIED GAMMA	INVERSE
4	278.83	276.64	270.62	239.96	7.85	2.94	13.94	7.757	7.643	6.660
6	415.87	430.22	420.63	377.93	-3.45	-1.14	9.12	4.988	4.917	4.229
8	546.21	581.98	568.47	503.51	-6.55	-4.08	7.82	3.687	3.638	3.174
10	671.23	728.70	711.13	616.00	-8.56	-5.94	8.23	2.945	2.908	2.595
12	788.83	868.56	846.86	716.87	-10.10	-7.40	9.12	2.471	2.442	2.229
14	901.11	1000.79	974.89	807.80	-11.10	-8.20	10.40	2.144	2.122	1.979
16	1006.60	1124.90	1094.94	890.33	-11.80	-8.80	11.60	1.908	1.889	1.795
18	1105.79	1240.89	1206.87	965.79	-12.20	-9.10	12.70	1.729	1.714	1.655
20	1200.30	1348.90	1310.75	1035.23	-12.40	-9.20	13.80	1.591	1.578	1.544
22	1289.19	1449.14	1407.00	1099.42	-12.40	-9.10	14.70	1.481	1.470	1.454
24	1372.09	1541.96	1495.90	1159.13	-12.40	-9.00	15.50	1.392	1.383	1.379
26	1449.07	1627.64	1577.80	1214.92	-12.30	-8.90	16.20	1.318	1.311	1.316
28	1519.84	1706.67	1652.19	1267.28	-12.30	-8.80	16.60	1.257	1.251	1.261
30	1584.66	1779.40	1722.42	1316.56	-12.30	-8.70	16.90	1.206	1.201	1.214
32	1639.96	1846.32	1785.91	1363.11	-12.60	-8.90	16.90	1.162	1.158	1.172
34	1685.88	1907.71	1844.08	1407.21	-13.20	-9.40	16.50	1.125	1.122	1.136
36	1724.38	1964.06	1897.35	1449.07	-13.90	-10.00	16.00	1.093	1.090	1.103
38	1756.58	2015.72	1946.07	1488.90	-14.80	-10.80	15.20	1.065	1.063	1.073
40	1783.60	2062.97	1990.59	1526.98	-15.70	-11.60	14.40	1.040	1.039	1.047
42	1804.74	2106.23	2031.19	1563.38	-16.70	-12.50	13.40	1.019	1.018	1.022
44	1820.07	2145.78	2068.29	1598.24	-17.90	-13.60	12.20	1.000	1.000	1.000

Note -ve deviations indicate Predicted > Observed ==> over-prediction

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Table 27. Observed and Predicted Cummulative productions from Multiplicative Factors for Friesian-Bunaji cows

WEEK	OBSERVED	GAMMA	MODIFIED GAMMA	INVERSE	DEVIATIONS(%) GAMMA	MODIFIED GAMMA	INVERSE
4	278.83	234.64	238.14	273.28	15.9	14.6	2.0
6	415.87	364.89	370.92	430.38	12.3	10.8	-3.5
8	546.21	493.65	500.29	573.43	9.6	8.4	-5.0
10	671.23	618.02	625.88	701.38	7.9	6.8	-4.5
12	788.83	736.57	745.32	816.54	6.6	5.5	-3.5
14	901.11	848.91	857.71	919.69	5.8	4.8	-2.1
16	1006.60	953.92	963.51	1013.97	5.2	4.3	-0.7
18	1105.79	1052.67	1061.88	1099.74	4.8	4.0	0.6
20	1200.30	1143.98	1153.40	1178.80	4.7	3.9	1.8
22	1289.19	1228.95	1238.14	1251.77	4.7	4.0	2.9
24	1372.00	1307.52	1316.03	1319.85	4.7	4.1	3.8
26	1449.07	1380.93	1388.31	1383.03	4.7	4.2	4.6
28	1519.84	1447.95	1454.89	1443.35	4.7	4.3	5.0
30	1584.66	1509.10	1515.46	1499.20	4.8	4.4	5.4
32	1639.86	1566.33	1571.74	1552.96	4.5	4.2	5.3
34	1685.88	1617.84	1622.17	1602.17	4.0	3.8	5.0
36	1724.38	1665.21	1669.79	1650.11	3.4	3.2	4.3
38	1756.58	1708.99	1712.20	1696.24	2.7	2.5	3.4
40	1783.60	1750.07	1751.75	1738.37	1.9	1.8	2.5
42	1804.74	1786.13	1787.89	1780.89	1.0	0.9	1.3

The observation for Inverse function between this period showed under-prediction of the observed or actual data. Generally, the absolute deviation figures showed that Modified Gamma model had the lowest figures with an overall average deviation of about 8.5% compared to Gamma figures of about 11.9% and 13.4% for Inverse function.

Columns 9, 10 and 11 gives the Multiplicative factors developed for predicting total production from part production(Abubakar and Buvanendran (1981)). Table 27. gives the summary of the observed and the predicted production derived from the factors on table 26. From this table, the predictions from the factors for Gamma and Modified Gamma generally under predicted the observed productions while the predictions from the factors from Inverse function over predicted the productions. The percentage deviations for each model are given in columns 6, 7 and 8 of table 27. Observations showed that the degree of over-prediction decreased as more records are available for prediction for Gamma and Modified Gamma functions. It was also found that factors computed under Inverse function appeared to have relatively the least absolute deviations from the actual data up to about the 24^{th} week part records though there were some over-estimation of the prediction between 6^{th} and 16^{th} week part production. Beyond the 24^{th} weeks production, the use of factors from Gamma and Modified Gamma provided better deviations from the observed with the values from Modified

Gamma found lower than those from Gamma models for Friesian-Bunaji data. The correlation coefficients increased with increase in the number of part week yield.

4.7 FACTORS AFFECTING CURVE AND PRODUCTION CHARACTERISTICS FRIESIAN-BUNAJI DATA UNDER GAMMA FUNCTION

Results of the analysis under Gamma model for Friesian-Bunaji data showed that the curve characteristics viz: the general level of production [a], the rate of rise to the peak [b] and the rate of decline from the peak [c], were influenced by various factors. The general level of production was significantly affected by the parity ($P<0.001$) and year ($P<0.001$) of calving of the animal. However, the parameter was not affeacted by the lactation length or season of calving. The summary for the Least squares analysis of variance is given on table 28 (Appendix B) while the summary showing the least squares means for the various factors is given on table 29. From the table, results showed that first calvers had the least general level of production, cows in parities 2, 3 and 4 were intermediate whereas those in parity 5 had the highest general level of production which did not differ significantly from those in parities 3 and 4.

TABLE 29: Least Squares means and standard errors for curve and production parameters under Gamma function for Friesian-Bunaji cow

PARAMETERS		a		b		c		R^2		s		pwk		Initprd		Mxprod		Tprod	
PARITY	N	Mean	S.E.	Mean	S.E.	Mean	S.E.	Mean	S.E.	Mean	S.E.	Mean	S.E.	Mean	S.E.	Mean	S.E.	Mean & S.E.	
1	67	2.64[d]	0.05	0.2696	0.03	0.0424[d]	0.004	0.60[d]	0.03	3.65[f]	0.09	6.6[f]	0.36	6.54	0.41	8.0[d]	0.00	1578.96[d] 66.35	
2	68	2.99[a]	0.05	0.2784	0.03	0.0590[a]	0.004	0.73[a]	0.03	3.33[a]	0.09	5.1[a]	0.35	9.10	0.42	10.9[a]	0.70	1799.16[a] 66.98	
3	56	3.12[a,f]	0.05	0.2515	0.03	0.0611[a]	0.004	0.78[a]	0.03	3.25[d,a]	0.09	4.1[d]	0.37	10.11	0.42	11.3[a]	0.80	1822.93[a] 67.66	
4	44	3.15[a,f]	0.05	0.2409	0.03	0.0571[d]	0.004	0.78[a]	0.03	3.34[a]	0.10	4.1[d]	0.40	10.15	0.47	12.8[a]	0.80	1894.54[a] 75.62	
5	32	3.17[f]	0.06	0.3301	0.04	0.0644[a]	0.005	0.81[a]	0.03	3.18[d]	0.12	4.7[a]	0.48	10.87	0.54	13.2[a]	1.00	1874.08[a] 87.13	
LACTATION LENGTH																			
<26	40	2.96	0.06	0.3076	0.03	0.0973[a]	0.005	0.74	0.03	2.72[d]	0.11	3.0[d]	0.42	8.79	0.49	9.8	0.60	920.16[d] 79.32	
26-35	83	2.97	0.04	0.3016	0.02	0.0570[f]	0.003	0.76	0.02	3.17[a]	0.08	4.8[a]	0.29	8.95	0.35	11.2	0.60	1585.02[a] 56.58	
36-45	99	3.01	0.04	0.2536	0.02	0.0410[a]	0.003	0.73	0.02	3.50[f]	0.07	5.8[f]	0.28	9.42	0.33	11.7	0.60	2175.84[f] 53.88	
>45	45	3.11	0.05	0.2336	0.04	0.0318[d]	0.004	0.74	0.03	4.00[f]	0.10	6.0[f]	0.44	10.25	0.46	12.1	0.90	2494.72[a] 74.33	
SEASON OF CALVING																			
Dec-Feb.	38	3.05	0.06	0.2224[d]	0.04	0.0495[f]	0.005	0.64[d]	0.03	3.62[a]	0.11	4.9[a]	0.45	9.70	0.51	11.3[a]	0.90	1810.10 81.60	
Mar-May	76	2.97	0.04	0.3369[f]	0.02	0.0623[a]	0.003	0.77[a]	0.02	3.13[d]	0.08	5.6[f]	0.30	8.83	0.35	11.7[a]	0.60	1848.07 56.73	
Jun-Aug.	58	3.06	0.05	0.3207[a]	0.03	0.0687[f]	0.004	0.83[f]	0.03	3.02[d]	0.09	5.0[a]	0.33	9.75	0.41	12.4[a]	0.70	1803.49 66.19	
Sep-Nov.	94	2.98	0.04	0.2165[d]	0.03	0.0467[d]	0.003	0.73[a]	0.02	3.62[a]	0.08	4.1[d]	0.32	9.13	0.34	9.4[d]	0.70	1714.08 55.54	

Note

Initprd=Initial week average daily production
pwk= peak week
R^2 = Coefficient of determination
s = persistency
Mxprod= peak production/day at peak week
Tprod=total production/lactation
a=general level of production under Gamma basedfuntions.
b=rate of rise to the peak under Gamma based functions.
c=rate of decline from the peak under Gamma based functions.

Note: Least squares means connected by the same letter within a subclass are not significantly different from each other (P<=0.05)

Lactation length had no significant effect on the general level of production. Although it was observed that animals in milk for less than 26 weeks had the least general level of production, animals in milk for more than 45 weeks were not significantly different from the former. Season of calving had no significant effect on the general level of production. Cows that calved in the period between December and February season had a similar magnitude of general level of production to those that calved between June to August season. The differences in the magnitude were not significant.

Looking at the rate of rise to the peak, it was found that there were significant effects of season ($P<0.001$) and year ($P<0.001$) of calving of the animal. Observation from table 29 showed that animals calving in the wet season (March - August) had significantly higher rate of rise to the peak than those calving during the dry season (September - February). This is as a result of the availability of feeds between March - August compared to September - February. No significant effect of parity and lactation class length was observed for the rate of rise to the peak.

Parity, lactation length, season and year of calving had significant effects on the rate of decline from the peak,[c]. Results showed that animals in the first parity had the least rate of decline compared to the cows in higher parities. The ratio of the rate of rise to the rate of decline showed a gradual decrease from first parity up to a minimum in the third parity then a gradual rise subsequently

in the fourth and fifth parities. Other observations were that cows that were in milk for less than 26 weeks had the highest rate of decline while those that were in milk for more than 45 weeks had the lowest rate of decline. It was also observed that animals with short lactation length showed high rate of rise to the peak and a correspondingly high rate of decline from the peak. Those in longer lactation length showed relatively low rate of rise to the peak and also relatively low rate of decline from the peak.

With respect to the effect of season of calving, it was observed that cows that calved in the rainy season (March - August) had significantly higher rate of decline from the peak than animals that calved between the dry season (September - February). In other words, cows that calved in the period immediately after the rainy season and the harmattan period (December - February) had lower rate of decline from the peak compared to those that calved in the hot season (March - May) and the rainy season (June - August).

Considering the coefficient of determination (R^2) which measured the goodness of fit or the adequacy of the model in representing the pattern of milk production in Friesian-Bunaji data, results showed significant effects of parity and season of calving. Table 28 showed that R^2 varied from about 73% for second parity to about 81% for fifth parity cows. For instance, the result indicated that first calvers had the lowest adjusted R^2 values of 60% which

differred significantly from the higher parities. Results showed positive relationship between R^2 and parity number. In other words, the coefficient of determination (R^2) increased with parity. The coefficient of determination also varied with season of calving of the cows. R^2 was highest for cows calving in the peak of the rainy season (June - August) and lowest in the December - February period frequently reffered as the Cool dry season (Abubakar and Buvanendran (1981)). Because of lack of consistency in feed availability of feed between December and February, the effect was marked on the milk flow and hence, the R^2 was affected compared to June - August season when the pastures are well established and available for grazing. There was no significant difference in the R^2 between the seasons March - May (Early rainy season) and the post rainy season (September - November). There was no effects of lactation class length on the the R^2 but a significant ($P<0.001$) effect of year of calving was noted.

For the production indicators, namely persistency, Initial week production per day, peak week, peak production and total production/lactation, the following results were obtained under Gamma model fitted to the Friesian-Bunaji data. Persistency which measures the rate at which the peak production is maintained was significantly affected by parity ($P<0.01$), lactation length ($P<0.001$), season ($P<0.001$) and year ($P<0.001$) of calving of the cows. Table 29 showed that the highest persistency was recorded for cows in the first

parity and lowest for those in fifth parity while the persistency for those in the intermediate parities do not differ significantly from one another. With respect to the lactation length, it was observed that cows that were in production for a period of between 35 - 45 weeks had significantly ($P<0.01$) higher persistency than those in other categories. Also, it was found that cows calving in the dry periods had significantly higher persistency than those calving in the early rainy and during the rainy seasons. The explaination for this may be as a result of the availability of good quality hay and supplementation during this period (December - February) than those periods when the source of food was usually on pasture which may not necessarily be of the best quality. These cows too had their gestation during the ralatively favourable season (Rainy season).

The occurrence of peak was significantly affected by the effects of parity($P<0.001$), lactation length ($P<0.001$), season ($P0.01$) and year ($P<0.01$) of calving. Cows coming into lactation for the first time, took significantly longer period to attain the peak compared to those that had been in milk before. It was observed that cows that had come into milk before took between 4 - 5 weeks after parturition to attain peak for the Friesian-Bunaji cows while those coming into lactation for the first time took about 6 weeks after parturition to attain the peak. There was positive relationship between the peak week and the lactation length. Shorter lactation animals attained the peak much earlier than

those with longer lactation.

Furthermore, cows that calved just before the onset of the rains took longer period to attain the peak than those of other periods. The reason for this is that, those animal require more time to build up the body before diverting the feed into milk production. Results showed a negative relationship between the time the peak is attained and persistency. The higher the peak, the lower the persistency (table 28).

For the production indicators viz, initial week production/day, peak production and total production some of the factors had marked effects on them. The initial week production/day was significantly affected by parity ($P<0.001$) and year ($P<0.001$) of calving of the cow. First time calvers had significantly ($P<0.01$) lower initial week production than those in higher parity. The magnitude of the initial week production appeared to increase with parity number. Animals in parities greater than 1 do not differ significantly in the initial week production/day. This parameter was not affected by either effects of season nor lactation length.

Peak production, were significantly affected by parity at calving, season and year of calving. Table 29 showed similarity of pattern of production between the peak production and the initial week production pattern. First calvers had significantly lower peak production than those that had been in milk before. The relative rate of rise to the peak from the initial production by parity were 0.22,

0.35, 0.29, 0.65 and 0.49 kg/day, respectively. Results indicated highest rate for fourth parity and lowest for the first parity group. Observation showed that cows calving in the September - November season had the least peak production while those calving in the period between June - August had significantly the highest peak. Although there was no significant effect of season in the initial production, there was significant ($P<0.01$) effect of season of calving in the peak production. The rate of rise to the peak was lowest for cows that calved during the September to November season. This was significantly ($P<0.05$) lower than those that calved in the other seasons. The peak production was not significantly affected by the lactation length of the animal. This implied that though the effect of lactation length was not significant on the peak production, the time of peak was affected by the lactation length.

Finally, it was found that for Gamma model, the total production per lactation was significantly affected by the parity ($P<0.01$), lactation length ($P<0.001$) and year ($P<0.001$) of calving. The total production for the first calvers was significantly ($P<0.01$) lower than the corresponding figures for other parities. The highest total production was recorded in the fifth parity. Furthermore, animals with shorter lactation length had significantly ($P<0.05$) lower total milk production. This is expected in any case in practise that there is a positive relationship between lactation length and total milk production in any

Table 30 Correlation between curve and production parameters under Gamma function for Friesian-Bunaji data.

		a	b	c	pwk	s	Initprd	Mxprod	Tprod
1.	a	1.000							
2.	b	-0.300***	1.000						
3.	c	-0.029*	0.606***	1.000					
4.	pwk	-0.563***	0.498***	-0.204**	1.000				
5.	s	0.103	-0.651**	-0.792***	0.147***	1.000			
6.	Initprd	0.910***	-0.344***	-0.157**	-0.457***	0.196***	1.000		
7.	Mxprod	0.649***	0.331***	-0.204**	0.044	0.044	0.557***	1.000	
8.	Tprod	0.330***	-0.060	-0.470***	0.346***	0.346***	0.370***	0.410***	1.000

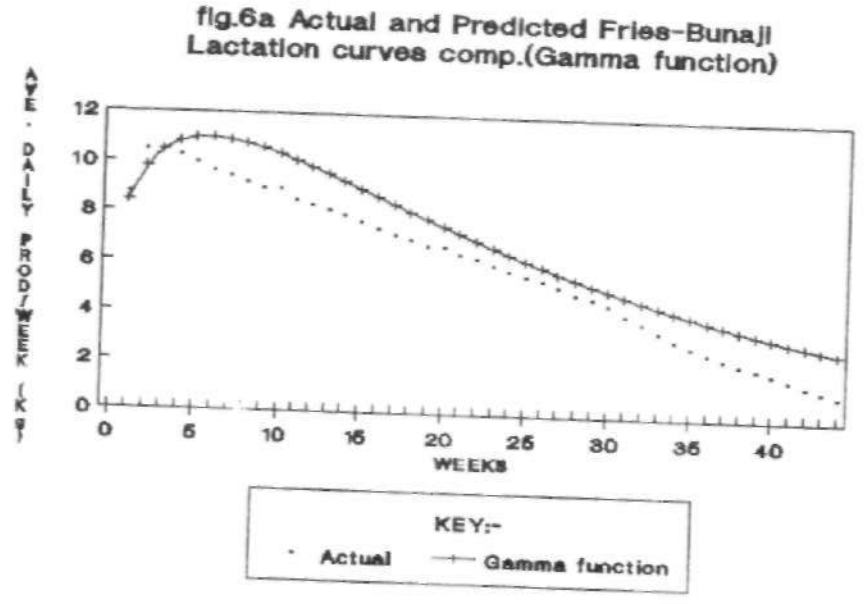
parameters viz;
a = the general level of production;
b = rate of rise to the peak;
c = rate of decline from the peak
s = persistency
Initprd=initial week average daily production,
pwk= peak week,
Mxprod= peak production
Tprod = Total production
Significance of correlation coefficients
* P < 0.05 ** P< 0.01 *** P < 0.001

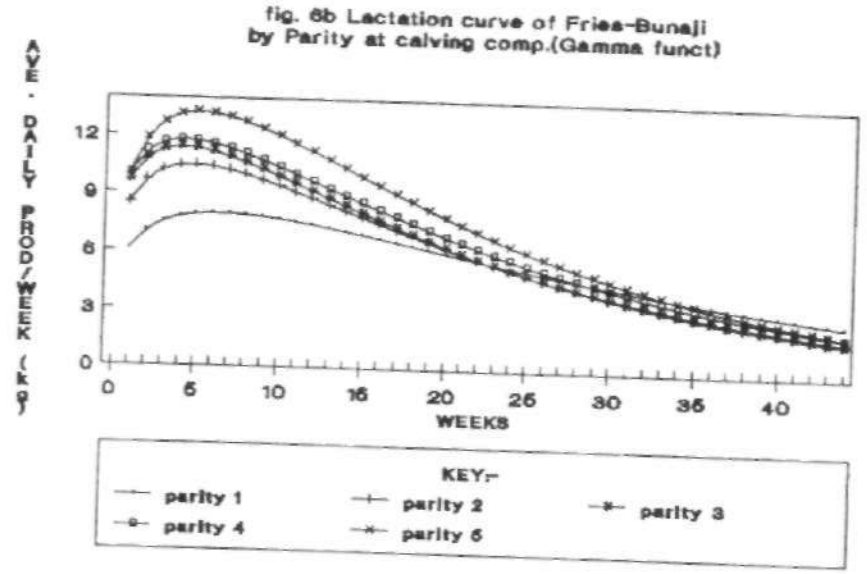
lacatation. No significant effect of season of calving on the total milk produced per lactation.

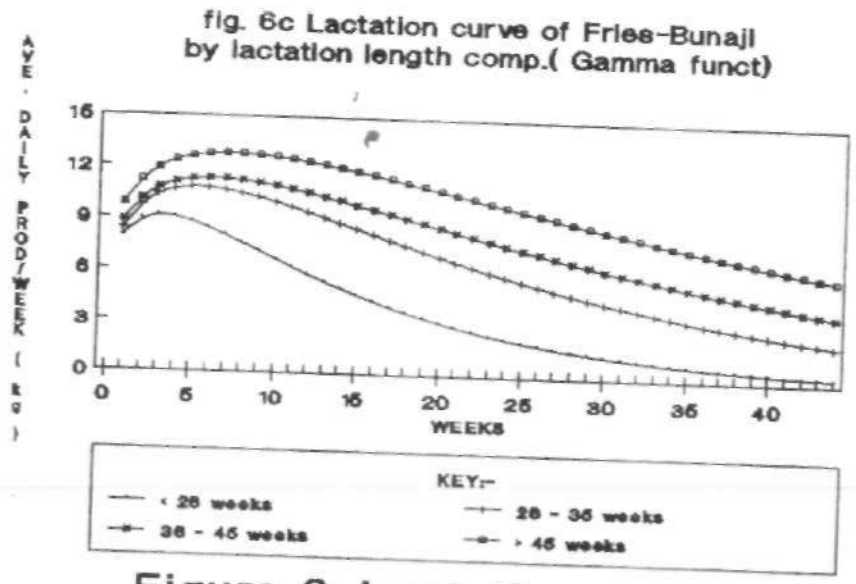
Finally, table 30 gives the summary of the phenotypic correlations between the curve parameters and the production indicators under Gamma model for the Friesian-Bunaji data. Considering the coefficients, it was observed that there were significant (P<0.001) correlations between the general level of production [a] and the peak week [pwk], peak production [Mxprod], initial week production [Initprd] and total production [Tprod] but not with the persistency, s. This parameter was found to be negatively but significantly (P<0.001) correlated with the rate of rise to the peak. The general level of production [a], was positively and highly correlated with the initial week production [Initprd]. The coefficients was about 0.91 while, the parameter was also significantly (P<0.001) and positively correlated with the peak yield [Mxprod] (r=0.649) and total production [Tprod] with a coefficient of r=0.330. These findings agreed with those of Rao and Sundaresan (1979). The general level of production can thus be considered as an indirect way of measuring the initial week production or *vice versa*. There was a negative but significant (P<0.05) correlation between the general level of production and the rate of rise to the peak [b] as well as the peak week [pwk]. The result showed a significant (P<0.001) and positive correlation between rate of rise to the peak and the peak week, peak production but a negative though significant (P<0.001)

correlation with persistency and initial week production. This results did not agree with the findings of Rao and Sundaresan (1979). They observed non-significant correlation between rate of rise to the peak and persistency. The rate of decline from the peak [c] was significantly ($P<0.01$) but negatively correlated with the peak week, initial week production, persistency and total production while it was positively correlated with the peak production. This results agreed with those of Rao and Sundaresan (1979). Finally, persistency was found to be positively correlated with the peak week, initial week production and total production. This observation agreed with the findings of Sikka (1950), Madsen (1975), Finley (1978) and Rao and Sundaresan (1979). Figure 6 gives the production pattern of Friesian-Bunaji for observed and fitted (fig. 6a), production pattern for parities (fig. 6b), by lactation length (fig. 6c) and by season of calving (fig. 6d)

figure 6.







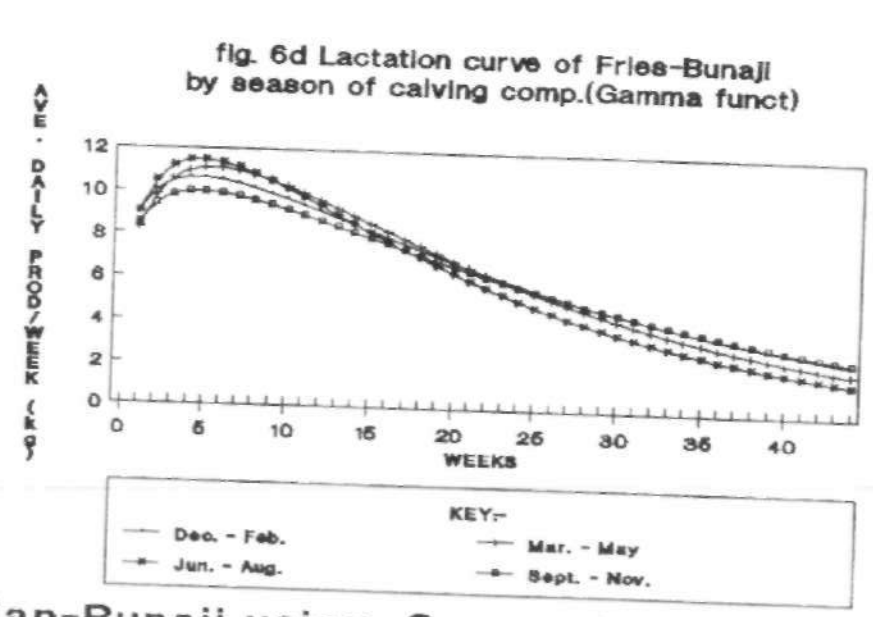


Figure 6. Lactation pattern of Friesian-Bunaji using Gamma function

4.7.1 DISCUSSION

From the results obtained for the data under Gamma model, it was observed that external factors had prominent effects on the shape of the lactation curves for Friesian-Bunaji cows. Results showed that the general level of production of the model was affected by parity and year of calving. Over the period covered by the data, many factors could have contributed to the differences in years. For example, rainfall pattern which directly affected the availability of pasture in the field is one of the factors other than different types of management pratices in the establishment as a result of change of emphasies from various government policies in animal production and products. Before 1976, there was alot of care for dairy animals in the Institute because the emphasis was on dairy production and the management practises were geared towards production of dairy cattle. When the mandate of the Institute changed sometimes in 1976 with an enlarged considerations for the Institute, there was less consideration for the Dairy industry and this subsequently affected the production of milk. Parity had effect on the general level of production. These findings agreed with those from several studies earlier conducted by others. These included Wood (1969), Rao and Sundaresan (1979) and Abubakar and Buvanendran (1981). The Curve parameter was however not affected by the lactation length and this finding disagreed with the result of Abubakar

and Buvanendran(1981). The general level of production was lower for the first parity compared to higher parities. The pattern followed the one reported by Wood (1969) and Abubakar and Buvanendran (1981), but differed from that reported by Rao and Sundaresan (1979). Considering the rate of rise to the peak [a] only the season and year of calving had significant effect on it. This implied that the rate of rise to the peak for Friesian-Bunaji cows were not affected by the parity and lactatation length of the animal. This findings disagreed with that of Abubakar and Buvanendran (1981) as significant effect of season was recorded in this study and not significant effect of lactation length as recorded in their study of the same breed of animal. This may be due to the fact that only one year data was used in their study. It was also found that cows that calved in the dry season September - February (Harmattan) had significantly ($P<0.05$) lower rate of rise to the peak than those that calved in the early rains and rainy season (March - August). This is explained by the fact that during the first period (September - February) there is usually less pasture available for grazing compared to the March - August season when the pastures has just regrown after burning and with the incoming rains, pastures are already well established in the field.

The rate of decline from the peak was affected by parity, lactation length and the effect of season of calving but not by year of calving. This result agreed with the

findings of Abubakar and Buvanendran (1981) with respect the lactation length but disagreed with respect to the other factors. The findings from this study was in perfect agreement with those of Rao and Sundaresan (1979) in their study on Sahiwal cows. The rate of decline from the peak was least for first calvers but there was no significant effects of parity order. It was found that the rate of decline from the peak decreased with increase in the lactation length. Shorter lactation length had higher rate of decline from the peak. This agreed with a similar observation by Abubakar and Buvanendran (1981). The combination of the curve characteristics showed that cows with shorter lactation length had higher rate of rise to the peak and were found to have an equally higher rate of decline from the peak.

Finally, for the curve characteristics, another parameter of importance is the persistency. Results showed the parameter was significantly affected by parity, lactation length, season and year of calving. This agreed with the findings of Asker et al. (1959). They found that the ability to maintain a high daily milk flow by bufallo in Egypt throughout the lactation period was significantly affected by parity and season of calving. Also, Singh *et al.* (1965) reported significant effect of season and age on the persistency of milk production in cattle while Balaine et *al.*(1970) reported significant effects of season of calving on persistency . Similar findings was reported by Wood (1972) who observed significant ($P<0.01$) effects of parity on the

persistency of Friesian cows. Others with similar observations were Madsen (1975) , Rao and Sundaresan (1979). Abubakar and Buvanendran (1981) reported significant effects of parity and lactation length on Friesian-Bunaji cows. Results from this study showed that cows in the first parity had significantly ($P<0.01$) higher persistency (table 24) than those of other parities. This observation may be due to the relatively lower rate of decline from the peak by cows in their first parity production. This observation agreed with the findings of Singh *et al.* (1965) and Abubakar and Buvanendran (1981) using Gamma model. Rao and Sundaresan (1979) reported similar findings with Sahiwal cows in India. The low peristency observed for animals in the fifth parity could perhaps be explained by the fact that those cows had relatively high rate of rise to the peak which was correspondingly followed by a high rate of decline from the peak. Thus the end result was the low persistency figure obtained. The pattern of production for the Friesian-Bunaji cows for the parities, season of calving and lactation length is demonstrated in figures 6.

The production indicators, notably the initial week production per day, peak week, average daily prodcution at peak and the total production for the entire lactation were found to have been affected by one factor or the other. Peak week was significantly ($P<0.001$) affected by parity. Thus, cows coming into milk for the first time took significantly ($P<0.01$) longer period of time to attained the peak than

those in higher parity. This could be attributed to the fact that milk production is a physiological development process which depends on quite a number of factors which could be age and or weight of the animal and perhaps the breed or specie. Looking at the initial week daily production, it was found that parity and year of calving had effects. This could be explained along with the previous explaination on the physiology of milk production in cows in general as well as variation in the environmental factors like rainfall pattern which in turn affect pasture development and disease incidence and management practices. It was observed that first calvers had significantly ($P<0.05$) lower initial week daily production than those in the higher parities. Also, there was a positive relationship between the initial week production and the general level of production parameter [A]. This implied that the parameter could be used as a measure of the initial week production.

The peak week was significantly ($P<0.001$) affected by parity order, lactation length, season and year of calving. This agreed with the findings of Wood (1972) who reported significant effects of parity on the peak week for the British Friesian cows. The Peak production was found to be significantly affected by parity ($P<0.001$), season ($P<0.01$) and year of calving ($P<0.05$). A similar observation was made by Rao and Sundaresan (1979) on the study of Sahiwal cows while Pam and Chaudhary (1976) reported a similar findings on the study of Friesian-Sahiwal cows in India. In this study,

it was observed that first calvers had significantly (P<0.01) lower peak production than those in higher parities. This information perhaps will serve a useful purpose in guarding against embarking on selection programmes based on first parity information or data.

When considering the total productions, the results showed that parity, lactation length and year of calving had marked effects on the Friesian-Bunaji cows. First calvers had significantly (P<0.01) lower total productions than higher parities. Furthermore, cows that were in milk for less than 26 weeks produced significantly (P<0.01) lower total production than those in milk for longer periods. There was a positive relationship between total production per lactation and lactation length. However, it was observed that season of calving did not have any significant effects on the total production for Friesian-Bunaji cows. The significant effects of parity and year of calving observed in this study agreed with the findings of Lindstrom and Solbu(1978), Rao and Sundaresan (1979) Ruvuna et al. (1984) and Johnson et al.(1984). Results on the effects of season of calving disagreed with those of Lindstrom and Solbu (1978) and Schneaberger et al. (1982) who reported significant effects of season of calving on total production. This may be as a result of breed by environment interaction between the two studies.

The effect of environmental factors was determined on the parameter evaluating the goodness or adequacy of the

model under consideration. The parameter called the coefficient of determination (R^2) was significantly affected by parity, season and year of calving. Results indicated that Gamma model fitted higher parity production records significantly better than first parity data. This may be due to the fact that cows that are in higher parities had a more stable stimulus of milk production within them than those coming into milk for the first time. Furthermore, it was observed that there was no significant effect of lactation length. Cows that calved between June - August the period co-inciding with the time when the rains had stabilized had significantly ($P<0.01$) higher R^2 value than other seasons. The Gamma model appeared least suitable for cows that calved between December and February.

Finally, on the basis of the findings in the correlation coefficients, these information could perhaps serve as a very useful tool in that the initial week production and the peak production could effectively be used in the selection programme for total production. This observation was made by Rao and Sundaresan (1979). Because of the significant correlation between some of the production indicators, it may be practicable to undertake some selection of the cows particularly where and when it becomes impossible to obtain complete records like the total milk production of the cows before the assessment of the sire could be made. Furthermore, as a result of the high phenotypic correlations obtained between some of the traits it may be feasible to compute the

genotypic correlations in order to establish the relibility of the use of some of this indicators in selection programmes.

4.8 FACTORS AFFECTING CURVE AND PRODUCTION CHARACTERISTICS OF FRIESIAN-BUNAJI DATA UNDER MODIFIED GAMMA FUNCTION

Table 31 gives the summary of the least squares analysis of variance for the Friesian-Bunaji data using Modified Gamma function. Analysis showed that the general level of production was significantly affected by parity ($P<0.001$) at calving and the year of calving ($P<0.05$) of the animals. The rate of rise to the peak was affected by season ($P<0.001$) and year of calving ($P<0.001$). Results, however, showed that the lactation length had no significant effect on neither the general level of production nor the rate of rise to the peak. Considering the rate of drop from the peak, results showed significant effects of parity ($P<0.001$), lactation length ($P<0.001$) and year ($P<0.001$) of calving. Persistency which is another important parameter determining the curve characteristics showed that parity ($P<0.001$), and year ($P<0.001$) of calving had significant effect. Table 32 shows the least squares means and the standard errors of the parameters for various effects under consideration.

TABLE 32: Least squares means and standard errors of curve and production parameters under Modified Gamma function for Friesian-Bunaji data

PARAMETERS		a		b		c		R^2		s		pwk		Initprd		Mxprod		Tprod	
PARITY	N	Mean	S.E.	Mean	S.E.	Mean	S.E.	Mean	S.E.	Mean	S.E.	Mean	S.E.	Mean	S.E.	Mean	S.E.	Mean	S.E
1	68	2.65[d]	0.05	0.260	0.03	0.040[d]	0.01	0.61[d]	0.03	4.2[f]	0.06	6.7[f]	0.4	6.5[d]	0.4	8.3[d]	0.6	1555.3[d]	69.9
2	69	2.99[e]	0.05	0.284	0.03	0.056[e]	0.01	0.75[e]	0.06	3.8[e]	0.06	5.0[e]	0.4	9.1[e]	0.4	11.4[e]	0.6	1805.3[e]	65.6
3	55	3.07[e]	0.06	0.253	0.03	0.060[e]	0.01	0.78[e]	0.03	3.5[d]	0.06	4.2[d]e	0.4	9.8[e]	0.4	11.6[e]	0.7	1821.1[e]	69.2
4	42	3.13[e]	0.06	0.252	0.03	0.072[d]	0.01	0.78[e]	0.03	3.6[d]	0.07	3.9[d]	0.5	10.5[e]	0.5	11.9[e]	0.7	1884.6[e]f	78.8
5	32	3.15[f]	0.07	0.294	0.04	0.058[e]	0.01	0.79[e]	0.03	3.6[d]	0.08	4.2[d]e	0.5	10.3[e]	0.6	12.6[e]	0.8	1917.3[f]	89.3
LACTATION LENGTH																			
<26	37	2.96	0.07	0.295	0.04	0.093[g]	0.01	0.76	0.03	3.1[d]	0.08	2.9[d]	0.5	8.7	0.6	10.9[d]	0.8	870.9[d]	84.3
26-35	88	2.95	0.04	0.293	0.02	0.057[f]	0.01	0.76	0.02	3.6[e]	0.05	4.8[e]	0.3	8.8	0.4	10.5[d]	0.5	1600.6[e]	56.2
36-45	95	2.99	0.04	0.241	0.02	0.047[e]	0.01	0.73	0.02	4.0[e]e	0.05	5.5[f]	0.3	9.4	0.4	11.0[d]	0.5	2148.0[f]	55.8
>45	46	3.10	0.06	0.244	0.04	0.032[d]	0.01	0.73	0.03	4.2[f]	0.07	5.9[e]	0.5	10.4	0.5	12.2[e]	0.8	2567.2[e]	75.9
SEASON OF CALVING																			
Dec-Feb.	38	2.96	0.07	0.223[d]	0.04	0.049	0.01	0.66[d]	0.03	3.9	0.08	4.8	0.5	9.3	0.5	10.8[d]	0.8	1728.9	82.3
Mar-May	74	2.98	0.05	0.315[e]	0.02	0.063	0.01	0.77[e]f	0.02	3.7	0.05	5.2	0.3	9.1	0.4	11.7[e]	0.5	1847.4	58.3
Jun-Aug.	57	3.07	0.05	0.323[e]	0.03	0.065	0.01	0.84[f]	0.03	3.6	0.06	4.9	0.4	9.9	0.4	12.7[e]	0.6	1883.4	67.2
Sep-Nov.	94	2.99	0.05	0.212[d]	0.03	0.052	0.01	0.01[d]e	0.02	3.7	0.05	4.1	0.3	9.0	0.4	9.4[d]	0.6	1727.1	56.7

Note

a=general level of production under Gamma basedfuntions.
b=rate of rise to the peak under Gamma based functions.
c=rate of decline from the peak under Gamma based functions.
s= persistency
Initprd=Initial week average daily production
pwk= peak week
Mxprod= peak production/day at peak week
Tprod=total production/lactation

Note: Least squares means connected by the same letter within a subclass are not significantly different from each other ($p<=0.05$)

The lower parity had significantly ($P<0.01$) lower level of general production than animals in higher parities. Results also indicated that the general level of production for various lactation length were not significantly different and similarly no observed differences existed between seasons.

The rate of rise to the peak showed no difference between different categories of parity and lactation length. However, it appeared as if animals that calved between March and August had significantly ($P<0.05$) higher rate of rise to the peak. With respect to the rate of decline from the peak, there was a positive relationship between the parity and rate of decline from the peak.

There was a gradual increase in the rate of decline from the first parity up to a maximum at about the fourth parity. The change in the parameters over parity had no unique pattern as was observed for the general level of production. The rate of decline from the peak was highest for lactation length of less than 26 weeks and lowest for those greater than 45 weeks in production. This could perhaps be interpreted to mean that the longer the lactation class the more steady the pattern of production.

Figures 7(a,b,c and d) are the corresponding production curves for various classifications namely Observed and predicted; parity, lactation length and season of calving. From figure 8b, the production showed that despite the fact that first parity production pattern had the least

general level of production, the patterns appeared more steady when we consider the persistency parameter.

The first parity had a significantly higher persistency than other parities. This perhaps explained the steady pattern of production in figure 8b. The high persistency observed for first parity animals agreed with the findings of Wood (1968), Rao and Sundersan (1979) and Abubakar and Buvanendran (1981). Wood (1968) explained the apparent higher persistency observed in first parity animals as due to the inhibiting effect of pregnancy on production of older animals because of their higher yield. The pattern of production showed that animals in parity 5 had significantly ($P<0.05$) higher average weekly production per day up to about 35 weeks after parturition. Animals in 2nd, 3rd and 4th parity do not differ significantly before the 7th week after parturition.

figure 7

figure 7

fig.7a Actual and predicted FRIES-BUNAJI Lactation curvee comp.(Modified Gamma)

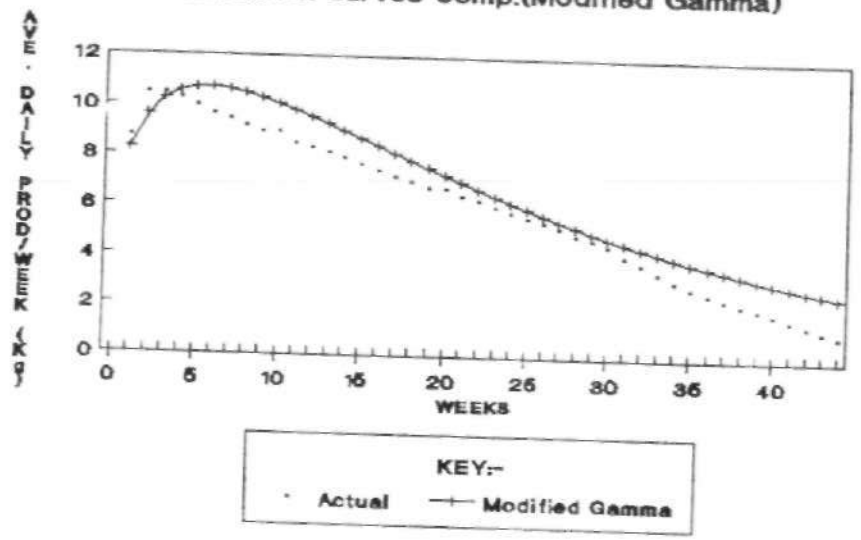


fig. 7b Lactation curve of Fries-Bunaji by parity comparson (Modified Gamma)

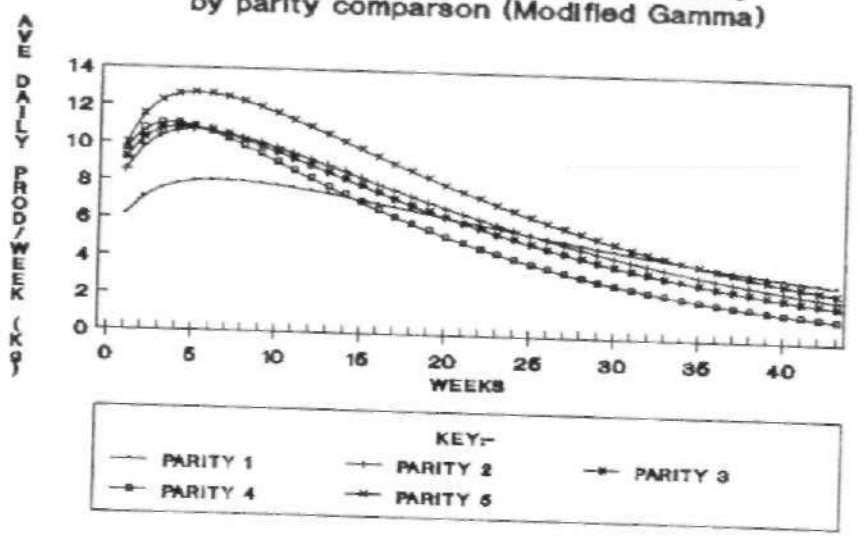


fig. 7c Lactation curve of Fries-Bunaji by lactation length comp(Modified Gamma)

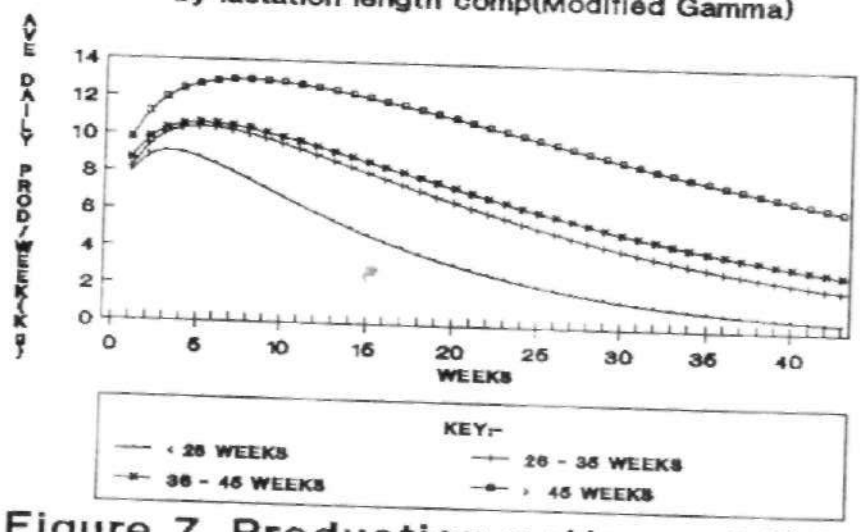


fig. 7d Lactation curve of Fries-Bunaji by season of calving (Modified Gamma)

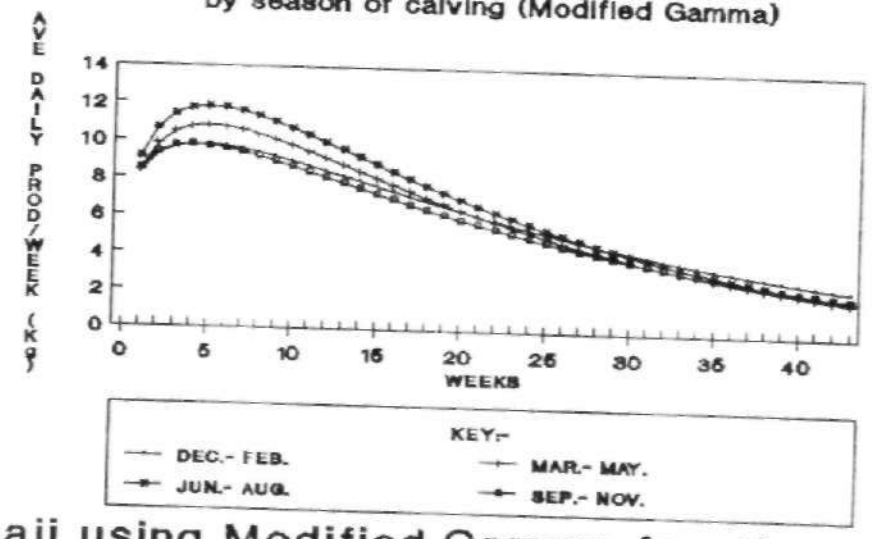


Figure 7. Production pattern of Fries-Bunaji using Modified Gamma function

Figure 7b showed a marked difference in the pattern of production within the first 14 weeks of production. Beyond the 16th week after parturition, the fourth parity animals differed from other parities. The pattern of production by lacation length is shown in Figure 7c. Results showed that animals that were in production for greater than 45 weeks have the highest production. Table 32 showed that this class has significantly ($P<0.05$) higher persistency than those in other classes while those in less than 26 weeks in production had the least persistency (Fig. 7c).

There was no significant effect of the lactation length, with respect to the general level of production and rate of rise to the peak. A significant effect of lacatation class was observed on the rate of decline from the peak. One would perhaps infer that the rate of fall from the peak could be a significant factor in measuring the persistency of the production pattern. The pattern of production in this study agreed with the findings of Abubakar and Buvanendran (1981) although the production per day in this study appear slightly higher than what they observed.

Figure 7d showed the production pattern for the different seasons. No noticeable difference existed in the initial (general level of production) as shown in table 32. The pattern showed that animals that calved in peak of rainy season (June - August) had the best production pattern, this was closely followed by those calving in the early rainy season (March - May). From the results, there was no

noticeable effect of season of calving on the curve parameters. It was however observed that there was a positive correlation between the rate of rise to the peak and the total production per lactation. Beyond 25 weeks after parturition, there was no difference in the pattern of production over the seasons. The observed differences in the production between third and 25th weeks after parturition may be due to the body conditions of the animal and subsequently subject to availability of feed for the animals. Generally in the savanna region of Nigeria, it is known that between March - August, there is availability of pasture to boost the performance of the animals. This is against the maintenance diet usually provided during the dry season which occurred in the period between November and February when the level of feeding is affected more severely.

The initial production and peak production are important parameters used in deciding whether a particular cow should remain in the herd or not. It is a known fact that there is a positive correlation between the initial production and peak production as well as total production. Peak week is also another important production parameter in the study of dairy production. Results from table 31 (Appendix B) showed significant effects of parity ($P<0.001$), lactation length ($P<0.001$), season and year of calving ($P<0.01$) on the peak weak. Cows coming into milk for the first time took significantly ($P<0.01$) longer period to get to the peak than older cows. This could be explained by the

fact that the milk secretory tissue in primaparous animals takes longer to reach its peak activity than pluriparous animals. There existed a negative relationship between the peak week and parity order. Records for Friesian-Bunaji showed that the peak week ranged between 3-7 weeks. This was consistent with the findings of Rao and Sundareson (1979), Abubakar and Buvanendran (1981) and Kasonta (1988). It was found that there was a direct and positive relationship between lactation length and the peak week. Animals with short lactation length attained the peak week faster than longer ones. For instance it was observed that cows that were in production for more than 45 weeks took significantly ($P<0.05$) longer period to attain their peak production. No significant ($P>0.05$) effect of season was observed in the time of attainment of peak production.

The results from this study agreed with the findings of Wood (1972) with respect to the effect of parity. It also agreed with those of Rao and Sundaresan (1979) with respect to parity and season. They however did not observe any year effect observed in this study.

For initial production, the findings showed that the initial production was greatly affected by the parity ($P<0.001$) of the animal and the year of calving ($P<0.001$). However, there was no significant ($P>0.05$) effects of lactation length and season of calving. The initial production is infact an indicator of the general level of production which was one of the curve parameters. With

regard to peak production, cows in higher parity had significantly (P<0.05) higher peak production than first parity cows. This is because the animal is already developed physiologically. Similarly, cows that calved in the period between March - August had significantly (P<0.05) higher peak production than those that calved in the other seasons. This could be explained to be due wet season stimulus and improved nutrition due to availability of pasture. Significant (P<0.01) effect of year of calving on peak production was also recorded in this study. The findings agreed with those of Rao and Sundaresan (1979).

Finally, total production was significantly affected by parity order (P<0.001), lactation length (P<0.01) and year of calving (P<0.05).

The effect of season did not have any significant impact on the total production. The shortfall in earlier production in the cows calving in the dry season were made up in by the wet season stimulus which has a net effect on the final total production. Cows in first parity had significantly (P<0.01) lower total production than those in higher parities. This showed a gradual increase in total production as the pattern observed for peak production. Similarly, cows that were in milk for a period less than 26 weeks have the least total production. The total production for each lactation class length differed significantly (P<0.01) between classes. There was a positive relationship between the total production and the lactation length.

The results agreed with those of Rao and Sundaresan (1979) with respect to parity, year of calving but disagreed with the seasonality observed in their study. This perhaps, could be due to difference in severity of the seasons in the different studies. The severity was more pronounced in their study than in this present study. Though significant ($P<0.001$) differences existed in the peak production between seasons, the net effect on total production was not significant (Fig.9) despite the fact that the absolute values for the wet season calvers appeared larger than those of the dry season calvers.

The overview of the production parameter for Friesian-Bunaji cattle showed positive correlation between peak and total production: higher peak production tended to lead to higher total production (table 33). This result is similar to the findings of Sikka (1958), Mahadevan (1951), Smith and Legates (1962), Belarne et al (1970), Sharma (1972), Madsen (1975) and Rao and Sundaresan (1979). This implied that the peak production may be useful in selection, instead of waiting for the entire lactation period before selection is done.

For the adequacy of the model in representing the pattern of production for Friesian-Bunaji cattle, it was observed that the coefficient of determination (R^2) varied between 61% and 84% with an overall average of about 73% which could be considered as a good fit. This was affected by parity order, season and year of calving. Results showed

that the fit was least for first parity with a goodness of fit of 61% and best for fifth parity with an R^2 of 79%. There was a gradual increase in the R^2 with increasing parity. For season category, the best fit was recorded for cows calving at the period when the rains have stabilised (June - August) with an R^2 of 84%. The response for March - May did not differ significantly from the June - August response. Also the response for the dry season (September-November and December-February) did not differ significantly. Results showed that cows calving during or just before the on-set of rains to about the period when the rains have stabilized have better goodness of fit than those calving at the ends of rains (September to February). During the latter period, the usual booster from the rains in the availability of pasture was reduced. The gradual drop thus affected the productivity of the animals. The goodness of fit was not significantly affected by the lactation class. Modified Gamma function appeared to fit data that have a lactation length of between 26-35 weeks better.

4.8.1 DISCUSSION

From the results for the Modified Gamma function, it was obvious that some similarities existed between the observations made on this model and that made on Gamma model. There were few incidences where they differed in the results between the two functions. One, was with respect to the effect of seasons on the rate of decline of the curve. There

was significant effect of season under Gamma function, the contrary was the case under Modified Gamma. This was the effect of the additional term V Cos (x) + U Sin(x) in the Modified Gamma function which was designed to take care of the effect of seasonality in milk production in cattle.

Generally, the results showed that effect of parity was consistently observed as significant for all the curve parameters with the exception of the rate of rise to the peak (b). The effect of parity was significant ($P<0.001$) for all the production indicators. This observation is in agreement with the findings of other investigators namely Sikka (1950), Mahadevan (1951), Asker et al (1959), Wood (1969) Madsen (1975), Kellog et al. (1976) and Rao and Sundaresan (1979). The findings here agreed with the findings of Abubakar and Buvanendran (1981) with respect only to the general level of production and rate of rise to the peak. The observed significance conflicted with the findings of Abubakar and Buvanendran (1981). This difference could be as a result of the number of year's data used. Their study was on one year data.

The result showed that there was a positive relationship between the general level of production and the parity order. This is to say that with Friesian-Bunaji, the general level of production (a) increased with increase in the number of parity. Furthermore, it was observed that the rate of increase to the peak was not varying in any specific order, result showed that the highest was recorded for fifth parity

though no significant effect of parity was recorded. With respect to the rate of decline from the peak c, results showed a gradual increase with parity order. The peak was attained in the fourth parity while the rate of drop was least for first parity (Figure 7b). The persistency was highest for first parity animals. This observation was in agreement with the findings by Singh *et al.*(1965), Rao and Sundaresan (1979) and Abubakar and Buvanendran (1981).

For the production indicators, result showed an inverse relationship between the week of peak production and the parity order while the initial production increased with the parity order. Similarly, the production at the peak week also increased with the parity order. The explanation to this was given earlier. This observation was in agreement with the findings reported by Ram and Chandhary (1976) in their studies of Friesian-Sahiwal crosses in India. They reported significant effects of season, years of calving, parity and genetic group on peak yield or production. The observation on the peak production was extended to the entire production per lactation that is total production. In this study, there was significant ($P<0.001$) effect of parity on total production. The total production increased with parity order. There was a gradual increase from first parity to the firth. The result however showed no significant difference between the production in the fourth and fifth parities although in absolute terms, the total recorded for the fifth parity was more than the fourth by about 32.7kg. The

goodness of fit measured by the coefficient of determination R^2, was also affected by the parity order. The results showed significantly ($P<0.05$) better value for parities higher than 1. Comparing the average daily rate of rise to peak from initial production/day with parity showed the following; 0.27, 0.46, 0.43, 0.36 and 0.40 kg for first, second, third, fourth and fifth parities, respectively. Thus, the average daily increase to the peak was highest for second parity animals. This followed a similar pattern as was observed for the rate of rise to the peak.

Considering the effect of lactation length, the results showed that the factor was significant for the rate of rise to the peak ($P<0.001$), persistency ($P<0.001$), peak week ($P<0.001$) and total production ($P<0.001$). The findings agreed with those of Abubakar and Buvanendran (1981) with respect to rate of decline from the peak and persistency. The results conflicted with respect to the general level of production and the rate of rise to the peak as there was no significant effect of the factor on those parameters (table 31). Higher persistency was observed for lactation length greater than 35 weeks. The pattern was similar to that observed by Abubakar and Buvanendran (1981). With respect to the production indicators, there was a positive relationship between persistency and the lactation length on one hand and persistency, peak production and total production on the other.

Furthermore, higher initial week yield and peak

production were found to be associated with higher lactation yield as can be seen from table 31. Similar results were reported by Sikka (1950), Madsen (1975) and Rao and Sundaresan (1979). With this, it may be possible to use the peak production or initial production as basis for selection in Friesian-Bunaji instead of waiting till the entire total lactation production is obtained.

Season of calving was found to have significant ($P<0.001$) effect on only the rate of rise to the peak. This finding conflicted with those of Abubakar and Buvanendran (1981) while lack of significant effects of season on the general level of production, rate of decline from the peak and persistency in this study agreed with the findings of Rao and Sundaresan (1979). It had significant ($P<0.001$) effect on the peak production but not on the total production per lactation. This aspect also conflicted with that of Rao and Sundaresan (1979). The effect of year of calving was significant ($P<0.001$) on all the curve parameters and with production indicators. This agreed with the findings of Rao and Sundaresan (1979). This observation is perhaps expected in this study because of various factors in force in the management of the herd over the entire 12 years. This was discussed earlier in section 4.7.1. Changes in management practises, changes in the availability of nutrients because of differences in the rainfall distribution over the various years.

Finally, when using Modified Gamma function to fit

Friesian-Bunaji data it is essential to note that external factors like parity and year of calving need to be corrected for. Other factors like the season of calving and lactation length though are important were found to affect some of the curve parameters.

Table 33 below gives the phenotypic correlations between the curve parameters and production indicators for Friesian-Bunaji data under Modified Gamma models.

The correlation between the curve parameters and production indicators showed significant ($P<0.001$) coefficients between the general level of production and peak week, initial week production per day, peak production, total production and persistency. The correlation with peak week, and persistency were negatively but significantly ($P<0.01$) correlated while the correlation with others were positively related (table 33). The results showed a negative but significant correlation between the rate of rise to the peak and general level of production as was reported under Gamma model. The findings agreed with those of Rao and Sundaresan (1979 and Finley (1978).

Table 33 Correlation between curve and production parameters under Modified Gamma function for Friesian-Bunaji data

		a	b	c	pwk	s	Initprod	Mxprod	Tprod
1.	a	1.000							
2	b	-0.346***	1.000						
3.	c	0.004	0.629***	1.000					
4.	pwk	-0.586***	0.463**	-0.208**	1.000				
5.	s	-0.328**	0.041	-0.596***	0.745**	1.000			
6.	Initprd	0.891***	-0.308***	-0.066	-0.446***	-0.232***	1.000		
7.	Mxprod	-0.586***	0.302***	0.219***	-0.001	-0.115	0.673***	1.000	
8.	Tprod	0.317***	-0.085	-0.290***	0.290***	0.492***	0.374***	0.365***	1.000

a=general level of production under Gamma basedfuntions.
b=rate of rise to the peak under Gamma based functions.
c=rate of decline from the peak under Gamma based functions.
s= persistency
Initprd=initial week average daily production
pwk= peak week
Mxprod= peak production/day at peak week
Tprod=total production/lactation

Note * P<0.05 ** P<0.01 *** P<0.001

Under Modified Gamma function, the significant correlation between the general level of production and persistency contradicted the observation under Gamma model. This finding also contradicted the findings of Rao and Sundaresan (1979). Considering the coefficients of the rising phase with the other parameters, there was significant correlation with peak week ($P<0.01$), initial week production per day ($P<0.001$) and peak production ($P<0.001$). For the declining phase, the parameter was significantly correlated with peak week($P<0.01$); peak production, total production and persistency ($P<0.001$). Of all these, it was negatively correlated with all the parameters with the exception of correlation with peak production. This was the pattern observed under Gamma model. The findings also agreed with the those of Rao and Sundaresan (1979). The coefficients recorded by Rao and Sundaresan was -0.527 compared to -0.596 observed in this study thus pointing to the close agreement despite the fact that RaO and Sundaresan used Gamma function instead of Modified Gamma function.

From table 33, the phenotypic correlation coefficients between the production indicators showed similar magnitude of coefficients as was observed under Gamma function. Persistency was observed to be highly and significantly correlated with total production. Similar coefficient was recorded (table 30) under Gamma function as well as under Modified Gamma function. Though the correlation was

significant as reported by RaO and Sundaresan (1979), the magnitude was negative. There was significant correlation with initial production/day, and was positively correlated with total production. Initial week production per day was significantly and positively correlated with peak production and total production. The usefulness of this information may be in the selection procedure when either the initial week production per day or the peak production could perhaps be a useful indicator of the total production of an animal per lactation.

The correlation coefficient between initial week production per day and persistency was negative under Modified Gamma function while it was positive under Gamma function. This is a contradiction that is difficult to explain. Generally the result showed that peak production and initial week production per day were positively correlated with the total production under any of the two models for Friesian-Bunaji records.

4.9 FACTORS AFFECTING CURVE AND PRODUCTION CHARACTERISTICS UNDER INVERSE FUNCTION

The Inverse polynomial was also considered as another model that can be used to represent the pattern of milk production in Friesian-Bunaji cattle. Table 34 (Appendix B) is the summary giving the factors that affected both the curve parameters as well as the production indicators. The curve parameters are the rising extreme to the peak (b_0), the average slope (b_1), the declining extreme (b_2) and the goodness of fit measured by the coefficient of determination R^2. The production indicators are the initial week production/day, peak week, peak production per day and the total production.

The summary showed that the rising and inclining extreme (b_0) was affected by the lactation length ($P<0.05$) and the year of calving ($P<0.001$). The average slope (b_1) was affected by parity ($P<0.01$) order, season ($P<0.01$) and year ($P<0.001$) of calving. The declining extreme (b_2) was affected by parity ($P<0.05$), lactation length ($P<0.001$) and year of calving ($P<0.001$). The summary agreed with the findings of Yadav et al.(1977) who used the same model for fitting Hariana and its Friesian crosses. They did not consider the effects of year of calving and the lactation length on the curve characteristics nor the production indicators.

TABLE 35: Least squares means and standard errors for curve and production parametres under Inverse function for Friesian-Bunaji data

	N	b_0		b_1		b_2		R^2		pwk		Mxprod.		Initprd		Tprod	
PARITY		Mean	S.E.	Mean	S.E.	Mean	S.E.	Mean	S.E.	Mean	S.E.	Mean	S.E.	Mean	S.E.	Mean	S.E
1		0.05582	0.0094	0.03363^{a}	0.0071	0.00344^{a}	0.0005	0.50^{a}	0.030	4.84^{bc}	0.25	9.17^{a}	0.86	6.00^{a}	0.38	1542.0^{a}	79
2		0.05213	0.0091	0.00779^{a}	0.0071	0.00415^{a}	0.0005	0.59^{b}	0.030	3.377^{ab}	0.24	13,78^{b}	0.84	7.43^{b}	0.38	1825.1^{b}	80
3		0.05740	0.0100	0.00727^{a}	0.0074	0.00575^{b}	0.0005	0.64^{b}	0.031	0.344^{a}	0.26	15.84^{c}	0.98	8.41^{bc}	0.39	1935.2^{bc}	83
4		0.05764	0.0105	-0.00044^{a}	0.0082	0.00504^{b}	0.0006	0.65^{b}	0.034	3.23^{a}	0.28	13.90^{b}	1.00	8.72^{bc}	0.44	1976.0^{bc}	92
5		0.07522	0.0121	-0.00063^{b}	0.0094	0.00454^{ab}	0.0007	0.71^{bc}	0.039	3.85^{ab}	0.31	14.20^{bc}	1.16	9.01^{c}	0.51	2017.7^{c}	10
LACTATION LENGTH																	
<26 WKS		0.07299^{c}	0.0113	-0.00562	0.0088	0.00901^{c}	0.0006	0.62	0.037	2.74^{a}	0.30	12.67	1.08	7.31^{a}	0.47	880.3^{a}	10
26-35 "		0.07065^{c}	0.0077	0.01081	0.0060	0.00429^{b}	0.0004	0.60	0.025	4.00^{b}	0.20	13.56	0.74	7.43^{a}	0.32	1675.6^{b}	68
36-45 "		0.05824^{b}	0.0074	0.01177	0.0058	0.00299^{a}	0.0004	0.62	0.024	4.52^{c}	0.19	14.34	0.70	7.85^{ab}	0.31	2245.5^{c}	65
>45 WKS		0.03669^{a}	0.0103	0.02113	0.0078	0.00204^{a}	0.0006	0.63	0.032	4.05^{c}	0.28	12.94	1.03	9.01^{b}	0.41	2635.5^{d}	87
SEASON OF CALVING																	
Dec-Feb.		0.04778	0.0117	0.02621^{c}	0.0088	0.00483	0.0006	0.50^{a}	0.037	3.54^{a}	0.30	14.50^{c}	1.10	8.25	0.47	1792.4^{a}	98
Mar-May		0.07517	0.0078	-0.00222^{a}	0.0062	0.00506	0.0004	0.64^{b}	0.026	4.30^{b}	0.20	13.22^{b}	0.77	7.49	0.33	1977.0^{b}	70
Jun-Aug.		0.06338	0.0090	-0.00450^{b}	0.0071	0.00476	0.0005	0.70^{bc}	0.030	3.88^{ab}	0.23	14.22^{c}	0.86	8.00	0.38	1953.9^{b}	79
Sep-Nov.		0.05230	0.0078	0.01860^{c}	0.0059	0.00368	0.0004	0.63^{b}	0.025	3.59^{a}	0.20	11.57^{a}	0.72	7.91	0.31	1713.5^{a}	66

Note

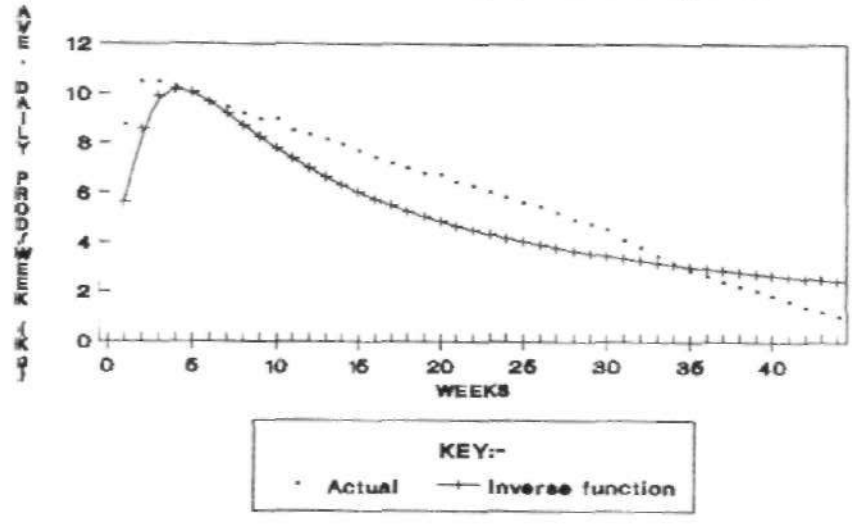
b_0 = rising phase under Inverse function.
b_1 = average slope.
b_2 = rate of decline for Inverse function.
Initprd=Initial week average daily production
pwk= peak week
Mxprod= peak production/day at peak week
Tprod=total production/lactation

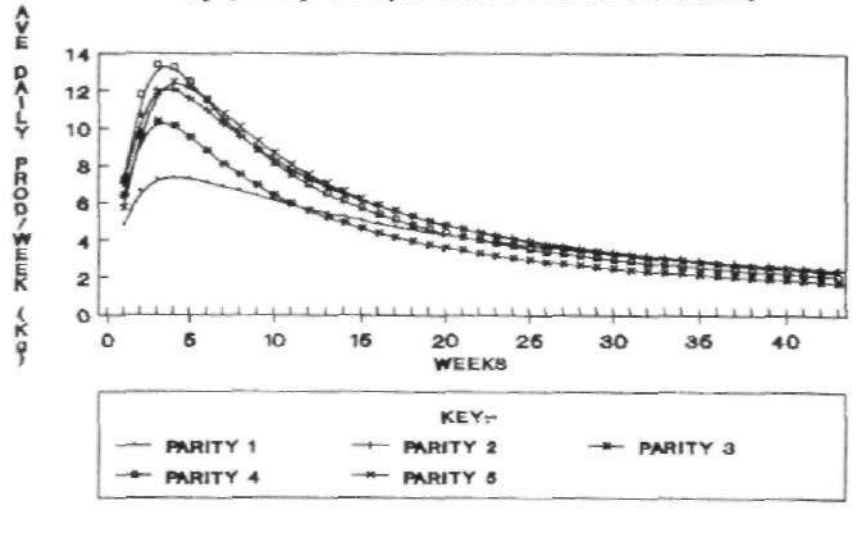
Note: Least squares means connected by the same letter within a subclass are not significantly different from each other ($p<=0.05$)

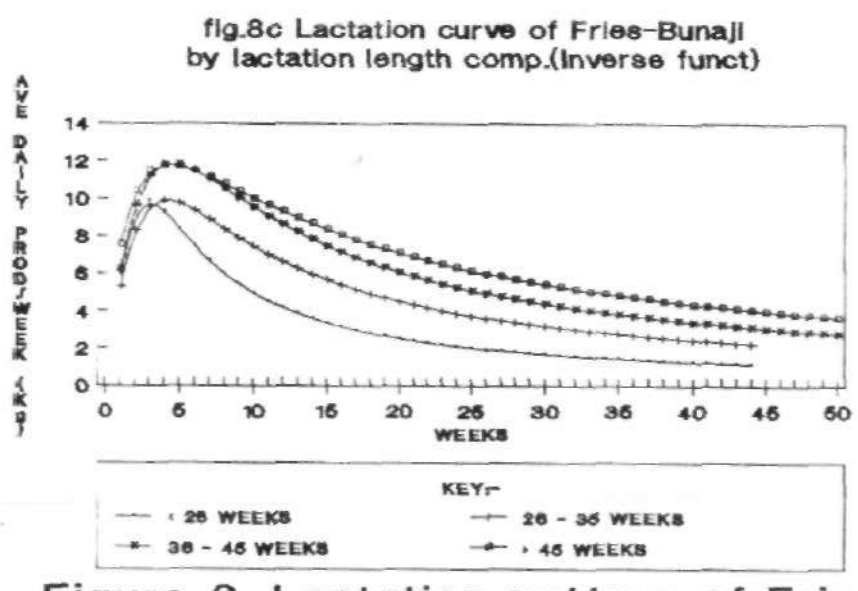
Yadav et al. (1977) observed significant effect of season for both, the average slope and the declining extreme of the curve characteristics. The least squares means are presented on table 35. On the rising extreme (b_0) it was observed that the value was lowest in the second parity and highest in the fifth parity, there was no indication of significant effects of parity. A trend was observed for the least squares means for the different seasons. The means showed that the rising or inclining extreme was highest for cows calving in the rainy season (March to May and June to August) than those in the dry season (September to November and December to February). However, no significant effect was observed. Figure 8 gives the production pattern of Friesian-Bunaji for observed and fitted (fig 8a), production pattern by parity (fig 8b), lactation class length (fig. 8c) and by season of calving (fig. 8d) under the Inverse function.

Results showed there was a significant effect of lactation length on the parameter. The cows with lactation length less than 26 weeks have significantly ($P<0.05$) higher inclining extreme value than the other categories.This trned was observedwith the other two models earlier described. Those with longer period, have smaller of inclining extreme value. This observation has a biological interpretation. This implied that those on a longer lactation period, tended to have a gradual inclining extreme than those on shorter lactations.

figure 8







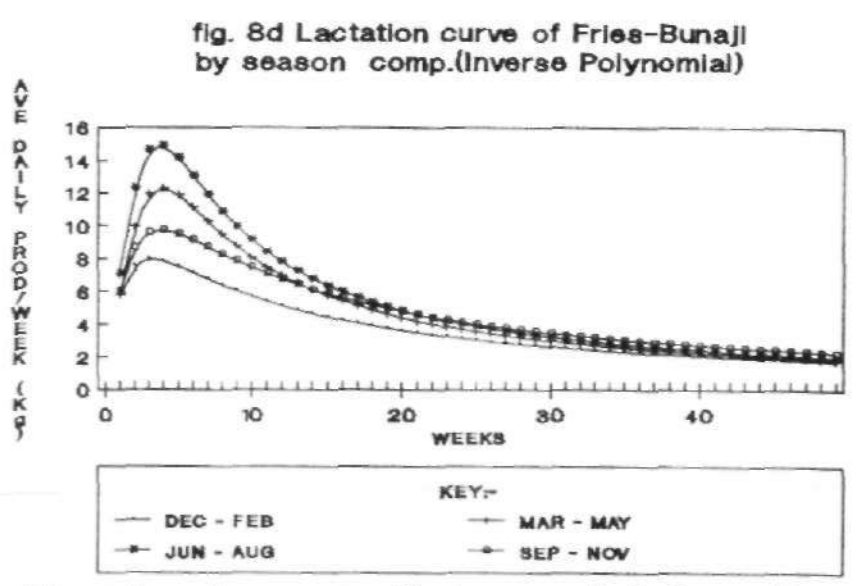


Figure 8. Lactation pattern of Fries-Bunaji using Inverse Polynomial function

Considering the average slope (b_1), cows in parities one to three had significantly ($P<0.05$) higher average slope than those of higher parities. Also, cows that calved during the rainy season had significantly ($P<0.01$) different slope from those calving in the dry period.

With respect to the declining extreme, the result indicated a trend with parity order. The declining extreme tended to increase with the parity number up to maximum in the third parity and then decreased. The pattern followed that observed by Yadav *et al.* (1979) with the exception that no significant effect of parity was recorded for the declining extreme phase in their own study. With respect to the lactation length, the declining extreme was highest for those in milk for less than 26 weeks. This was followed by those in milk for the next category (26-35) and least for those in production greater than 36 weeks. No significant effect of season was observed for declining phase. This tended to suggest that the declining extreme of the curve parameters for Friesian-Bunaji cattle was not affected by season of calving.

TABLE 36: Correlation coefficients between curve and production parameters for Friesian-Bunaji cows under Inverse Polynomial function

	b_0	b_1	b_2	Tprod	Initprd	pwk	Mxprod.
b_0	1.000						
b_1	-0.653***	1.000					
b_2	0.533***	-0.407***	1.000				
Tprod	-0.092	-0.068***	-0.423***	1.000			
Initprd	-0.524***	0.262***	-0.280***	0.342***	1.000		
pwk	0.492***	0.049	-0.196***	0.209***	-0.470***	1.000	
Mxprod	0.163*	-0.570***	0.171**	0.326***	0.158*	-0.057	1.000

Significance of correlation coefficients is given by
* P<0.05 ** P<0.01 *** P<0.001

parameters viz;
b_0 = the rising phase; b_2 = declining phase
b_1 - the general slope
Initprd=initial week average daily production,
pwk= peak week,
Mxprod= peak production
Tprod = predicted total production)

Production indicators showed that external factors had marked effects. Peak week, the week at which peak or maximum production is attained was affected by parity order, lactation length, season and year of calving. This observation agreed with that of Wood (1968) and Rao and Sundaresan (1979). The pattern reported was similar to the one reported using Gamma and Modified Gamma functions. First parity animals took significantly longer period to attain the peak than higher parity animals (Fig.8b). This was explained as a physiological development process which affects the milk secretory tissue such that primiparous animals takes longer time to reach peak activity than pluriparous animals. The observation agreed with other studies by Chanhan et al.(1976) with respect to the lactation length, shorter lactation length animals had significantly ($P<0.05$) lower peak week. Animals in this category attained the peak production significantly earlier than those with longer production period. There was positive relationship between the time the peak was attained and the lactation length. This has been the trend for all the models for Friesian-Bunaji animals. Cows that calved in the period between March - August had higher peak week than those that calved in the other months of the year. Friesian-Bunaji cows calving in the rainy season took longer time to attain the peak than those in other months on the year. Figures 8c and 8d give the comparison of the production by lactation length and season of calving.

Considering the productivity parameters, the result indicated that peak production was affected by the effect of parity, season and year of calving. Peak production increased up to maximum of about 15.84 kg/day in the third parity before it dropped. There was no significant effect of lactation length on the peak production. Furthermore, the peak production recorded during December to February was highest and differed significantly from the production recorded for those that calved between March to May and September to November. The production recorded for June to August was not different. The study revealed some agreements with the findings of Rao and Sundaresan (1979) though they used a different model from the one reported in this study.

With respect to the initial week production, significant effect of parity, lacation length and year of calving was recorded. No effect of season was observed. Results showed that the initial production increased with parity number: the higher the number of times a Friesian-Bunaji cows calved, the higher the initial production. Initial week production tended to increase as the calving increased. This same pattern of production was recorded under the Gamma and Modified Gamma models (tables 29, 32). The effect of lactation class length was significant with respect to the initial week production per day. Results revealed some positive association between the size of the initial week production per day with the lactation length. No noticeable effect of season on the parameter was observed.

Finally, considering the total production, all the non-genetic factors had effects on the parameter. The findings agreed with those of Sikka (1950), Ronningen (1967) and Wood (1970).

4.9.1 DISCUSSION

Using the Inverse polynomial function, the milk production pattern for Friesian-Bunaji data showed that the goodness of fit which was measured by the coefficient of determination (R^2) varied between 50 - 71 percent with an overall average value of 61%. Furthermore the non-genetic factors that affected the curve parameter included parity which affected the average slope (b_1) and the rate of decline extreme. Effect of lactation length affected only the rate of rise to the peak as well as the rate of decline from the peak. Significant effect of season was obtained for the average slope. The year of calving had effects on all the curve parameters. The goodness of fit measured by the was affected by the parity, season and year of calvings. From table 35, it was found that higher R^2 was recorded for animals in higher parities. Also, better fitness of the model was recorded for animals calving in the period from March to November.

For production parameters, it was observed that the average daily rate of change from initial week production per day to the peak was curve-linear in nature with a maximum occurring in the third parity. The values were 0.65, 1.68, 2.16, 1.60 and 1.30 kg/day for parities one,two,three,four

and five, respectively. It could therefore be concluded that the rate of milk flows in Frisian-Bunaji cows was optimum about the third parity before a drop as evaluated by Inverse function. From Figure 8, the trend showed that first parity production pattern appeared relatively more consistent and perhaps could be considered to have highest persistency using the definition which is a confirmation of what was observed for the other two models described earlier. Similarly, the production pattern by lactation length showed the corresponding rate of daily change from the initial week to the peak 1.96, 1.52, 1.44 and 0.97 kg. This implied that the change decreased with increase in the number of weeks in production. The corresponding value by seasons were 1.77, 1.33, 1.60 and 1.02 kg/day for December-February, March-May, June-August and September-November, respectively. The high rate recorded for the December-February and June-August coincided with the period of availability of good supply of feeds. Generally, the December-February period is the time good quality hay and other silages were made available to the animals while the period June-August coincided with the time of stable availablility of pasture in the field.

Furthermore, the results showed some positive relationship between the initial week daily production and the total production for parities and lactation class. Table 37 gives a summary of the correlation coefficients between the various lactation curve parameters and the production indicators for Friesian-Bunaji cattle using Inverse function.

The rising extreme was significantly (P<0.001) correlated with all other parameters with the exception of the total production. It was however found that the rising extreme was positively correlated with the rate of decline from the peak. This was similar to what was observed under other models discussed earlier (tables 33, 36). Correlating the declining extreme with the production indicators showed negative but significant (P<0.001) relationship with initial week production/day, peak week and total production. In essence therefore, it could be concluded that the lower the rate of decline from the peak, the larger or higher the values of the parameters mentioned. The initial week production was however found to be positively and significantly (P<0.001) correlated with the peak production which could be considered to be a normal and to be expected in practical terms. The significant correlation between initial production with peak productiokn and total production also agreed with previous findings by RaO and Sundaresan (1979) and Finley (1978). This confirmed the report under the two models decribed earlier. This information will be very useful for selection practises. Peak production was found to be significantly (P<0.001) and positively correlated to total production. In other words, it can be inferred that with this information, success made on the selection on the basis of toal production could also be achieved if based on the peak production and when this is not available, it could be done using the initial week production for Friesian-Bunaji data. Further studies may be

able to throw more light on this statement by computing the genetic correlations between these traits .

4.10. Model Comparisons for Friesian-Bunaji Data

From the factors affecting the curve characteristics under each model, it was observed that the factor parity was found to have significant effects on all the traits under consideration; viz: average slope, rate of decline and all production indicators. Using the Friesian-Bunaji data, the predicted production traits from the various models will now be compared with the actual observed data over the parities.

4.10.1 Initial Week

The initial week production per day as predicted by each model is given in table 37. Over all the parities, an average of 8.69, 9.06, 8.94 and 7.71 were recorded for the observed, Gamma, Modified Gamma and Inverse function, respectively. In terms of absolute figures, the estimation from the Gamma functions (Gamma and Modified Gamma) over-estimated the actual initial production while the Inverse Polynomial model under-estimated the observed. The percentages of over-estimation from the gamma functions were 4.3 and 2.9 and the under-estimation from the Inverse polynomial was about 11.3. In terms of absolute figures therefore, the estimation from Modified Gamma model was closest to the observed over all the parities.

Table 37: Observed and predicted average Initial week production/day by parity for_ Friesian-Bunaji cattle

PARITY	N	OBSERVED MEAN	GAMMA MEAN	MODIFIED GAMMA MEAN	INVERSE MEAN
1	67	6.523	6.54	6.47	6.00
2	68	9.003	9.10	9.06	7.43
3	57	9.979	10.11	9.80	8.41
4	43	9.518	10.15	10.46	8.72
5	32	9.125	10.87	10.91	9.01
Overall		8.69	9.06	8.94	7.71
Correlation with the observed			r=0.91*	r=0.89*	r=0.88n.s

* P<0.05 n.s Not significant

There was no significant differences between the Observed, the predicted values from Gamma and Modified Gamma models. However, the predicted values from the Inverse polynomials were found to differ significantly from those of other models. It was found that predictions obtained from the Inverse polynomials for the initial week production per day were consistently lower than the observed for all the parities while those from the Gamma based functions (Gamma and Modified Gamma) were consistently higher although to nonsignificant magnitudes. The degree of over-estimation expressed in percentages for the gamma based models for parities one to five were 0.26, 1.1, 1.3, 6.6 and 19.1 for Gamma and 0.84, 1.8, 9.9 and 19.6 for Modified Gamma while the corresponding figures under the Inverse polynomials were 23.4, 17.5, 15.7, 8.4 and 1.3, respectively. The figures recorded for the Inverse polynomials were under-estimated.

From the deviations, it would appear that the Gamma based models were good for lower parities or younger animals while the Inverse polynomial function appeared better for higher parities (four and five) or older animals. Generally, the Inverse polynomial function tended to under-estimate the actual production to a more significant level than the gamma functions. In terms of absolute deviations therefore, the predictions from Gamma and Modified Gamma models appeared to more acceptable than those from the Inverse polynomial functions.

The correlation coefficient between the actual and the predicted were 0.91, 0.89 and 0.88 for Gamma, Modified Gamma, Inverse function, respectively. Though high coefficients were recorded for each, it was found that the values were higher on the Gamma based models than the Inverse Polynomial function.

4.10.2 Peak Week.

The summary of the average peak week by parity for the Friesian-Bunaji data is given on table 38 below. The observed average peak week over all the parities was about 4.8 weeks. The estimated peak weeks from the models were 5.4, 5.5 and 4.2 weeks for Gamma, Modified Gamma and Inverse polynomials, respectively. The Gamma based models were found to have over-estimated the actual peak week by about 12 and 14 percent while the Inverse polynomial under-estimated the actual peak week by about 12%. The highest peak week recorded

for each model occurred in the first parity. Also, the estimated values for Gamma and Modified Gamma models do not differ from the actual over the parities. However, the predicted from the Inverse polynomial differ significantly ($P<0.05$) from the actual and the predicted for the other two models. Furthermore, the predicted peak week for each parity under the Inverse polynomial was consistently lower than the Observed. The Inverse polynomial had the closest prediction to the actual in the first parity with a deviation of about -14 percent while the corresponding deviations recorded for Gamma and Modifeid Gamma models were 18 and 20 percent over-prediction, respectively. For parities greater than 1, the absolute deviation recorded for the inverse polynomial varied between 11 to 30 percent as against an absolute variation of less than 10 percent recorded under the gamma based or tansformed exponential (Gamma and Modified Gamma) models. The absolute deviations under the Gamma models were lower than Modified Gamma in parities two, three and four though not significantly. The corresponding correlation coefficients between the observed and the predicted were 0.90, 0.88 and 0.79 for Gamma, Modified Gamma and Inverse polynomial, respectively. The coefficients for the transformed exponential models differed significantly ($P<0.05$) from the Inverse polynomial models while there was no difference between the coefficients for the gamma based models.

Table 38: Observed and predicted Peak week by Parity for Friesian-Bunaji Cows

PARITY	OBSERVED MEAN	OBSERVED S.E	GAMMA MEAN	GAMMA S.E.	MODIFIED GAMMA MEAN	MODIFIED GAMMA S.E.	INVERSE MEAN	INVERSE S.E.
1	5.6	0.51	6.6	0.36	6.7	0.38	4.8	0.25
2	5.4	0.62	5.1	0.35	5.0	0.37	3.8	0.24
3	4.0	0.42	4.1	0.37	4.2	0.40	3.4	0.26
4	4.1	0.52	4.1	0.40	3.9	0.45	3.2	0.27
5	4.3	0.56	4.7	0.48	4.2	0.50	3.9	0.31
Overall	4.8	0.25	5.4	0.18	5.50	0.16	4.2	0.11
Correlation coefficients between observed and predicted			0.89*		0.88*		0.79ns	

Significance * = P<0.05, ns = non-significance

Further evaluations of the three models were undertaken to assess their adequacy. This was done by examining how frequent the predicted peak week coincided with the observed which is another way of determining the suitability of the individual model under consideration. Table 39 gives the summary of the assessment of the models. Column A under each model, is the percentage frequency of times when the predicted peak week is the same as the observed. Column B, is the percentage frequency of times when the predicted is less than the observed (Under-prediction) while Column C gives the percentage frequency of times when the predicted is more than the observed(Over-prediction).

Table 39: Assessment of model prediction coinciding with Observed Peak week by parity for Friesian-Bunaji

PARITY	GAMMA A	GAMMA B	GAMMA C	MODIFIED GAMMA A	MODIFIED GAMMA B	MODIFIED GAMMA C	INVERSE A	INVERSE B	INVERSE C
1	3	7	15	2	6	18	7	9	10
2	2	11	13	3	7	16	2	12	12
3	3	10	9	2	7	12	6	6	8
4	3	6	7	3	5	8	2	6	8
5	0	4	6	0	4	7	2	5	6
Overall	11	38	50	10	29	61	18	38	44
		[255]			[218]			[242]	

Key: A = % Predicted peak week coincides with actual peak (coincidence)

B = % Predicted < Actual peak week (under-prediction)
C = % Predicted > Actual peak week (Over-prediction)

For the Friesian-Bunaji records and using this measure, it was observed that the highest frequency of co-incidence was in the Inverse polynomial model. The peak week was correctly predicted by this model about 18 percent while the figures for the Gamma and Modified Gamma models were 11 and 10 percent, respectively. Consider for example in the first parity, the rate of co-incidence for the Inverse polynomial was 7% compared to 3 and 2 percent recorded for Gamma and Modified Gamma models.

For cases of under-prediction(column B), the lowest was recorded under Modified Gamma model (29%) while an equal rate of 38% were recorded under Gamma and the Inverse models. As for over-prediction, the least percentage was recorded for the Inverse polynomial while the highest was in Modified

Gamma model. Generally over the parities, there was a higher rate of over-prediction of the peak week for the three models. However, the Gamma based models tended to over predict the peak week more than the Inverse polynomial. Also, the Inverse polynomial had higher rate of co-incidence and lower rate of over-prediction of the peak week compared to other two models.

4.10.3 Peak Production

The summary of peak production per day for the Friesian-Bunaji data on the three models is on table 40 given below. The observed actual production per day at peak showed a gradual increase from first parity with an average production of about 11.13 kg to about 12.45 kg in the fifth parity. The pattern of production for the observed showed that the peak production increased with parity order. Comparing the predicted values between the models averaged over the parities, the prediction from the Inverse polynomial was 10% larger than the observed while there was an under prediction of about 6 and 7% under the Gamma and Modified Gamma models. Under the Inverse polynomial, the peak production was over-predicted in all the parities greater than 1. The predicted under Modified Gamma model on the other hand were lower than the actual in all except the prediction in the fifth parity while those under Gamma were larger than the observed in all the parities except those in the first and second parities.

Table 40: Observed and Predicted Peak production per day for models by parity for Friesian-Bunaji

PARITY	OBSERVED MEANS	S.E.	GAMMA MEANS	S.E.	MODIFIED GAMMA MEANS	S.E.	INVERSE MEANS	S.E.
1	11.13	1.51	8.02	0.74	8.35	0.62	9.17	0.86
2	11.66	0.36	10.86	0.74	11.38	0.62	13.78	0.84
3	12.12	0.33	11.33	0.78	11.59	0.68	15.84	0.98
4	11.96	0.36	12.70	0.84	11.85	0.75	13.90	1.00
5	12.45	0.50	13.16	1.00	12.56	0.84	14.20	1.16
Overall	11.77	0.40	11.10	0.31	10.99	0.26	12.95	0.36
Correlation coefficient between observed and predicted			0.92*		0.93*		0.84ns	

Significance * = P<0.05, ns = non-significance

It was also observed that while the Inverse polynomial under-predicted the average daily production at the initial week, it over-predicted the average daily production at the peak week. However, the Gamma based models under-predicted the production at peak week despite the fact that there was a slight over-prediction of the initial week production. A general comparison of the predictions from the models showed that there was a relatively higher deviations between the actual and the predicted under the Inverse polynomials than the deviations under the other two transformed or modified exponential models. Between the two gamma based models however, there was a relatively lower deviations under the Modified Gamma function. This implied that the Modified Gamma function appeared to be more preferable considering the accuracy of the predicted peak production relative to the prediction from Gamma. The

correlation coefficient between the observed and the prediction from the models were 0.92, 0.93 and 0.84 for Gamma, Modified Gamma and Inverse polynomial, respectively. Finally, using the parameter Peak production as a measure of assessing the adequacy of the models for Friesian-Bunaji data, Modified Gamma model will be considered as the most reliable in view of the lower absolute deviations and the high correlation coefficients between the predicted and the observed.

4.10.4 Total Production/lactation.

The average total production per lactation for Friesian-Bunaji cows was 1862.04 kg with standard error of 44.08 kg. The corresponding predicted total production were 1860.30 $\pm$ 27.50, 1867.93 $\pm$ 27.78 and 1947.73 $\pm$ 33.16 for Gamma , Modified Gamma and the Inverse polynomial, respectively. The summary by parity for each model is presented in table 41. The prediction from Gamma model was about 0.1% less than the observed while those from Modified Gamma and the Inverse polynomial were larger than the observed by 0.3 and 4.6 percent, respectively. Comparison on parity by parity basis showed that the prediction from Gamma model was consistently lower than the actual with the exception of the prediction for the fourth parity. For Modified Gamma model, there was under-prediction for the first three parities while there was over-prediction in parities fourth and fifth. As for the Inverse polynomial,

there was a consistent over-prediction for all parities greater than two. A general assessment showed that the predictions from the Gamma based models do not differ significantly from the actual average total production per lactation.

Table 41: Observed and Predicted Total production by parity for Friesian-Bunaji data

PARITY	OBSERVED MEAN	S.E.	GAMMA MEAN	S.E.	MODIFIED GAMMA MEAN	S.E.	INVERSE MEAN	S.E.
1	1884.93	81.59	1578.96	66.35	1555.26	65.93	1542.03	79.34
2	1851.76	99.19	1799.16	66.98	1805.26	65.64	1825.09	79.90
3	1840.61	97.91	1822.93	67.66	1821.05	69.22	1935.24	63.05
4	1842.52	97.41	1894.54	75.62	1884.57	78.81	1975.96	91.87
5	1900.35	127.44	1874.08	87.13	1917.35	89.26	2017.74	103.84
Overal	1862.04	44.08	1850.30	27.50	1867.93	27.78	1947.73	33.16
Correlation between observed and Predicted			0.899*		0.940*			

Significance * = P<0.05, ns = non-significance

This suggests that the Gamma based models provided a good evaluation of the total production for the Friesian-Bunaji cow. The comparison of the predictions from the Inverse polynomial and those from the gamma based models showed significant (P<0.01) differences. This implied that using the Inverse polynomial to evaluate the total milk production in Friesian-Bunaji cow is less accurate than the predictions from either Gamma or Modified Gamma functions because of the relatively high deviations between the predicted and the observed.

4.10.5. Coefficient of determination (R^2)

The goodness of fit measure from the three models have been compared to assess the adequacy by parity. The summary is given in table 42. A higher R^2 values were recorded for the Gamma based functions than the Inverse polynomial function. The values for Gamma and Modified Gamma functions were 74 and 73 percent while 61 percent was obtained for the Inverse Polynomial function. All the values have been adjusted for factors (breed, lactation length season and year of calving) considered under each function.

Table 42: Comparison of Adjusted R^2 between models by parity for Friesian-Bunaji data.

	GAMMA		MODIFIED GAMMA		INVERSE	
PARITY	MEAN	S.E.	MEAN	S.E.	MEAN	S.E.
1	0.60	0.03	0.61	0.03	0.50	0.03
2	0.73	0.03	0.75	0.03	0.59	0.03
3	0.78	0.03	0.78	0.03	0.64	0.03
4	0.78	0.03	0.78	0.03	0.67	0.03
5	0.81	0.03	0.79	0.03	0.71	0.04
Overall	0.74	0.02	0.73	0.02	0.61	0.02

The R^2 increased with parity order for all models. This implied that the goodness of fit measure or the adequacy of the models improved as the number of calvings increased. On comparing the R^2 between models over the parities, there was no significant differences between the values for the Gamma based models i.e between Gamma and Modified Gamma models however, the values obtained for the Inverse polynomial

differed significantly from those obtained from the gamma based models. Assessment by the R^2 values showed that the Inverse polynomial had a relatively inferior adequacy than those obtained using the transformed exponential models or gamma functions.

4.10.6 Persistency

This was defined earlier as the rate at which the peak production is maintained in the production pattern of the cow. From the previous parameters(e.g Peak week,Peak production, total production and goodness of fit measure (R^2)), it was observed that the Inverse polynomial was relatively less adequate when compared to the other two models. Also, the other two models were found to be about equally effective by the measure of the parameters listed above. Gamma and Modified Gamma were compared on the basis of the persistency measure which is a very important parameter to the animal breeder and the dairy farmer in selection programmes on the farms.

Table 43 gives the summary of the persistency measure for the two models.

Table 43: Comparison of Persistency between functions by parity for for Friesian-Bunaji cows.

	GAMMA		MODIFIED GAMMA	
PARITY	MEAN	S.E.	MEAN	S.E.
1	3.65	0.090	4.18	0.061
2	3.33	0.091	3.75	0.061
3	3.25	0.094	3.53	0.064
4	3.34	0.104	3.60	0.074
5	2.18	0.121	3.60	0.084
Overall	3.41	0.038	3.90	0.026

The result showed that Modfied Gamma model had a relatively higher persistency measure averaged over all the parities and also in individual parity. This is an indicator of adequacy for representing the pattern of milk production in Friesian-Bunaji cow. For Friesian-Bunaji data, both the curve characteristics and the production parameters showed that the use of a Gamma based models provided a better fit of the milk production pattern. Furthermore, with the exponential or gamma based models, the model with correction for cylicity appeared to have provided a better measure of fitness considering the R^2 and persistency measure though no significant differences existed between the two models with respect to the lactation curve parameters and production indicators.

4.11 EVALUATION OF THE MODELS USING FRIESIAN DATA

A Total of 111 lactations from 39 Friesian cows compiled over five lactations were analysed. Summary of the data is given in table 44. Results showed an average production per lactation to be about 4016 kg with a standard error of 143.5 kg. The average lactation length was about 50.32 week. There were few cows that were in milk for up to about 128 weeks while only about three cows showed a location length of less than 26 weeks. The average production per day for a Friesian cow in this study was about 11 kg. The average initial production per day ± S.E was about 8.69 ±0.60, the average production at peak was about 18.91 kg attained about 6.91 weeks after parturition. This implied that the average rate of rise to the peak in the Friesian cow was about 0.21 kg/week.

Table 44. Observed average Productivity parameters for Friesian cows.

VARIABLE	N	MEAN	S.E
Initprd/day	110	8.89	0.60
pwk (week)	111	6.91	0.43
Mxprod (kg)	110	18.91	3.23
Tprod/lactation (kg)	111	4016.03	143.51
Average Lactation length	111	50.23	1.10
Average Daily Product(kg)	111	11.42	

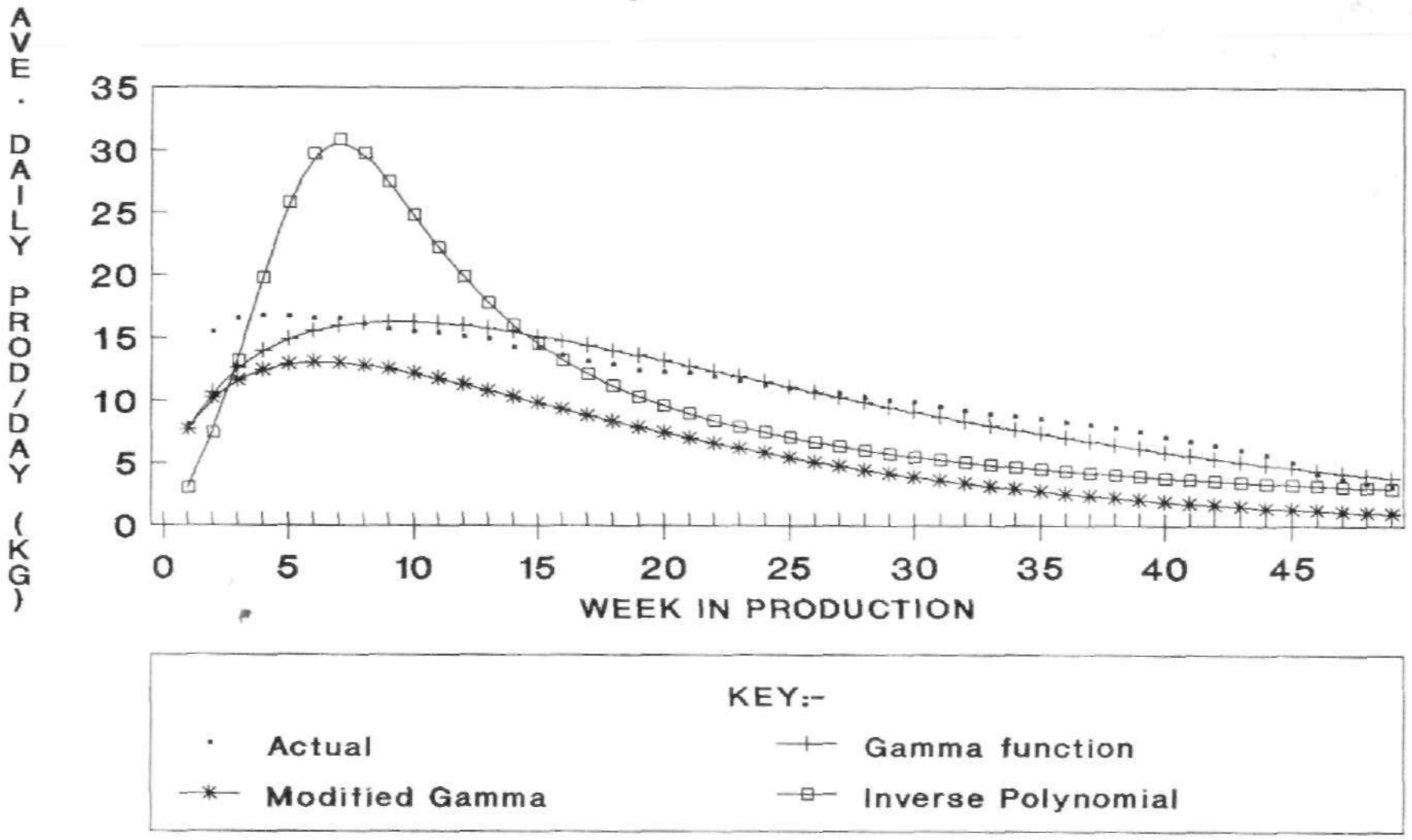
Table 44 gives the summary of the relative performance of the three models using the Friesian data. While figure 9 represents the observed and predicted production pattern for the Friesian cattle under the three functions under consideration. From table 44, the results showed that, the

Gamma based models (Gamma and Modified gamma) over-estimated the observed initial production while the Inverse Polynomial under-estimated the actual initial production. The absolute percentage deviation of the predicted initial production from average observed were 3, 4 and 29 percent, respectively for the Gamma, Modified Gamma and the Inverse functions, respectively. There was a gross under-estimation in the peak week. The over-estimation was least for the Inverse function and highest for the Gamma function with deviations of about 2, 1.8, 0.2 weeks, respectively.

Considering the production at the peak, the observed average production per day was 18.91 while the estimated predicted peak production were 12.03, 16.64 and 12.6 Kg, respectively for Gamma, Modified Gamma and Inverse polynomial. The results showed that there was a general under-estimation of the peak production by the three models. There were no significant ($P>0.05$) differences between the three models. The total production per lactation showed that the Gamma function under-estimated the total production by about 5% while, the Modified gamma and polynomial functions over-estimated the observed by 3 and 6%, respectively. Comparing the adequacy of the three models by the Coefficient of determination, R^2, the results showed a value of 68% for the Gamma based models and a value of 52% for the Inverse polynomials. Using Seber (1972) argument, this is an indicator of a poor fit for the Inverse Polynomial.

figure 9

fig. 9 Friesian cow production
Curves Comparison between Models



parameters from Least Squares means

In other words, the Inverse polynomial was not a good model for fitting the Friesian data. Considering the persistency measure, only the gamma based models have this measure. The results showed that although the goodness of fit measure for the two models were the same, the persistency measure of the Modified Gamma model was much better than the corresponding value for the Gamma function.

The other values in table 45 are the average curve parameters fitted to the Friesian data for each of the model under consideration. A close study of figure 9 showed that, generally, the Inverse polynomial over-predicted the total production while it under-estimated the initial prediction. The curves showed that the Inverse polynomial under predicted in the first 3 weeks and over-predicted between 4 and 14 weeks and underpredicts beyond the 15th week. From the graph 10 and figure 10c, the rate of under-prediction decreased as the lactation progresses (Table 46) until the 50th week.

Considering the Gamma based models, the result showed that the prediction from the Modified Gamma function differed significantly ($P<0.05$) from the actual data throughout the entire lactation despite the fact that high persistency was recorded for the function.

Table 45 Predicted average curve characteristics by models for Friesian data

CHARACTERISTICS	GAMMA MEAN	GAMMA S.E	MODIFIED GAMMA MEAN	MODIFIED GAMMA S.E	INVERSE MEAN	INVERSE S.E
Initprd/day (kg)	9.19	0.46	9.26	0.47	6.29	0.40
Pwk (week)	9.00	0.30	8.70	0.37	7.10	0.30
Mxprod/day (kg)	17.03	0.47	16.64	0.51	17.76	1.70
Tprod/(kg)	3817.14	126.60	4127.44	143.35	4258.60	207.6
Persistency s	3.20	0.07	3.15	0.06	N/A	
Adjusted R^2	0.68	0.02	0.68	0.02	0.52	0.02
Curve Parameters						
General level of Production [a /b_0] [A]	2.8904	0.065	2.9176	0.055	-0.0379	0.01
Rate of Rise [b /b_1] [B]	0.5609	0.379	0.5369	0.033	0.1806	0.02
Rate of Decline [c/b_2] [C]	0.0598	0.045	0.0861	0.027	0.0038	0.0004

Note

Initprd=Initial week average daily production
pwk- peak week
Mxprod- peak production/day at peak week
Tprod-total production/lactation
a-general level of production under Gamma basedfuntions.
b-rate of rise to the peak under Gamma based functions.
c-rate of decline from the peak under Gamma based functions.
b_0 = rising phase under Inverse function
b_1 = average slope under Inverse function
b_2 = rate of decline from peak under Inverse function

A close observation of the pattern of production showed that the model under-estimated the actual production pattern for the Friesians. The Gamma function on the other hand under-estimated the production between the first and the seventh week and also between the 26th and 45th week in production - while it over-estimated beween 7th and the 25th week and beyond the 45th weeks. From graph 9, the Gamma function fitted the pattern of production in Friesian data better than the other functions.

Table 46 provides the deviations of each model from observed. This provided detailed information on the adequacy of each of the functions in representing the average production/day for Friesian milk production in Nigeria. From the graph and table 46, there were clear indications to show that the Gamma based models (Gamma and the Modified Gamma) were better than the predictions from the Inverse Polynomial. However the comparison between the Gamma based models showed that the Modified Gamma function consistently under estimated the observed average daily production over the entire average 50 week production period recorded for the Friesian cow.

Table 46. Observed Daily, Predicted and % Deviations of Models for Friesian data

Week	Observed	Gamma	%Dev	Modified Gamma	%Dev.	Inverse	%Dev
1	8.06	7.69	4.6	7.7	4.4	3.1	61.7
2	15.52	10.68	31.2	10.2	34.0	7.6	51.3
3	16.58	12.63	23.8	11.7	29.6	13.5	18.8
4	16.78	13.98	16.7	12.5	25.4	20.3	-20.8
5	16.77	14.93	11.0	12.9	22.8	26.5	-58.1
6	16.59	15.58	6.1	13.1	21.1	30.5	-83.9
7	16.57	16.00	3.4	13.1	21.2	31.6	-90.9
8	16.18	16.24	-0.4	12.9	20.5	30.5	-88.4
9	15.76	16.34	-3.7	12.6	20.3	28.1	-78.3
10	15.54	16.33	-5.1	12.2	21.4	25.3	-63.0
11	15.45	16.23	-5.0	11.8	23.7	22.6	-46.5
12	15.12	16.05	-6.1	11.3	25.1	20.2	-33.7
13	14.98	15.91	-6.2	10.9	27.6	18.1	-20 9
14	14.32	15.53	-8.5	10.4	27.6	16.3	-13.8
15	14.29	15.20	-6.4	9.9	30.9	14.8	-3.3
16	13.71	14.85	-8.3	9.4	31.6	13.4	1.9
17	13.21	14.47	-9.6	8.9	32.8	12.3	6.9
18	12.96	14.07	-8.5	8.4	35.2	11.3	12.6
19	12.49	13.66	-9.4	7.9	36.4	10.5	16.1
20	12.33	13.25	-7.5	7.5	39.2	9.7	21.0
21	12.27	12.82	-4.5	7.1	42.5	9.1	25.9
22	11.97	12.40	-3.6	6.6	44.6	8.5	28.9
23	11.63	11.97	-2.9	6.2	46.4	8.0	31.2
24	11.30	11.55	-2.2	5.9	48.2	7.5	33.3
25	11.01	11.13	-1.1	5.5	50.2	7.1	35.3
26	10.75	10.72	0.3	5.1	52.2	6.8	37.1
27	10.63	10.31	3.0	4.8	54.8	6.4	39.6
28	10.29	9.92	3.6	4.5	56.3	6.1	40.5
29	10.09	9.53	5.5	4.2	58.3	5.8	42.1
30	9.97	9.15	8.3	3.9	60.6	5.6	44.1
31	9.59	8.77	8.6	3.7	61.7	5.3	44.3
32	9.29	8.41	9.4	3.4	63.1	5.1	44.8
33	9.03	8.06	10.7	3.2	64.5	4.9	45.4
34	8.81	7.72	12.4	3.0	66.2	4.7	46.2
35	8.61	7.39	14.1	2.8	67.7	4.6	46.9
36	8.33	7.08	15.0	2.6	68.9	4.4	47.0
37	8.12	6.77	16.6	2.4	70.3	4.3	47.5
38	7.87	6.47	17.8	2.2	71.5	4.1	47.7
39	7.58	6.19	18.3	2.1	72.4	4.0	47.5
40	7.13	5.91	17.2	1.9	72.8	3.9	45.9
41	6.78	5.64	16.9	1.8	73.5	3.7	44.9
42	6.48	5.39	16.9	1.7	74.1	3.6	44.0
43	6.12	5.14	16.0	1.6	74.5	3.5	42.3
44	5.72	4.91	14.1	1.5	74.6	3.4	40.0
45	5.10	4.68	8.3	1.3	73.7	3.3	34.5
46	4.25	4.46	-5.0	1.3	70.6	3.3	23.5
47	3.79	4.26	-12.5	1.2	64.4	3.2	16.3
48	3.44	4.06	-18.0	1.1	68.6	3.1	10.2
49	3.16	3.87	-22.3	1.0	68.4	3.0	4.9
50	2.89	3.68	-27.1	0.9	67.9	2.9	-1.6

-ve deviations indicate over-estimation
+ve deviations indicate under-estimation

Table 47 provided the cummulative production for 44 weeks for observed and predicted under each model, the multiplicative factors for computing part yield for each model, and the % deviations for each period. On the table, columns 2, 3, 4 and 5 give the cummulative production at two weeks intervals for observed and predictions from Gamma, Modified Gamma and Inverse polynomial functions, respectively. Columns 6 to 8 provide percentage deviations of the predicted from observed for the three models while column 9, 10 and 11 are the derived multiplicative factors for computing total 44 week production from past records.

TABLE 47. Observed and Predicted Cummulative Production, % Deviations and Multiplicative Factors for Friesian Data

	PREDICTED PRODUCTION FOR MODEL				PERCENTAGE DEVIATIONS FROM OBSERVED AVERAGE PRODUCTION			MULTIPLICATIVE FACTORS FOR PREDICTING PART YIELD		
WEEK	OBSERVED	GAMMA	MODIFIED GAMMA	INVERSE	GAMMA	MODIFIED GAMMA	INVERSE	GAMMA	MODIFIED GAMMA	INVERSE
4	398.52	314.86	294.91	310.73	21.00	26.00	22.00	10.96	7.19	11.19
6	631.99	528.43	477.12	709.80	16.40	24.50	-12.30	6.53	4.44	4.90
8	861.21	754.11	658.49	1144.64	12.40	23.50	-32.90	4.58	3.22	3.04
10	1080.32	958.80	831.95	1518.65	9.00	23.00	-40.60	3.51	2.55	2.29
12	1294.34	1208.76	993.79	1818.60	6.60	23.20	-40.50	2.85	2.13	1.91
14	1499.44	1428.84	1142.26	2059.47	4.70	23.80	-37.30	2.42	1.86	1.69
16	1695.38	1639.19	1276.94	2256.87	3.30	24.70	-33.10	2.11	1.66	1.54
18	1878.58	1838.97	1397.90	2422.28	2.10	25.60	-28.90	1.88	1.52	1.44
20	2052.30	2027.34	1505.91	2563.82	1.20	26.60	-24.90	1.70	1.41	1.36
22	2222.88	2203.88	1601.67	2687.02	0.90	27.90	-20.90	1.57	1.32	1.29
24	2382.47	2368.52	1684.23	2795.80	0.60	29.20	-17.30	1.46	1.26	1.24
26	2535.81	2521.47	1760.64	2893.03	0.50	30.50	-14.10	1.37	1.20	1.20
28	2681.25	2663.08	1825.81	2980.81	0.70	31.90	-11.20	1.30	1.16	1.17
30	2821.67	2793.80	1882.79	3060.75	1.00	33.30	-8.50	1.24	1.13	1.14
32	2953.81	2914.10	1932.49	3134.04	1.30	34.60	-6.10	1.18	1.10	1.11
34	3078.66	3024.56	1975.75	3201.73	1.80	35.80	-4.00	1.14	1.07	1.09
36	3197.19	3125.85	2013.34	3264.59	2.20	37.00	-2.10	1.10	1.05	1.07
38	3309.12	3218.53	2045.89	3323.25	2.70	38.20	-0.40	1.07	1.04	1.05
40	3412.12	3303.23	2074.10	3378.13	3.20	39.20	1.00	1.04	1.02	1.03
42	3505.00	3380.44	2098.46	3429.72	3.60	40.10	2.10	1.02	1.01	1.01
44	3587.83	3450.79	2119.53	3478.44	3.80	40.90	3.00	1.00	1.00	1.00

Note -ve deviations indicate Predicted > Observed ==> over-prediction

Table 48. Observed and Predicted Cummulative productions from Multiplicative Factors for Friesian cows

					D E V I A T I O N S (%)		
WEEK	OBSERVED	GAMMA	MODIFIED GAMMA	INVERSE	GAMMA	MODIFIED GAMMA	INVERSE
4	398.52	327.36	499.00	320.63	17.86	-25.2	19.6
6	631.99	549.44	808.07	732.21	13.06	-27.9	-15.9
8	861.21	783.37	1114.23	1180.21	9.04	-29.4	-37.0
10	1080.32	1022.17	1406.99	1566.74	5.38	-30.2	-45.0
12	1294.34	1258.89	1684.43	1878.45	2.74	-30.1	-45.1
14	1499.44	1482.57	1928.94	2122.98	1.12	-28.6	-41.6
16	1695.38	1700.39	2161.34	2329.76	-0.30	-27.5	-37.4
18	1878.58	1908.42	2360.41	2491.55	-1.59	-25.7	-32.6
20	2052.30	2110.49	2544.56	2638.11	-2.84	-24.0	-28.5
22	2222.88	2285.24	2718.05	2781.26	-2.81	-22.3	-25.1
24	2382.47	2457.42	2847.48	2893.41	-3.15	-19.5	-21.5
26	2534.81	2618.85	2989.86	2989.86	-3.32	-18.0	-18.0
28	2681.25	2759.87	3092.96	3066.52	-2.93	-15.4	-14.4
30	2821.67	2893.41	3175.07	3147.22	-2.54	-12.5	-11.5
32	2953.81	3040.53	3261.66	3232.28	-2.94	-10.4	-9.4
34	3078.66	3147.22	3353.11	3291.59	-2.23	-8.9	-6.9
36	3197.19	3261.66	3416.98	3353.11	-2.02	-6.9	-4.9
38	3309.12	3353.11	3449.84	3416.98	-1.33	-4.3	-3.3
40	3412.12	3449.84	3517.48	3483.33	-1.11	-3.1	-2.1
42	3505.00	3517.48	3552.31	3552.31	-0.36	-1.4	-1.4

From the percentage deviations, the result showed that generally the Gamma based models under-estimated the production while the Inverse polynomial was found to have over-estimated the past yield. This was very pronounced between the 4th and 14 weeks (figure 9) and table 36 when the model was found to have grossly over-predicted the actual average daily production. The cummulative effects was therefore well demonstrated and explained the high figures observed particularly between weeks 8 and 16. Considering the Modified Gamma function, the figures showed a gradual increase in the percentage deviation. The model was found to have a consistent under prediction of the actual production of the average production for the Friesian.

The under-estimation in the Gamma function was highest before the 8th week. The under-estimation gradually diminished up to the 28th week in production. The deviation then picked up again. However the rate of increase was not as high. The pattern in the Modified Gamma was slightly more consistent though the deviation was much higher. The deviation was least in the earlier lactations but gradually increased to a maximum of 40% in the 44 week cummulation production. From table 47, it was found that the Modified Gamma under-estimated the cummulative total production by 40% compared to about 4% recorded in the Gamma Function. For the Inverse polynomial, the model over-estimated the cummulative production between 6^{th} and 36^{th} weeks. The highest occurred at the time the peak was attained (Compare table 46). Beyond

this point, there was an under-prediction in the cummulative production.

Multiplicative factors developed on table 47 have been used to estimate part total production for each of the periods. The deviations of the estimated values from the observed have been computed and shown in columns 6, 7 and 8 for each model.

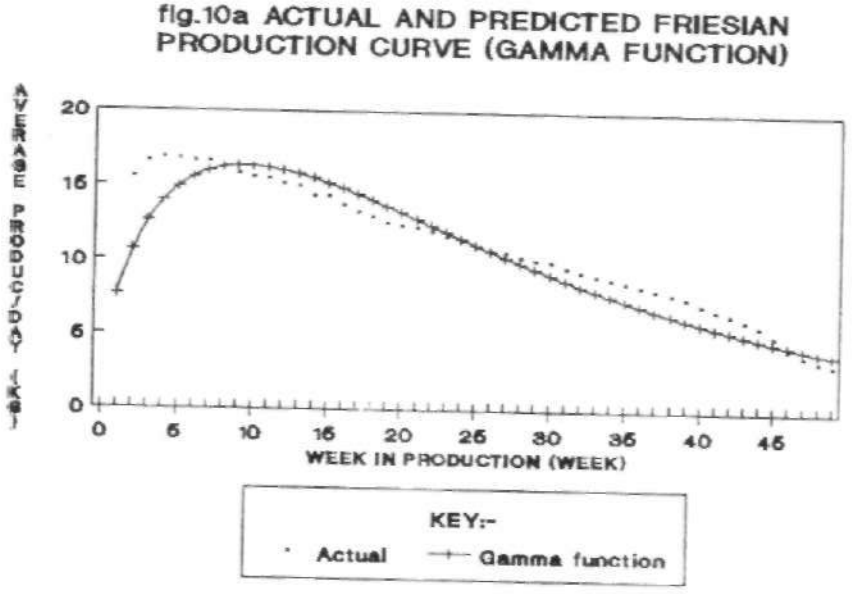
The result showed that estimated values from factors for the Gamma function generally had lower deviations compared to those from the Modified Gamma and the Inverse polynomial functions. For instance, under the gamma function, the factors tended to have under-estimated the actual in the earlier part of the lactation period (14^{th} week) and beyond this point the factor over-estimated the actual production by an average of about 2.5%. The pattern observed for the modified Gamma function showed a generally high level of over-estimation. The values were particularly high up to 32^{nd} weeks of cummulative production. This dropped slightly beyond the point although the values were relatively higher than the corresponding for other two moelds. The pattern observed for the values estimated using factors under the Inverse function was similar to those generated under the Modified Gamma function, however, the deviations were much higher particularly between the productions for 10 and 20 weeks. Comparatively, the factors generated from Gamma function have lower deviations and appeared more stable considering the percentage deviations computed relative to

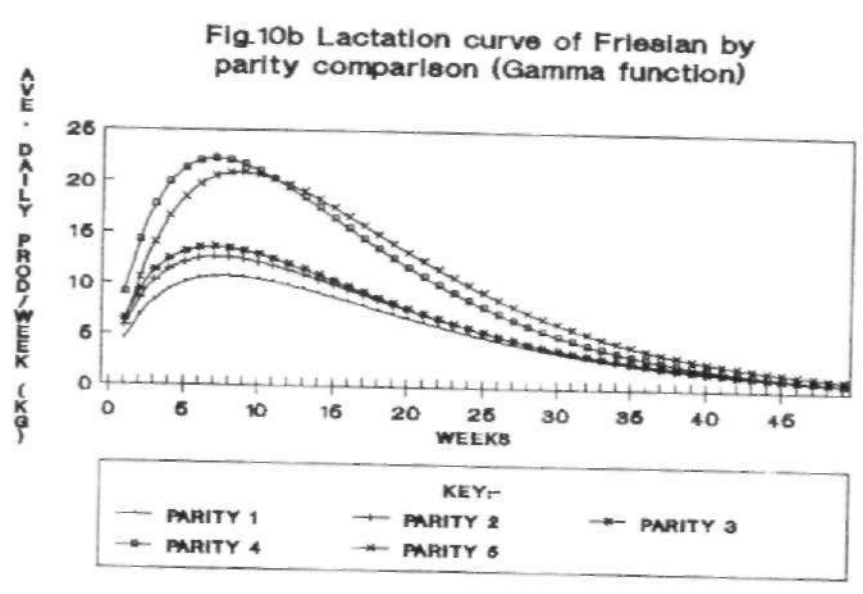
the other models.

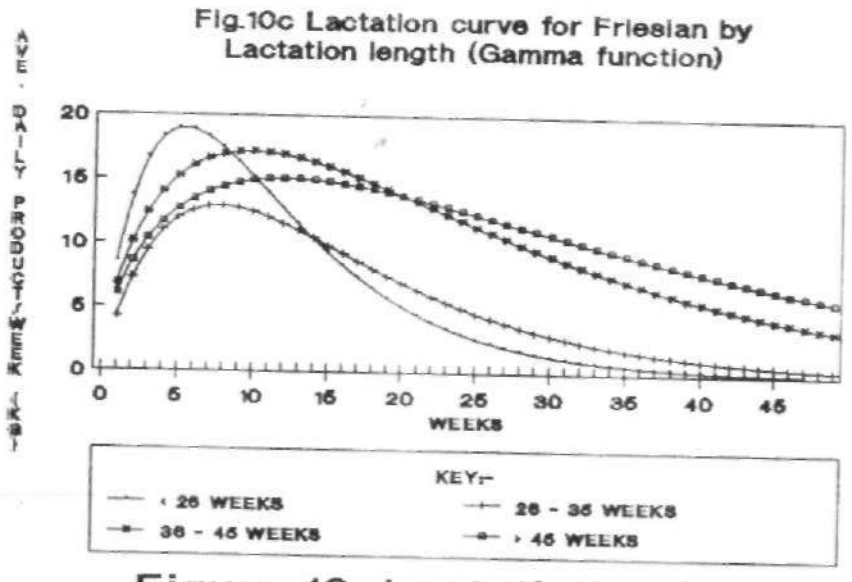
4.12 FACTORS AFFECTING LACTATION CURVE AND PRODUCTION CHARACTERISTICS OF FRIESIAN COWS UNDER GAMMA FUNCTION.

A total of 111 lactations obtained from 39 Friesian cows were analysed to evaluate the effects of parity, lactation length, year and season of calving on the lactation curve parameters namely; the general level of production evaluated by constant, a, rate of increase in production, b and the relative rate of decline, c. The effect of factors on the predicted production parameters were also evaluated. The results are summarised on tables 49 (Appendix B) and 50 while figure 10 is a graph of the fitted and the observed production pattern. From table 49, the results showed that only the effect of season of calving significantly($P<0.05$) affected the general level of production. There was a significant effect of lactation length($P<0.05$) and year($P<0.05$) of calving on the rate of rise to the peak while all the other factors with the exception of parity had significant effects on the rate of decline from the peak. These effects were particularly pronounced on the lactation length. The distribution of the Friesian data with respect to the lactation length showed that only about 8.5% of the cows had lactation length below 35 weeks. Because of the low percentage relative to the other categories, one might therefore use this to explain the high significance observed in this category. The adjusted coefficient of determination was significantly affected by year of calving.

figure 10







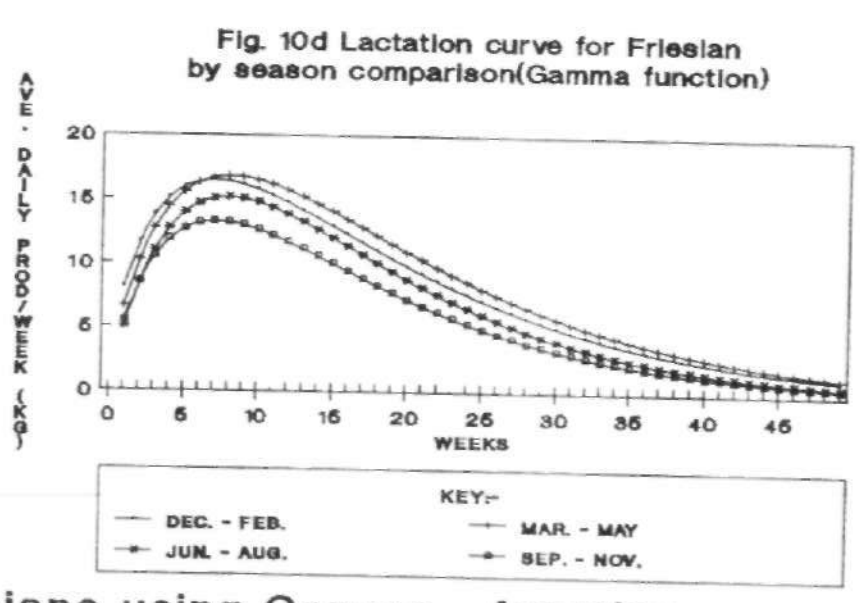


Figure 10. Lactation pattern of Friesians using Gamma function

Considering the parameters which measure the rate at which the peak is maintained is called persistency. The result showed significant effect of the lactation length ($P<0.001$), season of calving ($P<0.05$) and year of calving ($P<0.05$).

For the production indicators, the result showed that only the season of calving had significant ($P<0.01$) effects the predicted initial production and there was no significant effect ($P>0.05$) on any other factors on when the peak was attained. The result, however, showed that the maximum production was significantly affected by parity ($P<0.01$), season and year of calving ($P<001$) of the animal. Finally, the total production was significantly affected by lactation length ($P<0.001$), season of calving ($P<0.01$) and year of calving ($P<0.01$).

TABLE 50 : Least squares means and standard errors for curve and production characteristics under Gamma function for Friesian cows

PARAMETERS		a		b		c		Adjust R^2		s		pwk		Initprd.		Mxprod.		Tprod
PARITY	N	Mean	S.E.	Mean	S.E.	Mean	S.E.	Mean	S.E.	Mean	S.E.	Mean	S.E.	Mean	S.E.	Mean	S.E.	Mean & S.E.
1	26	2.396	0.25	0.736	0.15	0.095	0.02	0.55	0.09	2.81	0.26	9.8	1.6	5.45	2.1	10.9[d]	2.10	1934.80 529.8
2	30	2.652	0.20	0.689	0.12	0.095	0.01	0.64	0.07	2.82	0.21	8.2	1.3	7.46	1.7	14.2[de]	1.70	3008.96 429.0
3	28	2.760	0.19	0.685	0.11	0.099	0.01	0.65	0.06	2.86	0.20	7.5	1.3	8.88	1.6	16.1[e]	1.50	2860.86 394.9
4	18	3.117	0.23	0.813	0.13	0.115	0.01	0.72	0.08	2.98	0.24	6.7	1.4	12.20	1.9	21.8[f]	1.90	3623.16 480.3
5	9	2.696	0.29	0.979	0.17	0.113	0.02	0.69	0.10	3.06	0.30	7.5	2.0	7.78	2.4	22.1[f]	2.30	3785.76 600.3
LACTATION LENGTH																		
<26	3	3.110	0.34	0.923[e]	0.20	0.172[f]	0.02	0.70	0.12	2.50[d]	0.36	5.4	2.1	10.10	2.9	15.2	2.80	2617.50[d] 721.4
26-35	6	2.363	0.24	0.953[e]	0.14	0.124[e]	0.01	0.63	0.08	2.54[d]	0.25	8.0	1.5	6.34	2.0	14.0	1.90	2102.09[d] 504.0
36-45	35	2.782	0.13	0.666[d]	0.08	0.068[d]	0.01	0.62	0.04	3.13[e]	0.14	8.4	0.9	9.00	1.1	16.7	1.10	3200.65[de] 273.8
>45	62	2.642	0.09	0.579[d]	0.05	0.048[d]	0.01	0.65	0.03	3.47[e]	0.09	9.9	0.6	8.00	0.7	17.7	0.70	4250.59[f] 187.2
SEASON OF CALVING																		
Dec-Feb.	22	2.979[e]	0.16	0.648	0.09	0.092[d]	0.01	0.66	0.05	2.98[de]	0.16	7.2	1.0	10.92[e]	1.3	18.4[e]	1.30	3454.41[e] 328.3
Mar-May	12	2.778[de]	0.19	0.764	0.11	0.094[de]	0.01	0.58	0.06	3.18[e]	0.19	7.3	1.2	8.72[de]	1.6	18.0[e]	1.60	3545.04[e] 391.5
Jun-Aug.	24	2.535[d]	0.17	0.912	0.10	0.115[e]	0.01	0.69	0.06	2.81[de]	0.18	8.2	1.1	6.89[d]	1.4	17.0[e]	1.40	2728.32[d] 360.6
Sep-Nov.	53	2.605[de]	0.14	0.797	0.08	0.111[de]	0.01	0.67	0.05	2.66[d]	0.14	9.1	0.9	6.89[d]	1.1	14.7[d]	1.10	2443.07[d] 287.5

Note

Initprd=Initial week average daily production
pwk- peak week
Mxprod- peak production/day at peak week
Tprod-total production/lactation
a-general level of production under Gamma basedfuntions.
b-rate of rise to the peak under Gamma based functions.
c-rate of decline from the peak under Gamma based functions.

Note: Least squares means connected by the same letter within a subclass are not significantly different from each other ($p< =0.05$)

Table 50 provides a summary of the table of means for all the factors using Gamma function. From table 49, results showed that cows calving in the period between December and February had a relatively high and significantly ($P<0.05$) higher general level of production compared to other periods. Those that calved between June - August, had the lowest level of general level of production. There was no significant effect of parity or lactation length on these parameters.

Furthermore, the result showed that cows that were in milk for less than 35 weeks had higher rate of rise to peak compared to those in milk for longer period. Also, cows with high rise to the peak were found to have similarly high rate of decline from the peak. Those cows in milk for less than 26 weeks were found to have relatively higher general level of production although no significant difference was recorded between classes. Cows that were in milk for less than 26 weeks had a rate of decline of about 3.6, 2.5, 1.4 times more than those in categories >45, 36 - 45, and 26 - 35 weeks, respectively. Furthermore, cows that calved between June - August, had significantly ($P<0.05$) higher rate of decline from the peak when compared to those that calved in other seasons. The production patterns by the different factors notably parity, lactation length and season of calving are given in figure 10.

Persistency showed that cows in the third to fifth

parity had a relatively higher persistency compared to those of lower parity-although no significant effect of parity was recorded. Cows in milk for more than 36 weeks had significantly ($P<0.01$) higher persistency while cows that calved in the period March to May had the highest persistency which differed significantly ($P<0.05$) from those that calved in September to November and those between June to August.

Considering the production indicators, the initial production was significantly ($P<0.01$) affected by season of calving. Cows that calved in the December to February period had significantly ($P<0.05$) higher average initial production than those that calved in other periods particularly the June to November periods. Attainment of maximum production which was measured by the Peak Week was not affected by any of the factors. However, the result showed that cows coming into milk for the first time took averagely longer time to attain the peak than those higher parity although there was no significant ($P>0.05$) difference noticed for any of the factors studied. In the lactation class category, there was a positive relations between the lactation class length with the time of attainment of peak. It was observed that the longer an animal stayed in milk, the longer it took to reach the peak. Shorter lactation length lead to the peak being attained earlier. In other words, early peak is an indicator of a short lactation length. Result for the Friesian data also showed that cows that calved between December to August attained the peak earlier than those that calved between June

to November though no significant difference was noticed between the values.

With respect to the peak production, there was significant effect of parity ($P<0.01$), season and year of calving ($P<0.01$). There was a positive relation between the parity number and the peak production. Result showed a gradual increase in the peak production as the parity increased. There was no significant effect of lactation length on peak production. The effect of season was significant ($P<0.01$) as the result showed that animals that calved in the period between September to November had significantly ($P<0.01$) lower peak compared to the other groups.

Comparing the rate of attaining the peak between the parity and season of calving showed the rate of change per week were 0.56, 0.82, 0.96, 1.4 and 1.9 kg/week, respectively for parities one to five. Thus showing that Friesian cows in higher parities produced at a higher rate compared to the lower ones. This is an indication of the development secretory tissue in older animals(higher parity cows) compared to younger animals(lower parity cows). Furthermore, the comparison between season of calving showed that cows calving in the period between March and August had higher rates per week. The rates for December - May, March - May, June - August and September - November were 1.03, 1.27 - 1.23 and 0.86, kg per week, respectively.

In the predicted total production, the result showed

significant effects of lactation length($P<0.001$), season ($P<0.001$) and year ($P<0.01$) of calving, the production increased with parity number however there was no significant effect of parity. Cows that calved between December and May had significantly ($P<0.01$) better predicted total production compared to those that calved in the other seasons. The pattern of production by each of the factors is given in figure 10.

4.12.1 Discussion

From the analysis, the observation showed that the effect of parity was only significant ($P<0.05$) for peak production and was not significant $P>0.05$ for any of the curve parameters or the production indicators (persistency, Initial production, predicted total production). This findings contradicted the findings of Wood (1968) with respect to persistency, the curve parameters (general level of production), a, rate of inclination to the peak, b, and, c, rate of decline from the peak, respectively using Friesian data. It also contradicted the findings reported by Rao and Sundaresan (1979) with respect to the lactation curve parameters and persistency and with the significant effect of parity on the peak production and non-significant effect of parity on total production. The result from this study agreed with the findings of Abubakar and Buvanendran (1981) using Friesian- Bunaji crosses for the curve parameters and persistency.

The result from this study showed significant effect of season on the general level of production, a, (P<0.05) and the rate of decline from the peak, c (P<0.01), persistency, s (P<0.05), initial week average daily production (P<0.01), peak production and total production (P<0.01). This finding agreed with Wood (1968) with respect to the general level of production, rate of decline from the peak and persistency. It also agreed with the findings of Rao and Sundaresan (1979) with respected to the general level of production rate of decline from the peak, persistency, total production and peak production. It however conflicted with Wood (1968) and Rao and Sundaresan (1979) with respect ot the rising phase.

The result agreed with a study by Ram and Chaudhary (1986) who reported significant effect of season of calving on peak yield. While the study agree with the findings of Singh et al. (1965) with respect to the significant effect of season on persistency and that of Branton et al. (1974) who showed that season of calving had significant effect on the shape of lactation curve, peak production, persistency and lactation lengths in Luisiana-Holstein herd. It agreed with Lindstrom and Solbu (1978), Schneeberger et al. (1982) with respect to significfant effects of season of calving on Total production.

Using the Gamma function, it was observed that cows calving during the rainy season March - August had lower general level of production compared to those calving during the dry season. This might be due to the fact that the onset

of the rains had a stimulating or boosting effect thus leading to a higher production level. Generally, from table 40, it is obvious that cows that calved during the March-May period had on average the best production with respect to rate of rise to the peak, decline from peak, total production, peak production and subsequently persistency although the average coefficient of determination appeared lower.

With respect to the lactation length, this was found to have significant effect on the rate of rise to the peak ($P<0.05$), rate of decline from the peak ($P<0.001$), persistency ($P<0.001$) and total production ($P<0.001$). This agreed with the findings by Abubakar and Buvanendran (1981) except for the general level of production. Result showed that animals that stayed longer in milk had significantly ($P<0.01$) higher persistency (Table 50) and also there was a positive relationship between total production and lactation length.

Finally, the period of calving was found to have significant effect on all the lactation curve parameters and the production indicators with the exception of the general level of production initial production and peak week. This finding agreed with a similar observation by Rao and Sundaresan (1979).

Table 51 Correlation between curve and production parameters for Friesian cows under Gamma function

		a	b	c	pwk	s	Initprd	Mxprd	Tprod
1.	a	1.000							
2.	b	-0.755***	1.000						
3.	c	-0.383***	-0.815***	1.000					
4.	pwk	-0.584***	0.327***	-0.107	1.000				
5.	s	0.390***	-0.793***	-0.836***	0.011	1.000			
6.	Initprd	0.918**	-0.695***	-0.366**	-0.664***	0.409***	1.000		
7.	Mxprod	0.413**	0.158	0.235*	-0.152	-0.263**	0.421***	1.000	
8.	Tprod	0.328***	-0.260**	-0.422***	0.133	0.331***	0.362***	0.596***	1.000

Note

a=general level of production under Gamma basedfuntions.
b=rate of rise to the peak under Gamma based functions.
c=rate of decline from the peak under Gamma based functions.
Initprd=Initial week average daily production
pwk= peak week
Mxprod= peak production/day at peak week
Tprod=total production/lactation

Significance * = P<0.05, ** = P<0.01, *** = P<0.001

A study of the correlation between the lactation curve paramaters and the production indicators presented on Table 51 showed correlation between some of the parameters. Notable among these are significant (P<0.001) and positive correlation between the general level of production a and Initial production with a coefficient of 0.918, persistency peak production and total production. On the other hand it was observed that the general level of production was significantly (P<0.001) and negatively correlated with peak week. This by implication means that the higher the peak week, the lower the general level of production. This could be found in table 40. Also, the positive phenotypic correlation observed particularly with the peak, initial and total production is an indicator to the fact that, the information might be a very useful tool in selection procedures.

The rate of rise to the peak and rate of decline were found to be negatively but significantly correlated with the indicators particularly persistency (P<0.001), initial and total production. Persistency was observed to be nagatively and significantly correlated with peak production (P<0.01) but was positively and significantly correlated with initial and total production. Within the production parameters the initial production was significantly and positively correlated with the peak production (P<0.001) and total production (P<0.001). This implied that a higher initial

production could be an indicator of higher peak and total production. The findings agreed with those of Sikka (1950) Sharma (1972), Belarne (1970) and that of Rao and Sundaresan (1979) except that the coefficients varied slightly. By this finding, it mihgt be a very useful tool also for selection procedure using either the initial production or Peak production rather than waiting for the entire lactation for the Friesian cow.

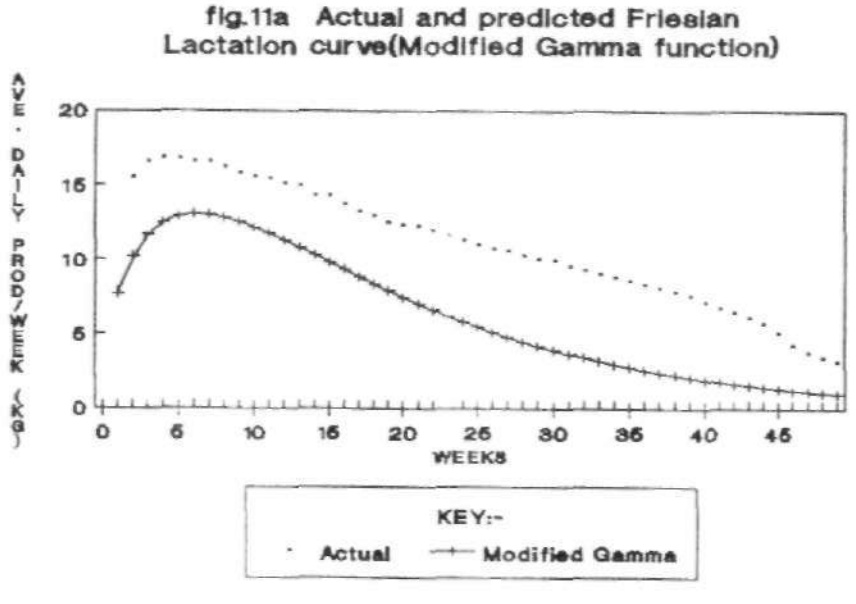
Finally, a close study of the coefficient of determination showed that the goodness of fit for parity ranged between 55% in the first parity to about 72% over all the factors under consideration . However, there was no significant effect of any of the factors on the Coefficient of determination. Best fitness was recorded for cows in the fourth parity or cows that were in lactation length for less than 26 weeks though the number of cows in this category were too few for such an assessment to be valid. Lowest R^2 was recorded for cows that calved between March - May sesaon although the highest persistency was recorded for the same period.

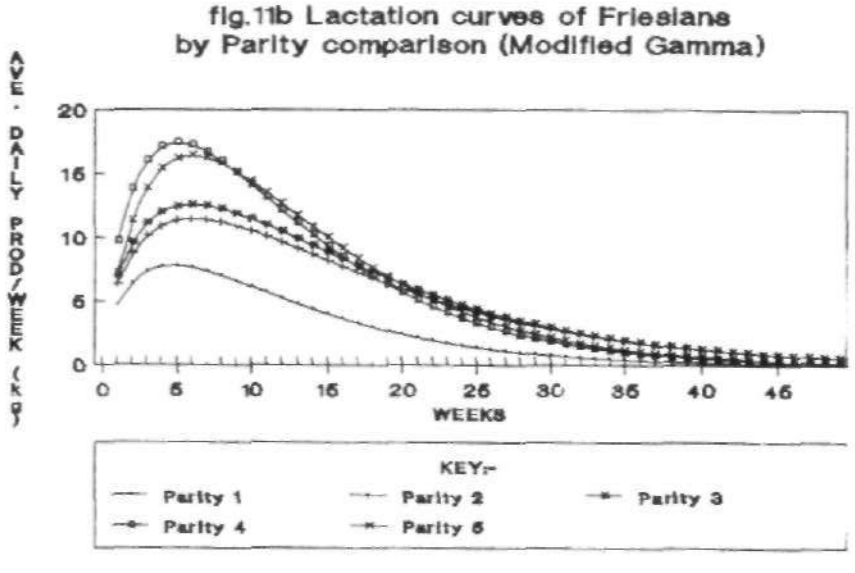
4.13 FACTORS AFFECTING LACTATION CURVE AND PRODUCTION CHARACTERISTICS OF FRIESIAN COWS UNDER MODIFIED GAMMA FUNCTION

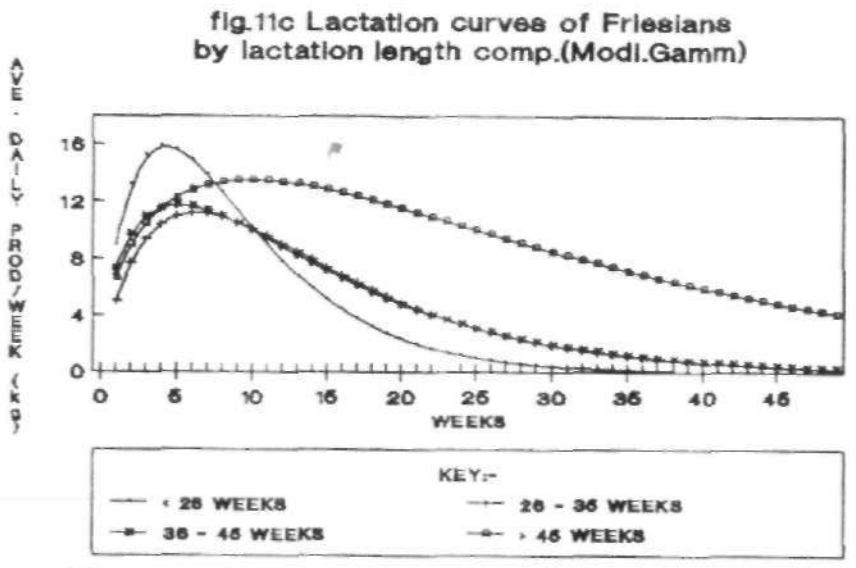
Table 52 (Appendix C) gives the summary of the analysis of variance under the Modified Gamma Model showing the effects of the factors under consideration. Table 53 provided the summary for the least squares means for each factor while figure 11a gives the graphical representation of the actual and fitted production curves using the Modified Gamma function. Figures 11b, c and d are the corresponding production pattern for the Friesian cow under the Modified Gamma function.

Under Modified Gamma function there was no significant ($P>0.05$) effect of lactation length, season and year of calving on any of the curve parameters. However, the effect of the factors were noticeable on some of the production parameters. It was observed that parity had significant ($P<0.05$) effects on the peak production. It was observed that there was an increase in peak production with increase in parity order. There was an average production of about 11.3 kg/day in the first parity compared to an average peak production of 23.1 kg/day at the 5^{th} parity. The same pattern of production was observed for trhe initial and the entire total production however, there was no significant ($P>0.05$) differences between the parities. While there was increase in the Initial peak and Total production with increase in the parity order, the peak week decreased with parity order. Effect of lactation length was significant

figure 11







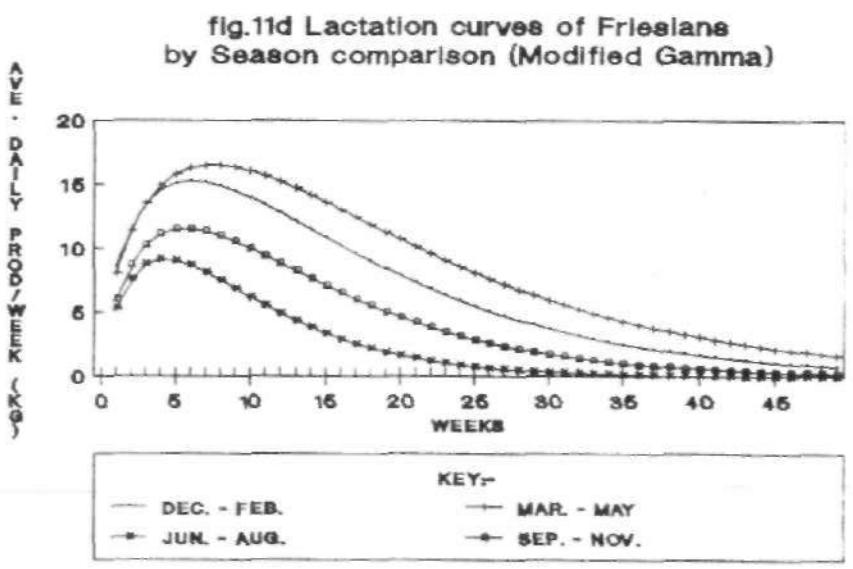


Figure 11. Lactation pattern of Friesians using Modified Gamma function

(P<0.001) on persistency only.

Persistency increased with increase in lactation length. Cows that were in production for a period greater than 45 weeks had the highest persistency while those in milk for less than 26 weeks had the least persistency. This could be as a result of number of cows in category and also due to the faster rate of rise to the peak which was correspondingly followed by a very sharp rate of decline from the peak leading to a poor measure in persistency.

Season of calving did not affect any of the curve parameters. It was however significant for Initial production (P<0.05) and peak production (P<0.01). Result showed that cows that calved in the period between December and February had significantly higher Initial average daily production than those that calved in order periods (Table 53). It was observed that there was no significant difference between the average daily production between seasons that is, between March -August compared to September to February. However, season had significantly (P<0.05) better average daily production than those that calved in the cool wet season (June - August) and between September to November. With respect to the peak production, cows that calved post rainy season September - November had significantly lower peak than those that calved in other periods. The rate of increase per week for the different season was highest for cows that calved between March - May with an average value of 1.17 kg/week while the others were

TABLE 53 : Least squares means and standard errors for curve and production characteristics under Modified Gamma function for Friesian cows

PARAMETERS		a		b		c		R^2		s		pwk		Initprd.		Mxprod.		Tprod
PARITY	N	Mean	S.E.	Mean	S.E.	Mean	S.E.	Mean	S.E.	Mean	S.E.	Mean	S.E.	Mean	S.E.	Mean	S.E.	Mean & S.E.
1	25	2.279	0.25	0.667	0.14	0.140	0.15	0.54	0.09	3.2	0.25	10.5	1.8	5.35	2.2	11.3[d]	2.2	2551.50 824.0
2	30	2.741	0.20	0.607	0.11	0.099	0.12	0.64	0.07	3.1	0.20	7.6	1.5	7.54	1.8	13.3[d]	1.8	3186.30 664.9
3	28	2.839	0.19	0.610	0.10	0.101	0.11	0.65	0.06	3.0	0.19	6.7	1.4	9.04	1.7	15.0[d]	1.7	2999.40 396.8
4	18	3.209	0.23	0.709	0.13	0.140	0.03	0.74	0.08	2.9	0.23	8.4	1.6	12.60	2.0	21.5[e]	2.1	4008.40 478.3
5	9	2.917	0.30	0.848	0.17	0.141	0.18	0.72	0.11	3.0	0.31	8.1	2.3	9.82	2.7	23.1[e]	2.7	4057.8 600.3
LACTATION LENGTH																		
<26	3	3.188	0.35	0.861	0.19	0.206	0.20	0.72	0.12	2.7	0.35	7.3	2.3	11.29	3.1	22.3	3.1	3009.7 1113.4
26-35	6	2.531	0.24	0.806	0.13	0.128	0.14	0.63	0.08	3.0	0.24	7.6	1.6	7.01	2.1	13.0	2.1	2328.9 732.5
36-45	35	2.892	0.13	0.577	0.07	0.113	0.08	0.62	0.05	3.1	0.13	8.6	1.0	9.17	1.2	16.7	1.2	3770.9 432.5
>45	62	2.736	0.09	0.508	0.05	0.051	0.05	0.66	0.03	3.4	0.09	9.4	0.7	8.00	0.8	15.4	0.8	4333.3 245.5
SEASON OF CALVING																		
Dec-Feb.	22	3.032	0.15	0.603	0.09	0.099	0.09	0.67	0.05	3.0	0.16	6.9	1.1	11.04[e]	1.4	17.8[d,e]	1.4	3603.1 505.3
Mar-May	12	2.958	0.19	0.630	0.11	0.084	0.11	0.58	0.07	3.1	0.19	7.7	1.3	9.36[d,e]	1.7	18.4[e]	1.7	3556.5 615.0
Jun-Aug.	24	2.646	0.17	0.800	0.10	0.187	0.10	0.69	0.06	3.1	0.17	9.8	1.2	7.67[d]	1.5	17.1[e]	1.6	3554.8 562.0
Sep-Nov.	53	2.712	0.13	0.719	0.08	0.127	0.08	0.68	0.05	3.0	0.14	8.6	1.0	7.42[d]	1.2	14.1[d]	1.2	2728.5 442.0

Note

a=general level of production under Gamma basedfuntions.
b=rate of rise to the peak under Gamma based functions.
c=rate of decline from the peak under Gamma based functions.
Initprd=Initial week average daily production
pwk- peak week
Mxprod- peak production/day at peak week
Tprod-total production/lactation

Note: Least squares means connected by the same letter within a subclass are not significantly different from each other ($p< =0.05$)

0.98, 0.96 and 0.77 for December - February, June -August and September - November, respectively. No significant effect of season of calving was recorded for Total production, persistency or peak week.

Table 54 is a presentation of the correlation between the curve parameters and the production indicators for Friesian data using the modified gamma function.

With the coefficient, the general level of production was positively and significant correlated ($P<0.001$) with the Initial and the peak production while there was no significant correlation between the curve parameters and the total production. The parameters had a significant ($P<0.001$) correlation with the persistency, peak week and rate of rise to the peak. The rate of rise to the peak was on the other hand observed to have significant ($P<0.001$) but negative correlation with the Initial week average production per day while it had positive and also significant correlation with the peak week and persistency. The rate of decline from the peak was not significantly correlated with any of the lactation curve parameters nor the production indicators. Peak week was positively correlated with persistency with a an r-value of 0.690 while it was negatively but significantly ($P<0.001$) correlated with average initial production per day. Persistency was found to be correlated with the total production and negatively but significantly ($P<0.001$) correlated with the initial average production observed between the initial average daily and total production on the

one hand and between the peak production and the total production on the other.

Table 54. Correlation between curve and production parameters under Modified Gamma function for Friesian cows

variables	a	b	c	pwk	s	Initprd	Mxprd	Tprod
1. a	1.000							
2. b	-0.713***	1.000						
3. c	-0.036	0.071	1.000					
4. pwk	-0.515***	0.262**	-0.009	1.000				
5. s	-0.586***	0.199*	-0.064	0.690***	1.000			
6. Initprd	0.924***	-0.684***	-0.063	-0.539***	-0.534***	1.000		
7. Mxprod	0.428***	0.146	-0.011	-0.051	-0.186	0.430***	1.000	
8. Tprod	0.111	-0.153	-0.060	0.165	0.236*	0.098	0.153	1.000

Note

a=general level of production under Gamma basedfuntions.
b=rate of rise to the peak under Gamma based functions.
c=rate of decline from the peak under Gamma based functions.
s=persistency
Initprd=Initial week average daily production
pwk- peak week
Mxprod- peak production/day at peak week
Tprod-total production/lactation

Significance of correlation coefficients
* P<0.05 ** P < 0.01 *** P < 0.001

4.13.1 Discussion

Under the Modified Gamma function it was observed that the result showed some marked differences from what was observed under the Gamma function. The parity effect was significant ($P<0.05$) only for the peak production. This was in agreement with the findings observed using the Gamma function. However considering the other factors particularly with the effect of season, it was observed that with the exception of the initial production per day and the peak production the season where the effect was significant at 5 and 0.1%, respectively there was no noticeable effect of season recorded on any of the parameters under consideration. This one may perhaps argue that the modification to the curve had achieved the objective of the model that the extra term V cos (x) + U Sin (x) was able to remove the seasonality or cyclicity in milking of cows as a result of the seasonal effect.

The non-significance of the effects due to parity and season of calving on the curve parameters agreed with similar observation by Abubakar and Buvanendran (1981). The non-significant effect of lactation length on the curve parameters in this study conflicted with the finding by Abubakar and Buvanendran (1981) particularly with respect to the general level of production and persistency. The result from this study was similar to the findings of Rao and Sundaresan (1979) who observed effects of periods of calving; on persistency as well as effects of season of

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calving, period of calvings and parity of calving on the peak production in the study of Sahiwal cows. There was a positive relashionship between the Initial week average daily production and the general level of production on the one hand, and average Initial production and the peak production on the other (Table 54). Positive correlation was obtained between persistency and total production but a negative though non-significant correlation, between persistency and peak production.

4.14 FACTORS AFFECTING LACTATION CURVE AND PRODUCTION CHARACTERISTICS OF FRIESIAN COWS UNDER INVERSE POLYNOMIAL FUNCTION.

Table 55 (Appendix C) is the summary of the analysis of variance for factors on fitting Inverse polynomial function to the Friesian data. Table 56 gives the least squares means and the standard error for each factor and for curve and production parameters under consideration. Figure 12 is the graph of the fitted and the observed pattern of production under the Inverse polynomial function under various factors.

Results showed that the effect of parity was not significant ($P>0.05$) for either the arising phase (a), the general slope or the declining phase of the curve. Similarly there was no significant effect of the parity on either of the production indicators or the coefficient of determination (R^2). Furthermore, the effect of lactation length was significant for the declining phase ($P<0.001$), the adjusted coefficient of determination ($P<0.05$) and the predicted total production ($P<0.05$). The effect was not significant ($P>0.05$) for the other parameters. As for the effect of season of calving, the result showed that the factor was observed to be significant for the declining phase ($P<0.05$), the average slope which is an indicator of general level of production ($P<0.05$) and the predicted initial production ($P<0.001$). Finally, the effect of year of calving was the only significant ($P<0.001$) factor for the declining phase of the curve.

figure 12

fig.12a Actual and predicted Friesian Lactation curve(Inverse Polynomial)

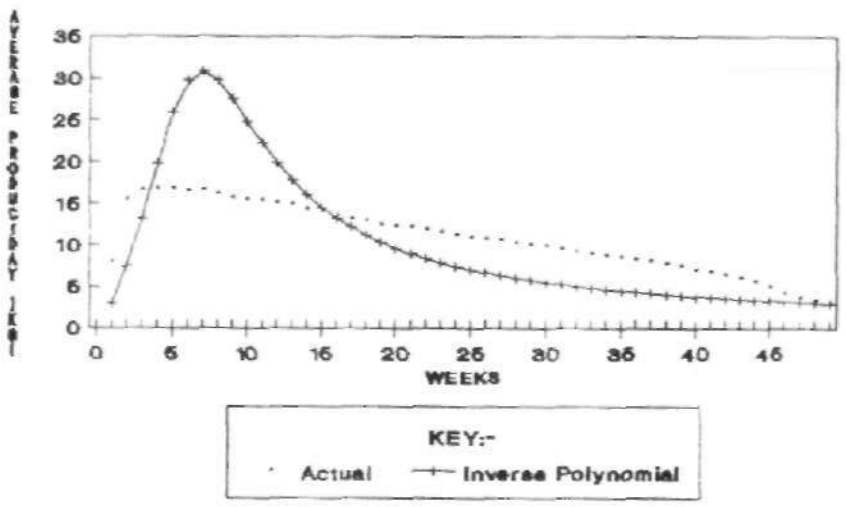


fig.12b Lactation curves of Friesians by parity comparison(Inverse Polynom)

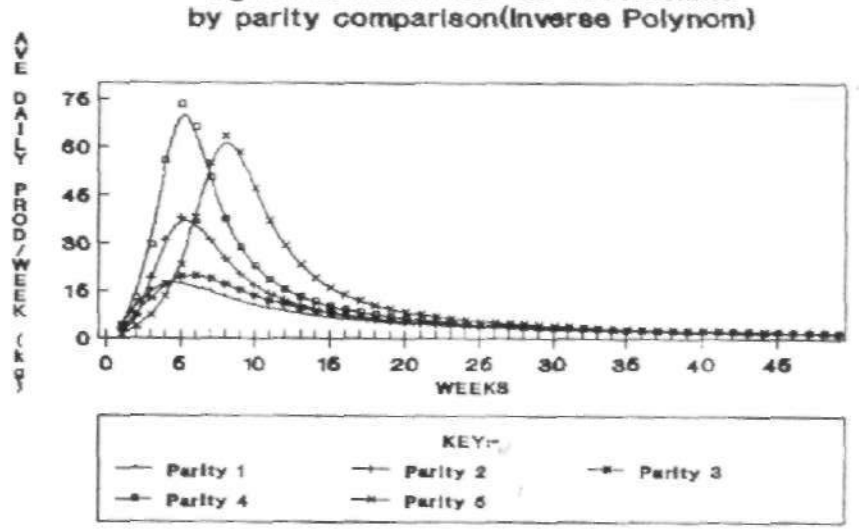


Fig. 12c Lactation curves of Friesians by lactation comp. (Inverse Polynomial)

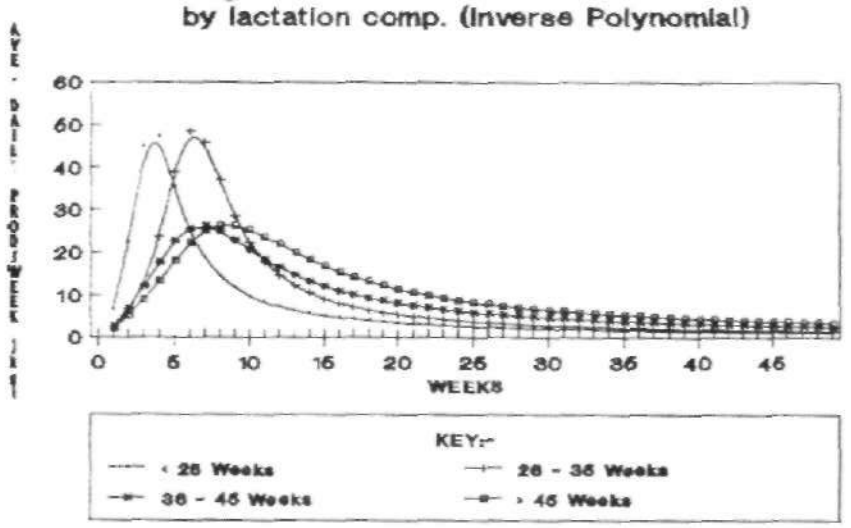


fig.12d Production curve of friesians by season of calving comp. (Inverse Polyn)

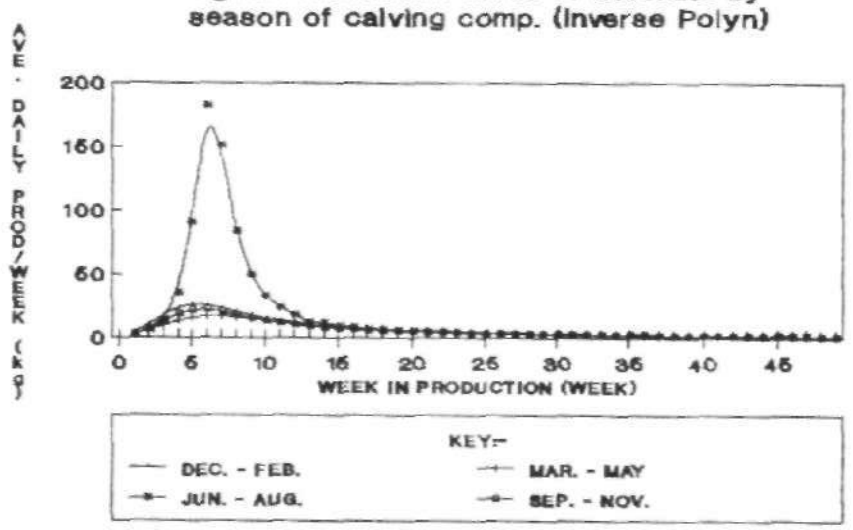


Figure 12. Lactation pattern of Friesians using Inverse Polynomial function.

TABLE 56 : Least squares means and standard errors for curve and production characteristics under Inverse Polynomial function for Friesian cows.

	N	b_0		b_1		b_2		R^2		pwk		Mxprod.		Initprd		Tprod	
PARITY		Mean	S.E.	Mean	S.E.	Mean	S.E.	Mean	S.E.	Mean	S.E.	Mean	S.E.	Mean	S.E.	Mean	S.E
1	26	0.1169	0.10	0.0261	0.03	0.0058	0.002	0.31	0.11	6.4	1.4	19.8	9.7	4.94	1.83	2117.7	509.3
2	30	0.1902	0.08	-0.0601	0.03	0.0068	0.001	0.47	0.09	7.1	1.2	25.4	7.9	4.75	1.50	3548.8	406.0
3	28	0.1813	0.07	-0.0416	0.03	0.0057	0.001	0.53	0.08	6.9	1.1	19.2	7.2	6.00	1.36	2874.1	368.9
4	18	0.1574	0.08	-0.0548	0.03	0.0059	0.002	0.53	0.10	5.1	1.2	17.5	10.5	8.38	1.62	4308.1	559.7
5	9	0.4310	0.10	-0.0995	0.04	0.0066	0.002	0.59	0.12	7.9	1.6	18.4	13.0	6.28	2.10	5427.7	725.5
LACTATION LENGTH																	
<26 WKS	2	0.1142	0.14	-0.0550	0.05	0.0090[c]	0.003	0.46	0.17	5.2[a]	2.2	5.32	18.3	7.15	2.75	2351.1[a]	997.0
26-35	7	0.3037	0.08	-0.0881	0.03	0.0078[b]	0.002	0.55	0.10	6.7[a,b]	1.2	24.80	9.1	5.36	1.55	2878.1[a]	441.4
36-45	35	0.2002	0.05	-0.0421	0.02	0.0044[a]	0.001	0.39	0.06	6.4[a]	0.7	25.50	4.6	6.21	0.97	3999.5[a,b]	243.4
>45 WKS	66	0.2433	0.03	-0.0405	0.01	0.0034[a]	0.001	0.54	0.04	8.4[b]	0.5	24.70	3.5	5.56	0.65	5392.5[b]	179.5
SEASON OF CALVING																	
Dec-Feb.	22	0.1330a	0.06	-0.0343[a]	0.02	0.0049	0.001	0.50	0.07	5.9	0.9	22.30	6.4	8.56[b]	1.16	4345.7	357.2
Mar-May	12	0.2075b	0.07	-0.0393[a]	0.03	0.0051	0.001	0.44	0.08	6.9	1.1	16.00	8.0	6.68[a,b]	1.41	3777.6	412.7
Jun-Aug.	24	0.3141c	0.06	-0.0979[a]	0.02	0.0080	0.001	0.49	0.08	6.6	1.0	16.90	8.3	4.69[a]	1.26	3513.5	450.4
Sep-Nov.		0.2068b	0.05	-0.0542[a,b]	0.02	0.0066	0.001	0.52	0.06	7.2	0.80	25.00	5.6	4.36[a]	1.01	2984.0	299.6

Note

Initprd=Initial week average daily production
pwk- peak week
Mxprod- peak production/day at peak week
Tprod-total production/lactation
b_0- rising phase under Inverse function.
b_1- average slope for Inverse function.
b_2- declining phase from the peak for Inverse functions.

Note: Least squares means connected by the same letter within a subclass are not significantly different from each other ($p \leq 0.05$)

The result of the correlation between the various curve parameters and the production indicators is provided on table 57.

TABLE 57 : Correlation coefficients between curve and production parameters under Inverse Polynomial function for Friesians data.

	b_0	b_1	b_2	pwk	Initprd.	Mxprod.	Tprod.
b_0	1.000						
b_1	-0.760***	1.000					
b_2	0.597***	-0.923***	1.000				
pwk	0.558***	-0.078	-0.138	1.000			
Initprd	-0.648***	0.544***	-0.460***	-0.552***	1.000		
Mxprod	-0.101	0.273**	-0.311***	0.174	0.145	1.000	
Tprod	0.139	-0.043	-0.155	0.216*	0.020	0.174	1.000

parameters viz;
b_0 = the rising phase; b_2 = declining phase
b_1 = the general slope
Initprd=initial week average daily production,
pwk= peak week,
Mxprod= peak production

Significance of coefficients
*= P<0.05 ** = P<0.01 *** = P<0.001

4.14.1 Discussion

On the basis of the result, it was observed that the average goodness of fit measured by the adjusted coefficient of determination (R^2) was about 52% which ranged between 31% to about 60% This by all available records was low. The result obseved here was much lower than the value of about 99% reported by Yadav et al. (1977) in a study of Harianna and its Friesian Crosses using the Inverse polynomial. The results of no significant effect of parity on the inclining phase, and declining phase reported in this study agreed with the findings of Yadav et al. (1977) but contradicted their findings on the average slope where they obseved significant effect of parity.

The results showed an increase in the inclining phase with increase in parity order although there was no significant differences between the parameter over parities. Similarly, the average soope increased with parity order, however the change in the declining phase did not follow any order. With respect to the coefficient of determination, R^2, it was observed that there was increase in good measure with increase in parity order although there was no significant effect of parity. There was no specific order noted for the production parameters with parity order.

For lactation length, the result showed significance for the declining phase, peak week and the predicted total production. Cows that were in milk for less than 26 weeks had

the largest rate of decline while those about 35 weeks had the lowest with the 26 - 35 weeks in the intermediate category. There was a positive relationship between the peak week and order of lactation length. In other words, cows that were in milk for longer period had larger peak week. Some pattern was noted with respect to the predicted total production. The peak production obsertved for the less than 26 weeks laction length was observed to be very low compared to the other categories. This could perhaps be explained by the proportion of animals in the group. From the records used, only about 2% of the entire Friesian data were in this category. The very large standard error could be used to explain the none significant differences between the categories with respect to the characteristic. As for the total production, there was a positive relationship between total production and lactation length.

The season of calving, significantly affected the inclining phase ($P<0.05$), average slope ($P<0.05$) and the initial production($P<0.001$). This observation contradicted the findings of Yadav et al. (1977) who reported non-significant effect of season on the curve parameters. The result showed that cows that calved in the period at the peak of the rains i.e June to August had the highest inclining phase (Table 56), highest declining phase, largest average slope and the smallest initial production. Those that calved between December to February on the other hand the lowest inclining phase, lowest rate of decline, highest

preidcted initial production and subsequently the largest predicted total production. This outcome was due to stimulus of the onset of the rains which led to a significant ($P<0.05$) effect on the total production for the cows that calved during this period compared to those that calved at the other periods. It was observed that the rate of change from the initial production to the peak production for the periods December-February, March - May, June - August and September - November were 2.33, 1.35, 1.85 and 2.87 kg per week, respectively. This implied that cows that calved between September - February (Dry period) had higher rate of change per week compared to those that calved between March to August (wet periods). This could be attributed to the stimulus created by the onset of the rains on those that calved during the dry periods which was non-existent for those that calved during the Wet periods. This effect perhaps explained the net effect on predicted peak production and total productions.

As for the phenotypic correlations between the parameters the result showed that the inclining phase was positively and significantly ($P<0.001$) correlated with the rate of decline and peak week negatively. It was also significantly ($P<0.001$) correlated with the average slope parameter and initial production. This implied that high initial production brings about lower inclining phase. In other words, cows that started very highly had a lower inclining phase and subsequently took longer period to

attain the peak production. The inclining phase was positively correlated with the total production but no significance was observed. The average slope was significantly ($P<0.001$) but negatively correlated with the declining extreme but positively and significantly correlated the peak production ($P<0.01$) and initial production ($P<0.001$). This implied that the initial production would provide a very good indicator or measure for the average slope or the peak production for Friesian cow. The average slope and the decline phase were negatively correlated with the total production, there was no significance noted.

Considering correlations coefficients between the production indicators namely; the initial week average daily production, peak week, production at peak and the overall production per lactation, it was observed that with the exception of the significant correlation observed between initial production and the peak with a coefficient of -0.522 and peak week and total production, there was no other significant correlation observed using this model. For this model, there was no significant ($P>0.05$) correlation between the initial production and the peak production. Neither was there any between peak production and the total. A remark that could be made with respect to the correlation between the curve and production characteristics would be that, under the Inverse polynomial function, the average slope provided a good indicator of the initial production of and the peak production although to varying degree of confidence.

A low peak is an indicator of sharp rate of decline in production with possibly not too high rate of rise in production. Furthermore, use of the coefficients in embarking on selection studies has to be done with some caution. As for others, the production pattern by the factors under consideration was given in graph 9.

4.15 Model comparisons for Friesian data

From the analysis under the various models, the result showed that the effect of parity was not significant for Friesian cows. However for consistency, and comparison of models as was done for the Bunaji, Friesian -Bunaji cattle, the models was compared on parity basis-for all the production characteristics.

4.15.1 Initial Production

The results of the observed and predicted from the various models is summarised in table 58 below.

Table 58: Observed and predicted average initial week production per day for Friesians.

	OBSERVED		GAMMA		MODIFIED GAMMA		INVERSE	
PARITY	MEAN	S.E	MEAN	S.E	MEAN	S.E	MEAN	S.E
1	4.15	0.3	5.45	2.1	5.35	2.2	4.94	1.8
2	4.09	0.5	7.46	1.7	7.54	1.8	4.75	1.5
3	4.11	0.6	8.88	1.6	9.04	1.7	6.0	1.4
4	2.84	0.5	12.20	1.9	12.60	2.0	8.38	1.6
5	1.50	0.5	7.78	2.4	9.82	2.7	6.28	2.1
Overall	3.69	0.6	9.19	0.5	9.26	0.5	6.29	0.4
Correlation with the observed			r=0.80*		r=0.78*		r=0.72*	

* P<0.05

On the basis of the available information on Table 58 there was a general over estimation of the initial production by the three models under consideration. For instance, the Gamma function overestimated the actual initial production by 149% while the corresponding figures for Modified Gamma and Inverse Polynomial function were 151, 70 percent respectively.

Considering the performances on individual parity basis showed averagely, the Inverse function appeared to have the least deviations relative to the actual values. Under the Gamma function the percentage deviation for parity ranged between 31% to about 418% in the fifth parity while the figures for the Modified Gamma ranged from 29% to a maximumn of 555% in the fifth parity. For the Inverse function, it was observed that the range though increased with parity, the magnitude was relatively lower than what was observed for the Gamma based models. The values obtained varied from 16% to about 317% The deviation was lowest for the second parity in the Inverse Polynomial function.

From Table 58, the performance of the models were not satisfactory and all the three models performed poorly beyond the third parity. Relatively, the prediction from the Inverse function provided the least deviation though significant ($P<0.01$) difference existed between prediction from Inverse function and the actual observed production for Friesian cows. Correlation coefficients between the observed and the predicted from each model for each cow showed

significant (P<0.01) correlations however the coefficients based on Gamma function was highest with a coefficent of 0.80 though not significantly different fron the coefficient for Modified Gamma function.

4.15.2 Peak Week

Considering this parameter, the estimated values from least squares analysis showed some degree of agreement between the observed time of peak production after parturition and the predicted for each of the models being evaluated. Generally over the entire parities, the observed peak week was about 6.9 week, the estimated for the Gamma function was 9 weeks while the corresponding values for Modified Gamma and Inverse functions were 8.7 and 7.1 weeks, respectively. Table 59 gives the summary of means of peak Week.

The result showed that the Inverse function under-estimated the average observed peak week over all the parities while the Gamma based model over-estimated particularly in the second and third parities for Gamma function and first to fourth parities for the Modified Gamma function. There was no significant (P>0.05) correlations between the observed and predicted except for Gamma coefficients, the Gamma function had the highest coefficient of 0.36 compared to 0.07, and 0.14 recorded for the Modified Gamma and Inverse functions, respectively. Furthermore, the predictions from Gamma function had higher rate of agreement than the other functions.

Table 59: Observed and predicted peak week for models by parity for Friesian

PARITY	OBSERVED MEANS	OBSERVED S.E.	GAMMA MEANS	GAMMA S.E.	MODIFIED GAMMA MEANS	MODIFIED GAMMA S.E.	INVERSE MEANS	INVERSE S.E.
1	9.4	1.1	9.8	1.6	10.5	1.8	6.4	1.4
2	5.2	0.5	8.2	1.3	7.6	1.5	7.1	1.2
3	6.1	0.8	7.5	1.3	6.7	1.4	6.9	1.1
4	6.7	0.9	6.7	1.4	8.4	1.6	5.1	1.2
5	8.2	1.8	7.5	2.0	8.1	2.3	7.9	1.6
Overall	6.9	0.40	9.0	0.3	8.7	0.4	7.1	0.3
Correlation coefficient between observed and predicted			0.36*		0.07		0.14	

* $P < 0.05$

Further evaluation of the adequacy of the three models was undertaken by observing the frequency of occurrance of coincidence, when the predicted coincides with the observed and vise versa. This is summarized on Table 60 below.

Table 60: Assessment of model prediction for Friesians.

PARITY	GAMMA A	GAMMA B	GAMMA C	MODIFIED GAMMA A	MODIFIED GAMMA B	MODIFIED GAMMA C	INVERSE A	INVERSE B	INVERSE C
1	2	9	13	2	9	13	2	15	6
2	1	5	21	3	5	19	2	7	18
3	1	7	18	1	7	18	2	9	14
4	1	5	10	2	5	9	3	6	7
5	0	2	6	0	2	6	0	3	5
Overall	5	28	69	8	28	65	9	40	51

Key: A = % Predicted peak week coincides with actual peak (co-incidence)

B = % Predicted < Actual peak week (under-prediction)
C = % Predicted > Actual peak week (over-prediction)

A study of the result presented on Table 60 showed that Inverse had the highest rate of coincidence with an overall percentage coincidence of 9% compared to the values of 8 and 5 percent - for Modified Gamma and Gamma functions, respectively. Highest cases of under-prediction was recorded for Inverse function with a percentage of 40 compared to 28 recorded for the Gamma based models. It was observed earlier that the Inverse function tended to under estimate the peak week (Table 60). The Gamma based models recorded higher rates of over-prediction compared to the Inverse function. These occurred in lower parities for all the three models (Column C) for each model.

Using the percentage of co-incidence as a measure to assess the performance of the model, one might consider the Inverse function as preferable compared to others. However such a decision might be in-accurate, since there was no information as to the magnitude of over-prediction. In practise, it might be more desirable to over-predict the peak week and to plan the nutritional requirements of the cattle rather than under-predict only to run into crisis of feed.

Considering the peak week production, the Gamma was found more reliable compared to the predictions from the modified Gamma and Inverse function. Furthermore, the correlation coefficient between observed and predicted for individual cattle record showed significant ($P<0.05$) between observed and predicted from Gamma function while there was no significant correlation observed for the Modified Gamma and

Inverse function.

4.15.3 Peak Production.

Generally peak production is a very useful measure of productivity in dairy. It is not enough to have the peak week, but what is the magnitude of such peak production?. Rao and Sundaresan (1979) demonstrated that there is significant positive correlation between the Peak production and total yield. This same was observed in this study for Bunaji, Friesian-Bunaji and Friesian data. Table 61 is the summary of the observed and estimated predictions from the three models by parity. There was no consistent pattern of deviations of predicted from the observed for each of the model. Over the parities, the Inverse polynomial over-estimated the observed peak or maximum production per day, while the Gamma based models under-estimated the parameter.

The Inverse function over-estimated by about 33% while the gamma function underestimated by 10 percent and the Modified gamma by about 12 percent, respectively. There was no significant difference between the estimated peak production between the Gamma based models and the observed. While significant ($P<0.01$) difference existed between the observed and estimated from the Inverse polynomial. An observation on table 61 showed that the Gamma based fuctions under-estimated in the first three parities while they over-estimated in the fourth and fifth parities. The Inverse function over-estimated in the first, second and fifth parities with

an under-estimation in the third and fourth parity.

Table 61: Observed and predicted peak production per day for models by parity for Friesian

PARITY	OBSERVED MEANS	S.E.	GAMMA MEANS	S.E.	MODIFIED GAMMA MEANS	S.E.	INVERSE MEANS	S.E.
1	16.6	0.6	10.9	2.1	11.3	2.2	19.8	9.7
2	20.3	0.7	14.2	1.7	13.3	1.8	25.4	7.9
3	20.3	1.2	16.1	1.5	15.0	1.7	19.2	7.2
4	19.6	1.3	21.8	1.9	21.5	2.1	17.5	10.5
5	15.6	1.1	21.1	2.3	23.1	2.7	18.4	13.0
Overall	18.9	0.5	17.0	0.5	16.6	0.5	25.1	1.7
Correlation coefficient Observed vs. Predicted			0.74*		0.64*		0.07	

* $P < 0.05$

Considering the absolute values, the Inverse function had relatively lower percentage deviations compared to the Gamma based functions. However, the correlation Coefficients showed that the correlation between the observed and the predicted from Inverse function was low and non-significant with a coefficient of 0.07 compared to significant ($P<0.05$) coefficients of 0.74 and 0.64 recorded for the Gamma and the Modified Gamma functions. Evaluation of the adequacy of the three functions showed that with respect to the maximum or peak production, the Gamma based models provided relatively more reliable predictions than the Inverse function. And a comparison of the deviations and the size of the correlation coefficient, showed that the Gamma function was more preferable than the Modified Gamma function. In other words, the Gamma model provided more reliable representation of the peak production for Friesian data than the Modified Gamma or

the Inverse polynomial.

4.15.4 Total Production/lactation.

The comparision of the estimated total production per lactation from each of the model with the observed is presented in Table 62. Generally over the parities, the gamma function under-estimated the average total production per laction by about 7% while the Modified Gamma and Inverse function over-estimated the production per lactation for Friesian cows by 3 and 6%, respectively. The Gamma based or exponential functions under-estimated the actual production of Friesian cows in the first four parities and over-estimated in the fifth parity while the Inverse function under-estimated in the first parities and over-estimated in the fifth parity. The magnitude of over-estimation was highest for the Inverse function.

Table 62: Observed and predicted total production by parity of Friesian data for functions

	OBSERVED		GAMMA		MODIFIED GAMMA		INVERSE	
PARITY	MEAN	S.E.	MEAN	S.E.	MEAN	S.E.	MEAN	S.E.
1	4022.41	193.3	1934.80	529.0	2551.5	664.5	2117.7	509.3
2	4271.81	275.7	3008.96	429.0	3186.3	664.5	3548.8	406.0
3	3754.75	283.4	2860.86	394.9	2999.4	610.0	2874.1	368.5
4	4144.88	509.3	3623.16	480.3	4008.4	739.0	4308.1	559.5
5	3700.19	470.5	3785.76	300.3	4057.8	996.0	5427.7	725.5
Overall	4016.03	143.5	3817.14	126.6	4127.4	143.4	4258.6	207.6
Correlation between observed and Predicted			0.64*		0.58*		0.44*	

The degree of under-estimation was higher for the Gamma function though no significant difference, between those from

Modified gamma and Inverse function. Correlation between observed and the estimated from each of the model for the Friesion cows showed significance coefficients for the three models. The coefficients were 0.64, 0.58 and 0.44. For Gamma, Modified Gamma and the Inverse polynomial, respectively. The coefficients obtained from the Gamma based models differed significantly($P<0.05$) from the coefficients from the Inverse function. While comparison the Gamma and the Modified Gamma functions also differed significantly ($P<0.05$) from each other. High correlation coefficient is more prefered since it is an indication of higher reliability provided other considerations are the same. This implied that the Gamma function was more preferable in the prediction of total production per lactation for Friesian cows.

4.15.5 Co-efficient of determination (R2)

Another important measure of evaluating models is the coefficient of determination, R^2. Wood (1967), Yadav et al. (1977) and Kellogg et al. (1977) used the parameter to evaluate the adequate of models. The comparision of the three functions on the basis of the R^2 values is presented in Table 63 by parity. The goodness of fit measure increase with increase in parity for the three models. However this parameter attained the optimum in the fourth parity before droping in the fifth.

Table 63: Comparison of R^2 between models by parity for Friesian data.

	GAMMA		MODIFIED GAMMA		INVERSE	
PARITY	MEAN	S.E.	MEAN	S.E.	MEAN	S.E.
1	0.55	0.01	0.54	0.09	0.31	0.11
2	0.64	0.07	0.64	0.07	0.47	0.09
3	0.65	0.06	0.63	0.06	0.53	0.08
4	0.72	0.08	0.74	0.08	0.53	0.10
5	0.69	0.10	0.72	0.11	0.59	0.12
Overall	0.68	0.02	0.68	0.02	0.52	0.02

Comparatively, the goodness of fit measure obtained for the gamma based functions was significantly (<0.01) higher than the value obtained for the Inverse function. Best fit was obtained for the fourth parity with an R^2 value of above 70% for Gamma based functions while the best fit recorded under the Inverse function was in the fifth parity with a R^2 value of 69% which was comaparatively lower than the corresponding values recorded for same parity using the Gamma functions.

Observation of the table showed that better goodness of fit measure was recorded for Gamma based or Exponential functions than the Inverse functions for all the parities. This implied that either of the Gamma or the Modified Gamma is preferable to the Inverse Polynomial in modelling the pattern of milk production for Friesian cattle.

In conclusion therefore, the Inverse Polynomial was least suitable for modelling the milk production of Friesian cows.

4.15.6 Persistency

The last measure for comparing the models is their persistency. This was available for the Gamma related models, that is the Gamma and the Modified Gamma functions, the table for the summary by parity is provided on Table 64.

Table 64: Summary of persistency measure by parity for Friesians.

	GAMMA		MODIFIED GAMMA	
PARITY	MEAN	S.E.	MEAN	S.E.
1	2.81	0.26	3.18	0.25
2	2.82	0.21	3.08	0.20
3	2.86	0.20	3.01	0.19
4	2.98	0.24	2.90	0.23
5	3.06	0.30	3.06	0.31
Overall	3.22	0.07	3.15	0.06

Generally, the result showed that the persistency measure obtained for the Gamma function was lower than those from Modified Gamma function but there was no difference between them over the entire data set using the Friesian data. On the basis of persistency measure, the two models were obsereved to be equally effective. Modified Gamma was better in the first three parities.

The general assessment of the parameters for the three models showed that the Inverse function was least adequate. Between the Gamma and the Modified Gamma, the results from various measures used in evaluating the functions showed that the Gamma function was the most adequate. This conclusion

was based on the a number of factors. Firstly, the fitted model derived from the Gamma curve parameters based on the Gamma function was found to have represented the graph much better compared to the others. Compare deviations on Table 36 and figure 9. From the table, the percentage deviations obtained from the Gamma function had lower absolute deviations from the observed compared to either the Modified Gamma or Inverse Polynomial functions.

Secondly, considering the reliability of the multiplicative factors derived for part lactations yield evaluations showed that factors based on the Gamma function had significantly ($P<0.05$) lower percentage deviations compared to the others. Also by way of the predicting ability of the models in indentifying some indicators for example the initial, peak week, peak and total production per lactation, the Gamma function was observed to be closely related to the observed than the other functions.

Although the persistency measure showed that the Modified Gamma was better, the R^2 statistic which measured the goodness of fit of the functionl did not show this. Infact, there was no significant difference between the R^2 values for Gamma and the Modified Gamma functions.

Therefore, for Friesian cattle, the Gamma function as defined by Wood (1967) was found to be the best for representing the production pattern for Friesian cattle.

CHAPTER 5

5.0 COMBINED ANALYSIS FOR BREEDS

The combined analysis of the breeds under each model was undertaken and the result is presented here. Model discussed in section 3.1 was enlarged to incorporate an additional factor for breed effect while the year effect was categorised into five groups viz: Pre-1966, 1966-1970, 1971-1975 and post 1975. This grouping was done for all the three models and the effects of the factors were evaluated by least squares analytical procedures.

5.1 GAMMA FUNCTION

5.1.1. RESULTS

The Least squares analysis of variance is given in table 65 (Appendix D) while the least squares means for the parameters are given in table 66. Breed effect was significant ($p<0.001$) for all the lactation curve parameters and the production indicators. Lactation length had significant ($P<0.001$) effects on all the parameters except the general level of production. Season of calving had no significant ($p>0.05$) effect on curve parameters, but highly significant ($p<0.01$) effect on persistency, peak production and total production per lactation. Parity was found to have significant ($p<0.001$) effects on all the parameters with the exception of the rate of rise to the peak and the total production while the period of calving had significant ($p<0.05$) effects on all except the peak production.

Table 66 : Least squares means and standard errors for Gamma function characteristics by factors

PARAMETERS		a		b		c		R^2		s		Initprd		pwk		Mxprod		Tprod	
	N	Mean	S.E.	Mean	S.E.	Mean	S.E.	Mean	S.E.	Mean	S.E.	Mean	S.E	Mean	S.E.	Mean	S.E.	Mean	S.E.
BREED																			
FRIESIAN-BUNAJI	268	2.926[e]	0.04	0.342[d]	0.02	0.063[e]	0.003	0.79	0.02	3.21[e]	0.05	8.9[e]	0.3	5.3[d]	0.3	11.27[e]	0.37	1733.9[e]	59.2
BUNAJI (ZEBU)	205	2.293[d]	0.04	0.348[d]	0.03	0.057[d]	0.003	0.79	0.02	3.24[d]	0.06	4.6[d]	0.3	5.9[d]	0.3	5.61[d]	0.39	1164.6[d]	62.9
FRIESIAN	111	2.782[e]	0.06	0.696[e]	0.04	0.094[f]	0.004	0.75	0.02	2.58[d]	0.08	8.6[e]	0.4	8.2[e]	0.4	17.14[f]	0.56	3200.1[f]	89.9
PARITY																			
1	146	2.395[d]	0.04	0.444	0.02	0.058[d]	0.003	0.66[d]	0.02	3.29[f]	0.06	5.8[d]	0.3	8.2[e]	0.3	9.08[d]	0.37	1938.50	60.6
2	153	2.726[e]	0.04	0.426	0.02	0.071[e]	0.003	0.78[e]	0.02	3.00[e]	0.06	7.5[e]	0.3	6.2[d]	0.3	11.59[e]	0.37	2117.05	61.0
3	135	2.781[e]	0.04	0.443	0.03	0.075[e]	0.003	0.80[e,f]	0.02	2.95[e]	0.06	8.0[e]	0.3	5.9[d]	0.3	11.77[e]	0.40	2016.85	63.8
4	91	2.750[e]	0.05	0.453	0.03	0.072[f]	0.004	0.81[e,f]	0.02	2.98[e]	0.07	7.8[e]	0.4	5.8[d]	0.4	12.04[e]	0.46	2067.59	74.0
5	59	2.683[e]	0.06	0.543	0.04	0.082[h]	0.005	0.84[f]	0.02	2.83[d]	0.09	7.7[e]	0.4	6.2[d]	0.4	12.22[e]	0.58	2024.24	93.6
LACTATION LENGTH																			
< 26 weeks	103	2.630	0.05	0.518[e]	0.03	0.110[g]	0.004	0.78	0.02	2.49[d]	0.07	6.9	0.4	5.0[d]	0.3	10.55	0.45	1326.1[d]	73.4
26 - 35 weeks	159	2.628	0.04	0.515[e]	0.03	0.079[f]	0.003	0.79	0.02	2.82[e]	0.06	7.2	0.3	6.1[e]	0.3	11.49	0.38	1778.5[e]	61.8
36 - 45 weeks	183	2.733	0.04	0.421[d]	0.02	0.056[e]	0.003	0.76	0.02	3.21[f]	0.05	7.8	0.3	6.8[f]	0.3	11.87	0.36	2279.7[f]	68.8
> 45 weeks	139	2.677	0.04	0.392[d]	0.03	0.043[d]	0.003	0.78	0.02	3.52[g]	0.06	7.6	0.3	7.9[g]	0.3	11.50	0.41	2747.1[g]	64.7
SEASON OF CALVING																			
Dec - Feb.	121	2.652	0.04	0.457	0.03	0.068	0.003	0.74[d]	0.02	3.12[e]	0.06	7.6	0.3	6.6	0.3	11.70[e]	0.41	2078.2[e]	66.4
March - May	152	2.667	0.04	0.492	0.02	0.076	0.003	0.79[e,f]	0.02	2.89[d]	0.06	7.2	0.3	6.7	0.3	11.73[e]	0.37	2104.4[e]	60.4
June - August	118	2.729	0.05	0.451	0.03	0.074	0.003	0.81[f]	0.02	2.93[d]	0.06	7.8	0.3	6.3	0.3	11.72[e]	0.42	2050.6[e]	68.1
Sept. - Novem.	192	2.621	0.04	0.446	0.02	0.069	0.003	0.77[d,e]	0.02	3.09[e]	0.05	6.9	0.3	6.2	0.3	10.21[d]	0.34	1898.2[d]	55.0
PERIOD OF CALVING																			
< 1965	50	2.652[e]	0.08	0.543[e]	0.05	0.085[e]	0.006	0.87[f]	0.03	2.74[d]	0.11	7.6[e]	0.6	5.8	0.6	12.08[e]	0.73	1900.3[d]	118.1
1966 -1970	188	2.687[e]	0.05	0.494[e]	0.03	0.085[e]	0.004	0.84[f]	0.02	2.72[d]	0.07	7.5[e]	0.3	6.2	0.3	12.08[e]	0.44	1912.5[d]	72.7
1971 -1975	266	2.817[f]	0.03	0.395[d]	0.02	0.062[d]	0.002	0.73[e]	0.02	3.23[e]	0.05	8.2[f]	0.2	6.5	0.2	11.97[e]	0.31	2243.5[e]	48.9
> 1975	80	2.512[d]	0.06	0.415[d]	0.03	0.054[d]	0.004	0.65[d]	0.02	3.35[e]	0.08	6.1[d]	0.4	7.3	0.2	9.24[d]	0.51	2075.5[d]	83.0

Note

a=general level of production under Gamma basedfuntions.
b=rate of rise to the peak under Gamma based functions.
c=rate of decline from the peak under Gamma based functions.
s= persistency
Initprd=Initial week average daily production
pwk= peak week
Mxprod= peak production/day at peak week
Tprod=total production/lactation

Note: Least squares means connected by the same letter within a subclass are not significantly different from each other ($p \leq 0.05$)

The mean coefficient of determination R^2 was found to be 76%. This was affected by the effects of parity, season and period of calving. First parity recorded the lowest R^2 value of about 66% which is an indication that animal coming into milk for the first time are more influenced by the enviromental factors than those in higher parities. The R^2 increased with parity order while it decreased with period of calving. It was observed that R^2 value for first and second periods were significantly ($P<0.05$) larger than the third and fourth periods (Table 66). Also, the values for animals that commenced lactations during the wet months of June to August was higher than those of other seasons of production though the values were not significantly ($P>0.05$) different from those recorded for the period of March to May. This period coincided with the periods of the rainy season when the pastures were already established and thus provided stimulus to milk production for lactating animals. This suggests that the model had a better fit for animals that calved in the season than those that calved during the September to February period when the wet season stimulus would be expected to give a second hump in addition to the peak already attained in the production curve. Wood (1969) also reported significant ($P<0.01$) effect of month of calving on the goodness of fit of the model. The lower R^2 value recorded for the September to February might be due to the effects of double humps (first due to attainement of peak and the second due to the wet season stimulus)

Considering the lactation curve parameters, the result showed that Bunaji (Zebu) had a significantly ($P<0.05$) lower general level of production than the Friesian-Bunaji and the Friesian cows. Also, the general level of production was affected by the parity at calving. First calvers had significantly ($P<0.01$) lower general level of production than those in higher parities. The period of calving significantly affected the general level of production. Cows that calved in the period between 1971 to 1975 had significantly higher general level than those that calved in other periods. This was due to renewed efforts to better dairy production embarked upon by the establishment towards supplying milk to students cafeteria and yogourt sale in the meat laboratory and shops around Zaria.

The rate of rise to the peak was significantly ($P<0.001$) affected by breed, lactation length and period at calving. Friesians had significantly ($P<0.001$) higher rate of rise to the peak while there was no difference between the rates for Bunaji and Friesian-Bunaji cows. The rates observed for cows in milk for less than 36 weeks had higher rising phases compared to those that were in milk for longer duration. Also, rate of rise was higher for those that calved in the periods 1 and 2 than periods 3 and 4 corresponding to a production periods of Pre-1966, 1966 - 1970 , 1971-1975 and post 1975, respectively. This observation might be attributed to changes in the management practises which had distinct effects on the productivity of the animals.

The rate of decline from the peak was affected by breed, lactation length, parity and period of calving. Though Friesians had significantly ($P<0.001$) higher rate of rise to the peak, they also had a correspondingly higher rate of decline from the peak. Bunaji (Zebu) had the lowest rate of decline from the peak while the Friesian-Bunaji was intermediate between the two. Cows in milk for less than 26 weeks duration had the highest rate of decline from the peak. The rate of decline decreased with increase in lactation length while it increased with parity order (lowest for first parity and highest for animals in the fifth parity).

Persistency, defined as a measure of the ability of an animal to maintain the peak production, was affected by all the factors considered in this study. Friesians had the lowest measure while Bunaji had the highest though no significant difference existed between the values for Bunaji and Friesian-Bunaji. Animals in the first parity had the largest persistency while those in the fifth parity had the lowest. Cows calving in the dry season had higher persistency compared to those calving in the wet season. Persistency increased significantly ($P<0.05$) with increase in the duration of milk production. Cows that calved the third and fourth periods had significantly ($P<0.05$) better persistency than those that calved in earlier periods.

Friesians took significantly ($P<0.01$) longer period to attain the peak than the Bunaji or Friesian-Bunaji. Also, Friesians had significantly ($P<0.01$) higher peak and total

productions than the Bunaji or Friesian-Bunaji group. The Bunaji had the lowest with the Friesian-Bunaji as intermediate between the two with respect to the production indicators (table 53). Peak week decreased with parity order while the peak production increased with parity order. However, there was no significant ($P>0.05$) effect of parity on total production. Significant ($P<0.05$) effects of season was observed on peak and total productions. Lactations that commenced between september to November were significantly lower in peak and total production while no noticeable effect of season of calving on the peak week. Animals that were in milk for shorter duration attained the peak production significantly ($P<0.05$) earlier than those in milk for longer duration. There was a positive relationship between the duration of lactation and total production.

5.1.2 Discussion

The shape of lactation curve in cows is affected by the general level of production, rate of rise to the peak and the rate of decline from the peak. These parameters depend on other factors notably the body conditions of the animal which in turn is also affected by some external factors like nutrition and environmental conditions. The results from this study with respect to the lactation curve parameters agreed with the findings of Wood (1969), Rao and Sundaresan (1979) and Abubakar and Buvanendran (1981). However, the findings of significant effects of parity on the rate of decline from the peak in the present study conflicted with the one reported by

Abubakar and Buvanendran (1981). This could be due to the fact that the present study considered many years data. Also, the observation that there was no significant effect of season on the general level of production, rate of rise to the peak and rate of decline from the peak conflicted with the study by Rao and Sundaresan (1979) who had earlier reported sigificant effects of season although on another breed of cattle and in a different environment.

With respect to persistency, the results showed that animals in the first parity had the highest while those in higher parities had lower values. This agreed with the findings of other researchers, Smith and Legates (1962), Hamilton and Hilliers (1973), Rao and Sundaresan (1979) and Abubakar and Buvanendran (1981). Figure 11a gives the production curves by breeds. Results showed that animals that were in milk for longer than 45 weeks in production tended to be more persistent. Likewise, cows that calved in the period between September to February had higher peristency than those that calved in the rainy season (March - August). This finding agreed with those of Kasonta (1988) and Abubakar and Buvanendran (1981).

Friesian animals had significantly ($P<0.05$) higher peak and total production as well as longer lactation length. In this study the average lactation length for the Bunaji, Friesian and Friesian-Bunaji cows were 32.6, 50.0 and 36.4 weeks, respectively. Consequently, the Friesian took longer period to attain the peak production. Bunaji cows on the

other hand were found to have significantly ($P<0.001$) lower peak and total production per lactation. Since they had relatively shorter lactation length, they attained the peak relatively earlier than the other two breeds. The Friesian-Bunaji cross had intermediate production indicators. It was found that there was a positive relationship between peak yield and total yield. Similar results were reported by Balaine et al. (1970) and Rao and Sundaresan (1979). An estimate of the genetic correlation would be more useful in selection studies aimed at increasing the productivity of the indigeneous Zebu cattle.

In conclusion, the Gamma function fitted the Bunaji and the Friesian-Bunaji records better than the Friesian records using the R^2. The Bunaji (Zebu) and Friesian-Bunaji cows had significantly($P<0.05$) better persistency using the estimation of Wood (1969) than the Friesian. This could perhaps be due to the fact that the Zebu and their crosses are better adapted to this environment compared to the exotic Friesian cows. Also, using the short lactation length in the Bunaji and Friesian-Bunaji cows, it might be possible to effect earlier rebreeding programmes which could complement the lower total lactation production. This will succeed only if there is an adequate measure to improve the management of the animal in terms of provision of feed as well as veterinary services.

5.2 MODIFIED GAMMA FUNCTION

5.2.1 RESULTS

The result of the least squares analysis of variance is presented in the Table 67 (Appendix D) while the least squares means is presented on Table 68. From Table 67, it was observed that there was significant effects of breed on the general level of production ($P<0.001$) the rate of rise to the peak (b) $P<0.001$ and rate decline from the peak (c) $P<0.001$. Significant effect of breed was recorded on persistency (S) $P<0.001$, Initial Production ($P<0.001$), Peak week ($P<0.001$) Peak Production ($P<0.001$) and the Total production ($P<0.001$). There was however no significant ($P>0.05$) effect of breed on the Coefficient determination parameter which measured the goodness of fit of the function for the breeds.

Parity order was significant for the parameters a ($P<0.001$), R^2 ($P<0.001$), presistency s ($P<0.001$), Initial week peak week, peak production all at 0.1% while no significant ($P>0.05$) effect of parity was recorded on the parameter b and total production. As for the lactation length, the effect was significant ($P<0.001$) on the rate of change in the curve (b, c) persistency (s), peak week and the total production. No significant ($P>0.05$) effect for a, R^2, Initial production and the peak production.

Considering the season of calving, the combined analysis showed that neither the effects of season nor period of calving showed any significant effect on the parameters of Modified Gamma function.

Table 68 : Least squares means and standard errors for Modified Gamma function characteristics by factors

PARAMETERS		a		b		c		R^2		s		Initprd		pwk		Mxprod		Tprod	
	N	Mean	S.E.	Mean	S.E.	Mean	S.E.	Mean	S.E.	Mean	S.E.	Mean	S.E	Mean	S.E.	Mean	S.E.	Mean	S.E.
BREED																			
FRIESIAN-BUNAJI	268	2.910[a]	0.04	0.318[d]	0.02	0.057[d]	0.011	0.77	0.02	3.68[d]	0.04	8.7[a]	0.3	5.3[d]	0.3	10.31[a]	0.4	1735.4[a]	56.4
BUNAJI (ZEBU)	205	2.308[d]	0.05	0.341[d]	0.03	0.054[d]	0.013	0.79	0.02	3.89[a]	0.05	4.7[d]	0.3	5.8[d]	0.3	6.41[d]	0.5	1144.2[d]	65.2
FRIESIAN	111	2.850[a]	0.06	0.625[a]	0.03	0.122[a]	0.017	0.75	0.02	3.95[a]	0.06	8.6[a]	0.4	7.7[a]	0.4	15.85[b]	0.6	3212.3[b]	86.5
PARITY																			
1	146	2.434[d]	0.04	0.405	0.02	0.080	0.013	0.68[d]	0.02	4.20[a]	0.05	5.9[d]	0.3	8.0[a]	0.3	9.26[d]	0.5	1918.66	61.9
2	153	2.771[a]	0.04	0.401	0.02	0.072	0.012	0.78[a]	0.02	3.79[d]	0.05	7.6[a]	0.3	6.1[d]	0.3	11.64[a]	0.5	2119.00	60.4
3	135	2.775[a]	0.05	0.419	0.03	0.077	0.013	0.80[b]	0.02	3.67[d]	0.05	7.9[a]	0.3	5.5[d]	0.3	11.17[a]	0.5	1997.80	64.2
4	91	2.737[a]	0.05	0.431	0.03	0.080	0.015	0.80[b]	0.02	3.75[d]	0.06	7.7[a]	0.4	5.6[d]	0.4	10.84[a]	0.6	2043.10	73.2
5	59	2.729[a]	0.06	0.485	0.04	0.079	0.018	0.81[b]	0.02	3.77[d]	0.07	7.8[a]	0.5	6.1[d]	0.4	11.39[a]	0.7	2074.70	90.4
LACTATION LENGTH																			
< 26 weeks	103	2.661	0.05	0.484[a]	0.03	0.113[b]	0.015	0.78	0.02	3.25[d]	0.06	7.0	0.4	4.9[d]	0.4	10.21	0.6	1335.0[a]	73.3
26 - 35 weeks	159	2.641	0.04	0.470[a]	0.02	0.087[a]	0.012	0.78	0.02	3.75[a]	0.05	7.1	0.3	6.0[a]	0.3	10.61	0.4	1780.8[b]	60.6
36 - 45 weeks	183	2.771	0.04	0.382[d]	0.02	0.076[a]	0.012	0.75	0.02	4.05[b]	0.04	7.8	0.3	6.6[b]	0.3	11.66	0.4	2254.7[c]	59.4
> 45 weeks	139	2.683	0.04	0.377[d]	0.03	0.035[d]	0.013	0.77	0.02	4.30[a]	0.05	7.5	0.3	7.6[b]	0.3	10.95	0.5	2752.1[d]	64.8
SEASON OF CALVING																			
Dec - Feb.	121	2.645	0.05	0.429	0.03	0.065	0.013	0.73[d]	0.02	3.95[a]	0.05	7.5	0.3	6.5	0.3	10.72[a]	0.5	2069.9[a]	64.0
March - May	152	2.721	0.04	0.450	0.02	0.080	0.012	0.79[a,b]	0.02	3.82[d]	0.05	7.3	0.3	6.4	0.3	11.11[a]	0.5	2191.2[a]	60.7
June - August	118	2.736	0.05	0.422	0.03	0.097	0.014	0.71[b]	0.02	3.78[d]	0.05	7.7	0.4	6.2	0.3	11.91[a]	0.5	2061.8[a]	69.3
Sept. - Novem.	192	2.654	0.04	0.411	0.02	0.069	0.011	0.76[a,b]	0.01	3.82[a]	0.04	6.9	0.3	6.0	0.3	9.70[d]	0.4	1899.8[d]	55.6
PERIOD OF CALVING																			
< 1965	50	2.667	0.08	0.495	0.05	0.091	0.023	0.87[a]	0.03	3.45[d]	0.09	7.4[a]	0.6	5.4	0.5	10.45[d]	0.9	1914.1[d]	114.1
1966 -1970	188	2.715	0.04	0.464	0.02	0.092	0.012	0.82[a]	0.02	3.72[a]	0.05	7.4[a]	0.3	6.3	0.3	11.44[a,b]	0.5	1967.7[d]	61.2
1971 -1975	266	2.778	0.04	0.402	0.02	0.070	0.011	0.72[d]	0.02	4.02[b]	0.04	8.2[a]	0.3	6.6	0.3	12.10[a]	0.4	2276.4[a]	52.9
> 1975	80	2.597	0.07	0.352	0.04	0.058	0.020	0.68[d]	0.03	4.16[b]	0.08	6.4[d]	0.5	6.8	0.5	9.45[d]	0.8	1964.4[d]	100.1

Note

a=general level of production under Gamma basedfuntions.
b=rate of rise to the peak under Gamma based functions.
c=rate of decline from the peak under Gamma based functions.
s= persistency
Initprd=Initial week average daily production
pwk= peak week
Mxprod= peak production/day at peak week
Tprod=total production/lactation

Note: Least squares means connected by the same letter within a subclass are not significantly different from each other ($p< =0.05$)

However, the effect of season of calving was observed to be significant for persistency ($P<0.05$) peak production ($P<0.001$), total production ($P<0.05$) and the coefficient of determination ($P<0.01$). The effects of period of calving had significant effect on persistency ($P<0.001$), initial week production ($P<0.01$), peak production ($P<0.01$) and total production ($P<0.001$).

5.2.2 DISCUSSION

The results observed from the Modified Gamma function showed effect of breed on all the characteristics examined in this study with the exception of the Coefficient of determination R^2 which measured the goodness of fit for the function.

It was observed that the R^2 varied between 75% for Friesians while the corresponding values for Friesian-Bunaji and Bunaji were 77% and 70%. This figures were smilar to what was obtained using the Gamma function and furthermore were found to be in close agreement with what was observed by Abubakar and Buvanendran (1981), who reported an R^2 of 71% by using Gamma function. The figures also agreed with the findings of Wood (1969) who had earlier reported R^2 range of 74-91 for Friesians, Rao and Sundaresan (1979) who reported a mean of 76%.

The figures reported here also were found to be included in the range of 62-99 reported by Scheeffer **et al.** (1977) in their study of Holstein and Jersey; and a range of 61-99 in another study by Grossman **et al.** (1986).

Considering the curve parameters namely the general level of production, **a**, the rate of rise to the peak, **b**, and rate of decline, *c*, it was observed that Bunaji cows had the least general level of production which differed significantly ($P<0.05$) from those Friesian-Bunaji and Friesians. Though Friesian-Bunaji had highest a value but it did not differ significantly from that of Friesian. With respect to the rate of rise to the peak, b, the value for Friesians was highest and almost twice as large as those for Friesian-Bunaji and Bunaji cows. The comparision between Bunaji and Friesian-Bunaji rates was not significant. As for the rate of decline, *c* from the peak, the figure showed that Friesian cows had the largest rate of decline which differed significantly ($P<0.01$) from the corresponding values recorded for Bunaji and Friesian-Bunaji cross breeds.

The ability to maintain a particular production level defined by persistency was affected significantly ($P<0.001$) by the effect of breed in the Modified Gamma production function. It was observed that Friesian-Bunaji had significantly ($P<0.01$) lower persistency than any of the pure breeds which were found to differ, although Friesians had slightly higher persistency than the Bunaji cows.

The Initial week production per day parameter showed that Bunaji had the least with an average of about 4.73 kg compared to the values of 8.68 and 8.63 kg recorded for Friesian-Bunaji and Friesians, respectively.

The result also showed that Bunaji and Friesian-Bunaji

cross attained peak at significantly (P<0.01) lower number of weeks of about 5.8 and 5.3 compared to about 7.7 weeks estimated for the Friesian cows. The production per day at peak also differed between breeds. Bunaji had the lowest peak production of about 6.41 kg/day compared to 10.31 kg/day for Friesian-Bunaji and 15.85 kg/day for Friesians. The rate of change per week from initial to the peak for Bunaji, Friesian-Bunaji and Friesians were 0.31, 0.94 kg per week. From this study, the result showed that average rate of change per week for Friesian was significantly (P<0.01) larger than the corresponding rates for Bunaji and Friesian-Bunaji cross. In other words though the Friesian-Bunaji had better rate of initial week production, the rate of change to the peak was not significantly different from what was observed for Bunaji as shown in the Modified Gamma function.

Finally, the total production was affected by effect of Breed. The average production per lactation were 1735, 1144 and 3212 kg for Friesian-Bunaji, Bunaji and Friesians respectively. The production for Friesians was almost three times records for Bunaji and almost twice as large as the Friesian-Bunaji crossbreds. It was also observed however, that the corresponding average lactation length were 36.4, 32.3 and 50 weeks for Friesian-Bunaji, Bunaji and Friesians, respectively. On weekly averages, this implied a weekly production of about 47.7, 35.4 and 64.2 kg per week for Friesian-Bunaji, Bunaji and Friesian cows, respectively.

Considering the effects of other factors namely, the parity, lactation length, season and period of calving. Parity effect was observed for the general level of production, persistency, s, initial week average daily production, peak week, peak production and the Coefficient of determination R^2.

It was observed that the general level of production for first parity animals differred significantly for higher parity animals. This was similar to the findings of Sikka (1950), Smith and Legates (1962), Wood (1970), Kellog et al. (1976), Rao and Sundaresan (1979) and Abubakar and Buvanendran (1981). This could be explained as an indication that at the first parity an animal had not developed the secretory tissue to its peak compared to those that were in higher parity. The pattern of production showed that the highest level of general production was recorded in the third parity after which there was a drop. The goodness of fit of the model varied between 68% in the first parity to a maximum of 81% in fifth parity. The goodness of the fit increased significantly ($P<0.01$) with increase in parity number. Effect of parity was signficant ($P<0.001$) on persistency , initial week , peak week, peak production but not on other parameters . This findings agreed with a similar-finding of effect of parity on persistency by Singh and Hopal (1982) in the study of an unknown breed of cattle, Rao and Sundaresan (1979) in a study of Sahiwal cows and Abubakar and Buvanendran (1981) in a study of Friesian-Bunaji

cows. Cows in first parity had significantly higher persistency than those in higher parity.

With respect to the initial week production, animals in first parity had significantly ($P<0.01$) lower production than those in higher parities. This followed the pattern observed with the curve parameter **a**, general level of production. In other words the parameter **a** is a good indicator of the average initial week production per day. The correlation coefficient between the general level of production, a, and the initial week production was significant ($P<0.001$) as discussed in earlier sections. As for peak week, first parity animals had significantly ($P<0.05$) higher peak week than the corresponding figures for the other parities. The same reason given for persistency is relevant here in that longer time is required for the secretory tissues for first parity cows to reach its peak activity than primaparous cows. No significant effect of parity on the average total production per lactation.

The lactation length had significant ($P<0.01$) effects on the rate of change (both rate of rise and decline to the peak), persistency, peak week and total production per lactation. The findings agreed with those of Abubakar and Buvanendran (1981) generally but conflicted with the aspect of general level of production. The result showed cows in milk for less than 35 weeks had significantly ($P<0.05$) higher rate of rise and subsequently larger rate of decline than those in milk for longer period. This category were actually

mostly the Bunaji and Friesian-Bunaji crosses while quite a large percentage of the second group were mostly the Friesians and Friesians-Bunaji. In the class of less than 26 weeks, only about 3% were Friesians and about 5% in the 25 - 35 weeks category were Friesians.

With respect to persistency, it increased with increase in lactation length. The same pattern was observed for the total production. As for season of calving, there was not significant ($P>0.05$) effect of season on the lactation curve parameters. a, b and c. This was similar to the findings of Abubakar and Buvanendran (1981) and contradicted those of Wood (1968), Rao and Sundaresan (1979), who reported effect of season on curve parameters. In this study it was observed that cows that calved in the months of March-August had larger average general level of production than those that calved in the September to February. However, there was no significant difference between them. For persistency, it was observed that cows that calved in the December-February season known as harmattan had better persistency than those that calved in other periods. This conflicted with the findings of Abubakar and Buvanendran (1981) but agreed with those of Rao and Sundaresan(1979) who reported significant effect of season of calving on persistency. The study also showed that cows that calved in the September-November period had the least peak and had also the lowest total production. This might be explained by the fact that these cows were usually faced with problem of feeds. The quality of pastures

was no high enough to sustain high performance of the animal. Also, there were no more crop residues available. Furthermore, the animals had longer period of production during the harsh times before the onset of the rainy seasons for pasture development and grazing. While those that calved in the December-February period had crop residues in abundance, shorter period of harsh conditions with some stored body reserves which subsequently boosted the potential of the animals.

There was significant ($P<0.05$) effect of the season of calving in the coefficient of determination R^2. Results indicated that cows that calved during the rainy season generally had better goodness of fit R^2 than those that calved in other periods. Consider for instance those that calved at the peak of the rains (June-August) had an R^2 of about 81% compared to those that culved between hot and dry period of September - November with an R^2 of 0.76 or cool dry period of (Harmattan) December - February (73%). Hot dry period of March - May with a value of 79%.

Finally, the period of calving which is strongly related to the pattern of managements over the production years. No significant ($P>0.05$) effect of period on the lactation curve parameters. A consideration of the persistency showed that cows that calved after 1975 had significantly ($P<0.01$) higher persistency compared to those in the pre-1975 era. Also, most of the cows at this period were predominantly crossbreds and Friesians. This was the period when great emphasis was

placed on the use of crossbred Friesian-Bunaji for milk production. Similarly in the period before 1965, most of the animals were predominantly Bunaji when crossbreeding was just about being planned.

From Table 68 where the least squares means, showed that there was a positive relationship between Initial and the total production per lactation. Also large initial production led to larger peak and subsequently the total production. Furthermore, there was generally a positive relationship between the parameter, a and initial week production indicator. Another observation from the use of the Modified Gamma function was that there was no positively relationship between persistency and total production. In other words, the fact that a cow had higher persistency measure did not imply high total production per lactation.

Considering the coefficient of determination (R^2) by period of calving, it was observed that cows that calved in the pre 1965 had better goodness of fit measure compared to post 1975. As stated earlier, the pre-1970 data were predominantly Bunaji breed while post 1975 were predominantly Friesian-Bunaji and Friesian. The intermediate (1971-75) periods was combination of the three breeds.

In conclusion, the Modified Gamma model was found to have a high estimate of R^2 as the Gamma function and also a high value of the persistency which was comparable to those obtained under Gamma functions.

5.3 INVERSE POLYNOMIAL FUNCTION

5.3.1 RESULTS AND DISCUSSIONS

Table 69 (Appendix D) gives the summary of the least squares analysis of variance and table 70 gives the least squares means and the standard errors. From table 69, the results showed significant effects of breed ($P<0.001$), parity ($P<0.01$) and period of calving ($P<0.05$) on the curve parameters and the peak week. Effect of lactation length was significant effect on the rising phase ($P<0.05$), the declining phase ($P<0.05$) and the peak week ($P<0.001$). Season was not significant ($P>0.05$) for either of the curve parameters or the peak week. The total production was significantly ($P<0.05$) affected by all the factors except the period of calving, while all the factors with the exception of the lactation length have significant effects on the coefficient of determination (R^2).

The pure Friesian had significantly ($P<0.01$) higher rate of inclining phase compared to either Bunaji or Friesian-Bunaji cows. The inclining phase varied with the breed of animal. There was no significant difference between the Friesian-Bunaji and Bunaji values, thus suggesting some similarity in the inclining phases for the two breeds. The results also showed that inclining phase differred from one lactation length to another.

TABLE 70: Least squares means and standard errors for curve and production characteristics under Inverse function

CLASSIFICATION	N	$b_0 * 10^{-3}$ Mean	S.E.	$b_1 * 10^{-3}$ Mean	S.E.	$b_2 * 10^{-3}$ Mean	S.E.	R^2 Mean	S.E.	Initprd Mean	S.E	pwk Mean	S.E.	Tprod Mean	S.E.
BREED															
FRIESIAN-BUNAJI	268	90.65[a]	14.68	-1.25[a]	7.17	6.07[a]	0.51	0.66[b]	0.02	7.35[c]	0.26	4.08[a]	0.18	2101.37[b]	116.68
BUNAJI (ZEBU)	205	128.72[a]	15.40	19.47[a]	7.54	6.28[a]	0.54	0.69[b]	0.02	4.40[a]	0.28	4.60[a]	0.19	1241.73[a]	122.30
FRIESIAN	111	231.93[b]	21.94	-68.30[b]	10.78	8.22[b]	0.77	0.58[a]	0.03	5.40[b]	0.40	6.39[b]	0.27	4181.30[c]	186.03
PARITY															
1	146	136.71[a,b]	14.67	15.96[c]	7.19	4.81[a]	0.52	0.56[a]	0.02	4.98[a]	0.26	5.76[b]	0.18	2160.20[a]	115.93
2	154	126.09[a]	14.55	-11.70[b]	7.15	6.39[b]	0.51	0.62[b]	0.02	5.56[b]	0.26	4.95[a]	0.18	2464.85[a,b]	119.27
3	135	129.90[a]	16.04	-16.18[b]	7.73	7.23[b,c]	0.55	0.66[b]	0.02	6.06[b]	0.29	4.65[a]	0.20	2312.74[a]	126.72
4	91	141.62[b]	18.24	-19.96[b]	8.92	6.91[b]	0.64	0.66[b]	0.02	5.99[b]	0.32	4.52[a]	0.23	2620.32[b]	150.54
5	59	217.85[c]	22.94	-51.58[a]	11.20	8.94[c]	0.80	0.72[c]	0.03	6.00[b]	0.42	5.23[a,b]	0.28	2982.55[c]	187.96
LACTATION LENGTH															
< 26 WEEKS	103	147.46	18.40	-22.36	8.94	10.42[c]	0.64	0.65	0.02	5.35	0.33	3.97[a]	0.23	1670.41[a]	147.50
26 - 35 WEEKS	159	176.16	14.85	-26.64	7.27	7.60[b]	0.52	0.65	0.02	5.61	0.27	4.84[b]	0.18	2219.91[b]	120.80
36 - 45 WEEKS	183	127.53	14.28	-9.28	7.01	5.12[a]	0.50	0.63	0.02	6.04	0.26	5.22[b,c]	0.18	2662.83[b]	115.19
> 45 WEEKS	139	150.59	16.13	-8.48	7.70	4.29[a]	0.55	0.66	0.02	5.86	0.29	6.06[c]	0.20	3479.38[a]	129.56
SEASON OF CALVING															
DEC - FEB.	121	152.73	16.26	-14.67	7.94	7.35	0.57	0.59[a]	0.02	5.98[b]	0.30	4.99	0.20	2705.81[b]	132.28
MAR. - MAY	152	158.48	14.87	-22.75	7.28	7.02	0.52	0.65[b]	0.02	5.56[a,b]	0.27	5.12	0.18	2568.96[a,b]	121.58
JUNE - AUG.	118	142.75	16.47	-19.06	8.10	6.58	0.58	0.68[b]	0.02	6.08[b]	0.30	4.87	0.20	2472.48[a]	134.66
SEPT - NOV.	192	147.77	13.47	-10.29	6.50	6.48	0.47	0.66[b]	0.02	5.25[a]	0.24	5.10	0.17	2285.28[a]	107.51
PERIOD OF CALVING															
< 1965	50	178.15[b]	29.38	-26.29[b]	14.26	9.99[c]	1.02	0.74[c]	0.04	5.53[a]	0.52	4.56[a]	0.36	2596.87	231.67
1966 -1970	188	186.64[b]	17.61	-51.64[a]	8.73	9.06[c]	0.62	0.67[b]	0.02	5.15[a]	0.32	4.96[a,b]	0.22	2501.01	145.56
1971 -1975	266	118.87[a]	12.09	-4.01[c]	5.88	5.15[b]	0.42	0.59[a]	0.02	6.83[b]	0.22	4.89[a,b]	0.15	2425.13	96.07
> 1975	80	118.07[a]	20.31	15.17[c]	9.89	3.23[a]	0.71	0.59[a]	0.03	5.36[a]	0.37	5.67[b]	0.25	2509.52	164.81

Note

parameters viz;
b_0 = the rising phase; b_2 = declining phase
b_1 = the general slope
Initprd=initial week average daily production,
pwk= peak week,
Mxprod- peak production/day at peak week
Tprod-total production/lactation

Note: Least squares means connected by the same letter within a subclass are not significantly different from each other ($p \leq 0.05$)

The values for cows in the 26-35 weeks category was significantly (P<0.01) larger than those in other categories. For parity, animal in the fifth parity had significantly better inclining phase than those in lower parities. However, the values for animals in the first and fourth parities did not differ significantly (P>0.05). Also, records collected in the periods before 1970's had significantly (P<0.01) different inclining phases than those after 1970.

This perhaps might be due to changes in the management practises. There was no effect of seasons on the inclining phase. This agreed with the findings of Yadav et al. (1977) and Rao and Sundaresan (1979).

The constant (b_1) which measured the average slope of the lactation curve, indicated by period of optimum daily production, was significantly affected by breed (P<0.001) , parity (P<0.01) at calving and period (P<0.001) of calving. The season of calving did not affect this component (Table 69). The average slope for Friesian differred significantly (P<0.01) from that of Bunaji and Friesian-Bunaji. The slope for Friesian was lowest while that of Friesian-Bunaji was intermediate between the value for Friesians and the Bunaji groups. With respect to parity, the average slope for animals in first parity differed significantly (P < 0.01) from animals in other parities. Infact, the results could be categorised into animals in three groups viz, first calvers as one group, animals in the second, third and fourth parities constituted one group and cows in the fifth parity

formed another group. For periods of calving, the average slope of animals that calved between 1966 and 1970 had the lowest slope whereas those that calved before 1966 had intermediate slope while those that calved after 1975 had the largest slope. The results agreed with the findings of Yadav et al. (1977) who reported significant influence of breeds and parities while no effect of season was recorded.

Considering the declining extreme 'b_2', results showed significant ($P < 0.001$) effect of breed, lactation length, parity and period at calving. The declining extreme was highest for Friesians and differed significantly ($P<0.01$) from the values observed for Bunaji and Friesian-Bunaji.

This implied that although the Friesian cows had significantly ($P<0.01$) higher inclining phase to the peak than the other breeds, they also had a significantly ($P<0.01$) larger declining phase from the peak than the other two breeds. The ratios of the inclining phase to the peak to the decline from the peak showed that the Friesian values were significantly different from both Friesian-Bunaji and Bunaji values. The ratios were 28.1, 20.42 and 14.0 for Friesian, Bunaji and Friesian-Bunaji, respectively. From the values, one can perhaps say that the rate at which the peak was maintained was lowest for Friesian while there were also significant ($P<0.05$) differences between the values for Bunaji and Friesian-Bunaji responses. Cows that were in milk for less than 26 weeks had significantly higher declining phase than those with longer lactation length. Results

showed negative relationship between lactation length and declining rate. The longer the lactation length ,the lower the declining phase. For parity the results indicated that cows could be put into three groups comprising of first parity animals in the first group, second, third and fourth parity in the second group and the last group being the fifth parity animals. Animals in the second category (second,third and fourth parity) did not differ significantly in the declining phases of the model.

The pattern of the declining phase can be classified into three categories using the period at calving. These are periods up to 1970 constituting the first category, from 1971-1975 the second category and beyond 1975, the third category. The pattern was also similar to the rate of inclining phase. This may also be attributed to differences in management practises during the period. This lactation curve parameter was not affected by the effect of season. The observation conflicts with the findings of Yadav et al. (1977) where they found no significant effect of parity.

The degree of adequacy of the model which was evaluated by the adjusted coefficient of determination (R^2) ranged from 58-74% over the entire lactations. Results showed significant effects of breed, season of calving, parity and period of calving. There was no significant effect of lactation length.

The model fitted the Bunaji data significantly ($P<0.05$) better with an R^2 of 69% than the Friesian data which had the least R^2 value of 58% while the Friesian-Bunaji data had

intermediate value of about 66% which did not differ significantly from the Bunaji data (table 70). It was found that the model did not fit the data appropriately for animals that calved in the December - February period as compared to those that calved in other periods. This might be due to irregularity in the availability of feed particularly at this period when feed was relatively scarce and temperature was usually low . Thus milk let down would be affected more than other periods which appear relatively more favourable. The coefficient of determination was not affected by the lactation length. This implied that irrespective of the length of lactation the coefficient of determination was not affected.

The R^2 was highest for animals in the fifth parity with a value of 72% and worst for animals in the first parity with 56% while those in the second, third and fourth parity were intermediate in fitness with values ranging from 62 to 66%. For period at calving, results showed that the model was best suited to animals that calved in the early sixties (i.e.up to 1965) and worst for data collected after 1970. The obviously is correlated with changes in management (Olayiwole, 1971).

With respect to the production parameters, the peak week which marks the period in which an animal attains its optimum production and the total production are very important parameters in a dairy herd. No farmer is prepared to keep an animal longer than necessary if the production is not encouraging. The total production is an indicator constantly

used by farmers in selecting animals that are to be kept in the herd. Good producers are useful in selection procedures. They could also be used in effecting changes in management practises like changes in nutritional plains. If the nutrition can be improved in order to bring the attainment of peak to an earlier period, then it may also be feasible to increase productivity and earlier rebreeding of the animals. Table 69 showed effects of breed, lactation length parity and period of calving on the peak week with no significant effect of season. The observation showed that Friesians took significantly ($P<0.01$) longer period to attain peak than Bunaji and Friesian-Bunaji. Generally, it was found in this study that there was a positive relationship between lactation length and the peak week. The longer an animal took to reach the peak, the larger the number of weeks the animal will be in milk. The point was further confirmed by the results from the effects of lactation length. Animals with short lactation length attained peak much earlier than those which had longer lactation length. It is worth noting that those in milk for less than 26 weeks with peak week attained about 4 weeks after parturition and those over 45 weeks in milk had a peak week of about 6 weeks. Results from this study also showed that animals that calved earlier than 1975 had shorter calving period. The result of this was that the majority of the animals in this group were actually Bunaji/Friesian-Bunaji crosses that had relatively lower peak week while animals post 1975 were mainly Friesians.

Total production, indicated that Friesians had significantly ($P<0.01$) higher yield than either Friesian-Bunaji or Bunaji. The lowest yield was recorded for Bunaji while the yield for Friesian-Bunaji was intermediate between the yield for the pure breeds. Furthermore, results showed that animals that calved in December - May had significantly higher predicted total than those calving in other periods. This may be explained by the fact that the condition of the animals during gestation period in particular was favoured by the availability of good pasture and quality hay and thus at calving, the animals that were in good form required feed for production rather than for body maintenance. Between December and February, animals had good quality hay and the animal waited for shorter period before the onset of rains. However for animals calving between June- November, the earlier part of gestation was in the dry season when there was less feed. This implied the animal required feed to make up the body condition before better milk production could be guarranteed. This therefore affected the productivity and subsequently the total milk production. Significant difference between the lactation lengthes could be explained from the fact of the positive correlation between lactation length and total milk production. No noticeable difference in the total production was observed between period of calving.

This study has shown that the use of Inverse Polynomial in representing the pattern of milk production gave a

generally low goodness of fit when measured by coefficient of determination R^2 compared to what had been reported by Yadav et al. (1977). They reported an R^2 of about 99% in their study of Hariana and its Friesian crosses. This study further showed an R^2 of 69% for Bunaji, 66% for Friesian-Bunaji and 58% for Friesian. This goodness of fit measure was also low compared to the findings of Abubakar and Buvanendran (1981) and that of Rao and Sundaresan (1979). This suggests that the model is relatively better for the Bunaji and Friesian-Bunaji breed than for Friesian. The model fitted pre 1966 data better than other periods of calvings considering the R^2 values. If this model is the only one that can be readily used, correction factors must be developed for the effects of breed, parity, lactation length and period of calving.

5.4 Summary of the Combined Analysis

From the evaluation of the three models for the combined data, that is the Gamma, Modified Gamma and the Inverse functions, the analysis showed significant ($P<0.001$) differences existed between breeds for each of the models. There was significant ($P<0.001$) effect of breed for the lactation curve parameters in all the three models. Furthermore, it was observed that there was effect of parity on the curve parameters with the exception of the rate of rise to the peak, **b** under the Gamma function while it was significant ($P<0.001$) only for the general level of

production, a under the Modified gamma function.

As for the effect of season, no significant ($P>0.05$) of season was recorded for the Gamma based functions or the Inverse Polynomial function on the combined analysis. Result of the lactation length indicated effect on the rate of decline from the peak under the Gamma function but not for the Modified Gamma function.

The period of calving had effects on the general level of production, a ($P<0.05$), rate of decline from the peak, c ($P<0.001$) under the Gamma function but had no effect on any of the curve parameters under the Modified Gamma function. This factor had effects under the Inverse Polynomial function.

Considering the production indicators namely, initil week prduction per day, peak week and peak production, the factors had highly significant effects ($P<0.001$) under the Gamma based functions. Similar trend was noticed under the Inverse Polynomial function. However the level of significance varied.

With respect to the goodness of fit (R^2), there was no effect of breed particularly for the Gamma based functions. There was breed differences between the R^2 under the Inverse function. Under the Gamma function, the R^2 was about 79% for Bunaji, 79% for Friesian-Bunaji and 75% for the Friesian. Using the Modified Gamma function the corresponding values were 79% for Bunaji, 77% for Friesian-Bunaji and 75% for the Friesian cows. However, under the Inverse Polynomial function

the values recorded were much lower when compared to the values listed above. The values were 69, 66 and 58 percent for Bunaji, Friesian-Bunaji and Friesians, respectively after correcting for external factors like parity, season of calving, lactation length and period of calving.

Generally over the Gamma based functions, Bunaji cows have better peristency measure compared to the other breeds. Result showed significant ($P<0.01$) effect of breed on persistency under the Gamma and the Modified Gamma functions. Under the two models, Bunaji and Friesian-Bunaji had significantly ($P<0.05$) better persistency than the Friesian cows.

In conclusion, the result from all areas considered showed that the Gamma functions gave a better description of the production pattern of the three breeds of cattle than the Inverse function. This was based on the degree of variation noticed between the functions under the various consideration. And this is particularly so for the production indicators and also for the coefficient of determination (R^2) which measures the adequacy of the models. Furthermore, since the effect of season of calving could always be corrected for, the Gamma function was found to be most preferable. The function could be used without difficulty and also from the fact that the function generally provided better precision.

CHAPTER 6

SUMMARY AND CONCLUSION

6.1 SUMMARY

Five hundred and eighty four from Bunaji, Friesian-Bunaji and Friesians were used in the evaluation of three lactation curves to assess the suitability and reliability of each function in the modelling of the milk production curves of cattle in Nigeria. The three functions were fitted to each of the lactation records which comprised of 205 lactations from Bunaji, 268 from Friesian-Bunaji crosses and 111 from Friesian records. Data used covered a period from 1960 to 1978 with only animals that were in the first five parities and lactations less than 15 weeks were eliminated fom the analysis.

The lactation curves considered were the Inverse Polynomial function proposed by Nelder (1966), the Gamma function by Wood (1967) and the Modified Gamma function proposed by Kuck et al. (1976).

The study showed the average total milk production per lactation was 928.4, 1862.0 and 4016.0 kg for Bunaji, Friesian-Bunaji and Friesian cows, respectively. The corresponding average lactation lengths were 32, 36 and 50 weeks. On the average the Bunaji and Friesian-Bunaji cows attained their peak production within the range of 4 - 6 weeks after parturition. The corresponding time for the Friesian cows was between 6 - 9 weeks. The peak production

for the Bunaji averaged 6.4 kg, Friesian-Bunaji was 11.8 kg while the Friesian peak production averaged 18.9 kg per day, respectively. The average initial week production per day was 4.69, 8.69 and 8.39 kg for Bunaji, Friesian-Bunaji and Friesian cows, respectively.

Comparing the observed with the predicted production indicators namely, initial week average production per day, peak week, peak production and total production between models it showed that there were differences between the deviations. Observation showed that on using the Buanji data, the Gamma function had the lowest deviations. The Gamma based functions (Gamma and Modified Gamma functions) had lower deviations between the predicted and the observed average for the Bunaji cow. Furthermore, it was observed that the Inverse function generally under-predicted the average initial week production per day but over-predicted the total production for the entire lactaton and the peak productions. The Gamma function was found to have almost correctly predicted the indicators. By the coefficient of determination (R^2) which gives the measure of goodness of fit, the Gamma functions provided R^2 value of 84% while the Inverse function gave 70%. The comparison between the values showed significant ($P<0.01$) differences between the two groups. However, no difference existed between the R^2 values for Gamma and the Modified Gamma functions.

Using the Bunaji data, it was observed that the Multiplicative Factors (MF) developed for estimating the

305-day production using the factors based on Gamma function provided the best estimate of the actual considering the deviations of the estimated from the actual. Though the Persistency measure obtained from the Modified Gamma function was slightly higher, there was no difference between the Gamma and the Modified Gamma functions. Judging from the information on the other measures like the deviations of the predicted from the observed average, the performance of the models in the evaluation of other parameters showed that Gamma function was the most appropriate. The Inverse function was the least suitable in terms of the properties discussed above.

For the Bunaji data, effects of parity, lactation length, season of calving were observed on the curve parameters. The persistency was significantly affected by parity ($P<0.05$), lactation length ($P<0.001$), season of calving ($P<0.01$) but not by the year of calving. Under the three models, it was found that the parity and season of calving had effects on the initial week daily production ($P<0.001$), Peak production ($P<0.001$) but not on the total production.

There was significant correlation between the curve parameters and some of the production indicators. For each model, significant and positive phenotypic correlations were obtained between the general level of production, a, with **initprd, Mxprod and Tprod.** From the coefficients, between the curve parameters and the production indicators, the result

showed that **initprd** is a good measure of the general level of production. Also as a result of the positive and significant ($P<0.001$) correlation between **Mxprod** and initprd, it might be feasible to cull an animal on the basis of low **initprd** using this information without waiting to collect the total lactation production of such cows. In other words this could be a useful tool in selection practices.

With the Friesian-Bunaji data, the resultd showed a generally close agreement between the estimates obtained from the three functions with respect to the criteria used for evaluating the adequacy of the functions. These included the ammount of deviations between the predicted and the observed average curve production for the group, the co-efficient of determination (R^2) and the precision for the production indicators. The result showed that the Modified Gamma function provided the closest agreement between the observed pattern of production although no significant differences existed between values obtained for the Gamma function and those of Modified Gamma function.

Generally, the Inverse function under-estimated the observed average between the first 4 weeks and between the 7^{th} and 34^{th} weeks whereas the Gamma based functions over-estimated. The degree of over-estimation was lower for the Modified Gamma function compared to the Gamma function.

Multiplicative factors developed from the Inverse function over-estimated the cummulative production up to the 16^{th} week. Beyond this point, the percentage daviation of the

predicted compared to the observed became non-significant. On general assessment of the adequacy of the models, the Inverse function was least appealing and therefore considered not appropriate in representing the pattern of production for the Friesian-Bunaji crosses. Though the Modified Gamma was found to be best for the Crosbreds cows, no significant differences existed between the two functions considering the predicting abilities for the production indicators.

As for factors affecting the pattern of milk production in Friesian-Bunaji cattle, the results from the Gamma function showed significant effects of parity ($P<0.001$), lactation length ($P<0.001$), season and year of calving ($P<0.001$). The same result was obtained under the Modified Gamma function. Similar observation was recorded using the Inverse function.

As for the correlation between the lactation curve parameters and production indicators, the coefficients were similar in magnitude to what was observed using the Bunaji data.

The comparison of the models using the Friesian data showed that the three models generally under-estimated the peak production. The Modified Gamma under-estimated the observed production throughout the entire lactation period while the Inverse polynomial over-estimated around the peak week. The Gamma function under-estimated the total production. The three models under-estimated the total production by parity. The degree of under-estimation was

highest in the Inverse function particularly in the fourth and fifth parities.

Comparing the adequacy of the models using the Friesian data, the R^2 values were generally low compared to what was observed for the two set of data used earlier. However, the value obtained for the Gamma functions were larger than the corresponding R^2 values using the Inverse Polynomial function. This implied that the Inverse function was least suitable. With respect to the persistency measure, the comparison between the Gamma and the Modified Gamma function showed no difference. However, observations on the daily production pattern under the two functions showed that the Gamma function was superior.

The factors affecting the production pattern of the Friesian cattle were season of calving and year at calving. Parity had no effect on the curve parameters for the Gamma function. Season of calving had effect on the rate of rise to the peak, b, and the rate of decline from the peak, c, using the Gamma function but not for the Modified Gamma function. The implication of this is that the modification on the Gamma function as suggested by Kuck et al. (1976) achieved the objective of being able to remove the effect of seasonality in milk production. In the Inverse function, the effect of season of calving was significant. As for the effects of the factors on the production indicators, parity had no effect in either of the indicators except peak production ($P<0.01$) using the Gamma functions. The season of

calving had effects on the initprd and Mxprod for all the functions while the effect of season affected the total production in the Gamma based functions and not in the Inverse polynomial function.

A consideration of the relationship between the curve parameters and the production indicators for the Friesian data showed significant ($P<0.001$) and positive relationship between the general level of production a and initprd, Mxprod and Tprod. On the other hand, there was a negative and significant correlation between the rates of change (b, c) in the pattern of production for the Gamma based functions and the production indicators. Similar observation was made in the Inverse function except that there was no significant correlation between the curve parameters and the Tprod.

The combined analyses showed effects of breed on all the lactation curve parameters and the production indicators. It was observed that Bunaji cows had significantly ($P<0.01$) lower production indicators (Initprd, pwk, Mxprod and Tprod) than Friesian cows. The Friesian-Bunaji crosbreds generally had values between those of Friesian and Bunaji cows with the exception of the Initprd where the value for the Crosbred was highest though, no difference existed between those of Friesians.

The Coefficient of determination (R^2) showed no effects of breed for the Gamma or the Modified Gamma functions. The least squares means showed that R^2 values obtained using the Gamma functions had higher values for Bunaji and the

Friesian-Bunaji crosbreds than the Friesian cows. The same observation was made under the Inverse function though significant differences($P< 0.05$) existed between the breeds. Generally, the R^2 value obtained from any of the models indicated better fit for the Bunaji and the Friesian-Bunaji crosbreds than for the Friesians. This might be explained by the fact that the Bunaji and the Friesian-Bunaji crosbreds are more adapted to the environment than the Friesian cows. The comparison of the precision of the Multiplicative factors for estimating the total lactation yield from part records showed that factors from the Gamma based functions had relatively better precision. This conclusion was based on the deviations from each function. The deviations from the Gamma functions were relatively lower than those obtained from the Modified Gamma function.

6.2 CONCLUSION

Modelling the pattern of milk production of Bunaji, Friesian-Bunaji crosbred and Friesian cows is best described using the Gamma function.

The Persistency of the Bunaji and the Friesian-Bunaji crosbred cows was significantly ($P<0.05$) better than the Friesian cows. This might be due to higher adaptability in the Bunaji and the Friesian-Bunaji crosbreds cows. The observation from the study showed that Friesian cows had the highest rate of rise to the peak. They also had

correspondingly the highest rate of decline from the peak which lead to relatively lower persistency.

The Inverse Polynomial function might be good in estimating the initial week average daily production, it also grossly overpredicted the week of peak production as well as the production at peak week for all breeds which subsequently lead to over-prediction of the total production per lactation.

The study showed that, apart from the better goodness of fit (R^2) from the Gamma function, the use of Multiplicative factors for estimating the total production per lactation developed using the Gamma function had higher precision and was more reliable. This is as result of the low deviations of the predicted from the observed. As a result of the significant and positive correlation between the curve parameters and the production indicators, it is possible to use the information to enhance selection programs in a herd instead of waiting for groups of cows to complete the entire lactation before culling low milk producing cows from the herd. Furthermore, the assertion may perhaps be investigated more by studying the genetic correlations between the lactation curve parameters and the production indicators.

From this study, it was observed that Bunaji and Friesian-Bunaji crosbred cows had an average lactation length of about 32 and 36 weeks. An early rebreeding of the two should be encouraged as such effort would boost the milk production and possibly reduce the differential apart from

the fact that more progenies will be obtained.

In evaluating the pattern of milk production in cattle, it is important to correct for the effects of parity, season of calving, year of calving as well as the lactation length.

Finally, it is encouraged that when models or functions are to be compared, use of coefficient of determination (R^2) should not be made the sole criterion. Consideration should also be given on the precision by way of the deviations between the predicted and the observed before deciding on the model that is best for the pattern of lactation being investigated.

Generally, result showed that Multiplicative factors derived under Gamma function using data from either of Bunaji, Friesian or Friesian-Bunaji records were found to have the least deviations when compared to those developed from the other functions. The use of these factors is very relevant to our environment. This is particularly so because it is difficult to have asses to a nomadic fulani herd throughout the year to observe the production pattern of his animals. So for any factor developed to be useful in evaluating the milk production levels of his herd or possibly an individual animal in such a herd. The recommendation therefore, is that trials be carried out for such studies to be carried out in the Fulani herd or any LIBC centres especially now that the Peri-Urban dairy technology is being developed for the country.

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APPENDIX A

Table 7 : Least Squares Analysis of variance of the lactation curve parameters for Gamma function under Bunaji data

		MEANS SQUARES								
Source	d.f	a	b	c	R^2	s	pwk	Mxprod.	Initprd	Tprod.
Parity	4	1.363***	0.048	0.0024*	0.047*	0.4277*	19.1020**	3383.25***	3805.907**	102416.47
Lactation length	3	0.100	0.099	0.0232***	0.044*	3.9616***	50.6302***	1169.72	458.584	23695659.24*
Season of calving	3	0.5396*	0.181*	0.0017	0.026	0.6649**	18.1405**	498.22	2611.616**	120939.56
Year of calving	11	0.1495	0.034	0.0008	0.0377**	0.1923	4.1762	1118.04	851.878	1352121.99
Residual	184	0.1700	0.053	0.0009	0.016	0.1707	4.5148	620.42	681.820	244787.50

Note the significance of parameters
* P<0.05
** P<0.01
*** P<0.001

Note
a-general level of production under Gamma funtions.
b-rate of rise to the peak under Gamma functions.
c-rate of decline from the peak under Gamma functions.
s = persistency
Initprd=Initial week average daily production
pwk- peak week
Mxprod- peak production/day at peak week
Tprod-total production/lactation

Table 9 : Least Squares Analysis of variance of the lactation curve parameters for Modified Gamma function under Bunaji data

		M E A N S S Q U A R E S								
Source	df	a	b	c	R^2	s	pwk	Mxprod	Initprd	Tprod.
Parity	4	1.3144***	0.0247	0.00249*	0.0357*	2.7334***	13.6869	1468.88	3103.7**	168196.4
Lactation length class	3	0.2014	0.0999	0.02261***	0.0463	5.8761***	52.4993***	17756.58*	276.5	23682716.7**
Season of calving	3	0.5360	0.1893*	0.001886	0.0414*	0.8489*	20.0543**	18419.33*	2608.5**	98510.5
Year of calving	11	0.1611	0.0352	0.00094	0.0303*	0.6341**	3.9258	4633.08	857.40	1274535.5**
Residual	183	0.2176	0.0528	0.00089	0.0145	0.2457	4.9167	5309.973	690.645	240908.8

Note the significance of parameters
* P<0.05
** P<0.01
*** P<0.001

Note

a=general level of production under Gamma functions.
b=rate of rise to the peak under Gamma functions.
c=rate of decline from the peak under Gamma functions.
s= persistency
Initprd=Initial week average daily production
pwk= peak week
Mxprod= peak production/day at peak week
Tprod=total production/lactation

Table 11 : Least Squares Analysis of variance of the lactation curve parameters for Inverse Polynomial function under Bunaji data

Source	d.f	MEANS SQUARES b_0	b_1	b_2	R^2	pwk	Mxprod	Initprd	Tprod
Parity	4	0.0989*	0.0392**	0.00026**	0.0422	15.312***	20855.43*	1922.24**	571672.5
Lactation length class	3	0.0475	0.0155	0.0028**	0.0657	22.211***	23929.14*	68.75	34014963.0***
Season of calving	3	0.0323	0.0078	0.000027	0.0194	3.827	19356.63*	1395.87	485390.6
Year of calving	11	0.0216	0.0097	0.000057	0.0687*	2.627	3871.42	748.31	1351477.3**
Residual	183	0.0335	0.0103	0.000058	0.0322	1.765	6830.71	599.99	516583.6

Note: * = P<0.05
** = P<0.01
*** = P<0.001

Note

b_0= rising phase under Inverse Polynomial function
b_1= average slope under the Inverse Polynomial function
b_2= declining phase from the peak under Inverse Polynomial functions.
Initprd=Initial week average daily production
pwk= peak week
Mxprod= peak production/day at peak week
Tprod=total production/lactation

APPENDIX B

Table 28: Least Squares Analysis of variance of the lactation curve parameters for Gamma function for Friesian-Bunaji data

		MEANS SQUARES								
Source	d.f	a	b	c	R^2	s	pwk	Initprd	Mxprod	Tprod.
Parity	4	2.0126***	0.0314	0.0031***	0.2783***	1.3594**	37.6581***	26457.33***	31294.88***	3152299.9**
Lactation length	3	0.1805	0.0499	0.0337***	0.0126	11.0811***	62.2537***	4036.76	8191.83	97269433.7**
Season of calving	3	0.1229	0.1869***	0.0062***	0.2531***	5.4951***	20.6655**	2598.28	20992.46**	1135686.3
Year of calving	11	0.3237***	0.1352***	0.0063	0.2011***	3.3711***	12.3806**	6082.26***	10462.80*	3411749.7**
Residual	[A]	0.1041 [243]	0.0299 [199]	0.00069 [241]	0.0316 [243]	0.3782 [241]	4.5807 [193]	1835.18 [241]	4993.59 [201]	974273.6 [241]

Residual d.f are given in [ ] for each parameter.
Note the significance of parameters

* P<0.05
** P<0.01
*** P<0.001

Note

a=general level of production under Gamma functions.
b=rate of rise to the peak under Gamma functions.
c=rate of decline from the peak under Gamma based functions.
s= persistency
Initprd=Initial week average daily production
pwk= peak week
Mxprod= peak production/day at peak week
Tprod=total production/lactation

Table 31: Least Squares Analysis of variance of the lactation curve parameters for Modified Gamma function for Friesian-Bunaji data

		M E A N S S Q U A R E S								
Sourse	d.f	a	b	c	R^2	s	pwk	Initprd.	Mxprod	Tprod.
Parity	4	1.7358***	0.0108	0.0054***	0.2540***	3.087***	43.24***	28171.0***	22142.02***	3979358.8***
Lactation length	3	0.1918	0.0427	0.0244***	0.0202	8.719***	48.69***	5180.3	3517.81	98992269.3***
Season of calving	3	0.1001	0.1563***	0.0031	0.2666***	0.388	11.99**	2254.0	22954.36***	1733544.7
Year of calving	11	0.2831*	0.1293***	0.0074***	0.1992***	1.083***	13.47**	6891.2***	8765.44**	2324939.8***
Residual	[A]	0.1303 [241]	0.0321 [199]	0.0020 [241]	0.0302 [241]	0.1792 [240]	5.15 [188]	2053.4 [239]	3630.61 [198]	994709.6 [261]

Residual d.f are given in [ ] for each parameter.
Note the significance of parameters
* P<0.05
** P<0.01
*** P<0.001

Note

a=general level of production under Gamma functions.
b=rate of rise to the peak under Gamma functions.
c=rate of decline from the peak under Gamma functions.
s= persistency.
Initprd=Initial week average daily production
pwk= peak week
Mxprod= peak production/day at peak week
Tprod=total production/lactation

Table 34: Least Squares Analysis of variance of the lactation curve parameters for Inverse Polynomial function for Friesian-Bunaji data

		MEANS SQUARES							
SOURCE	d.f	b_0	b_1	b_2	R^2	puk	Mxprod.	Initprd	Tprod
Parity	4	0.002378	0.008235**	0.00003479*	0.21957***	14.7959***	52730.79***	13696.73***	6889021.30***
Lactation length	3	0.009479	0.004452	0.0003589***	0.00658	23.7455***	6351.43	5508.25*	108556055.60***
Season of calving	3	0.007670	0.011334**	0.00002778	0.27494***	6.7186*	21831.25*	1232.02	5028680.3**
Year of calving	11	0.024153***	0.0161***	0.0001100***	0.09742**	4.6688*	18386.32**	9358.50***	2612227.70*
Residual	[A]	0.003508	0.002342	0.00001172	0.04071	2.3044	6741.130	1558.14	1374133.50

Residual d.f are given in [ ] for each parameter.
[A] For b_0 = 222, b_1 = 244, b_2 , R^2,Initial prod = 243, Peak week = 242, Peak prod = 197, Total Prod = 235
Note the significance of parameters
* P<0.05
** P<0.01
*** P<0.001
b_0= rising phase under Inverse Polynomial function
b_1= average slope under the Inverse Polynomial function
b_2= declining phase from the peak under Inverse Polynomial functions.

APPENDIX C

Table 49: Least Squares Analysis of variance of the lactation curve parameters for Gamma function for Friesian data

		M E A N S S Q U A R E S								
SOURCE	D.F	a	b	c	R^2	s	pwk	Initprd.	Mxprod.	Tprod.
Parity	4	0.391	0.052	0.0004	0.017	0.028	5.33	8863.10	14313.11**	10101127.3
Lactation length	3	0.389	0.281*	0.0190***	0.007	2.302***	25.79	3090.9	8455.28	64449176.7***
Season of calving	3	0.830	0.193	0.0027*	0.024	0.887*	16.07	20152.2**	15963.19**	30795383.7***
Year of calving	8	0.529	0.222*	0.0026**	0.086**	0.724*	11.75	5613.5	15025.34**	15203656.4**
Residual	[A]	0.267 [92]	0.089 [86]	0.0009 [91]	0.031 [92]	0.287 [91]	9.91 [80]	4436.6 [92]	4124.32 [87]	5699809.7 [92]

Residual d.f are given in [ ] for each parameter.
* P<0.05 ** P<0.01 *** P<0.001

Note

a=general level of production under Gamma funtions.
b=rate of rise to the peak under Gamma functions.
c=rate of decline from the peak under Gamma functions.
s= persistency.
Initprd=Initial week average daily production
pwk= peak week
Mxprod= peak production/day at peak week
Tprod=total production/lactation

Table 52: Least Squares Analysis of variance of the lactation curve parameters for Modified Gamma function for Friesian data

		M E A N S S Q U A R E S								
SOURCE	d.f	a	b	c	ADJ R^2	s	pwk	Initprd.	Mxprod.	Tprod.
Parity	4	0.328	0.036	0.0169	0.022	0.105	15.82	7428.50	14236.18*	8422564.8
Lactation length	3	0.346	0.209	0.1268	0.013	2.029***	9.08	3961.9	12432.11	37935841.8
Season of calving	3	0.686	0.132	0.0861	0.028	0.078	23.82	15895.3*	19948.60**	22851217.8
Year of calving	8	0.481	0.140	0.1330	0.081*	0.540	11.41	7103.5	18823.10***	30180006.8
Residual	[A]	0.269 [91]	0.083 [87]	0.0921 [91]	0.032 [91]	0.273 [91]	11.61 [79]	5083.4 [91]	4937.60 [79]	56137297.8 [91]

Residual d.f are given in [ ] for each parameter.
Note the significance of parameters
* P<0.05
** P<0.01
*** P<0.001

Note

a=general level of production under Gamma funtions.
b=rate of rise to the peak under Gamma functions.
c=rate of decline from the peak under Gamma functions.
s= pesistency
Initprd=Initial week average daily production
pwk= peak week
Mxprod= peak production/day at peak week
Tprod=total production/lactation

Table 55: Least Squares Analysis of variance of the lactation curve parameters for Inverse Polynomial function for Friesian data

		M E A N S S Q U A R E S							
SOURCE	d.f	b_0	b_1	b_2*10^{-3}	R^2	pwk	Mxprod.	Initprd	Tprod*10^6
Parity	4	0.0668	0.0036	0.0034	0.0444	9.939	16573.30	2840.30	20.789
Lactation length	3	0.0253	0.0035	0.0491**	0.1358*	29.442*	23461.43	863.90	86.0424*
Season of calving	3	0.0925*	0.0126*	0.0324	0.0142	7.334	37662.77	19614.1***	33.3039*
Year of calving	8	0.0825*	0.0089	0.0328**	0.0755	9.148	51658.54	4603.60	21.6946
Residual	[A]	0.0348 [91]	0.0046 [91]	0.012b [90]	0.0503 [91]	8.057 [91]	59965.70 [91]	5011.00 [89]	14.9379 [71]

Residual d.f are given in [ ] for each parameter.
Note the significance of parameters
* P<0.05
** P<0.01
*** P<0.001

Note

b_0 = rising phase under Inverse Polynomial function
b_1 = average slope under the Inverse Polynomial function
b_2 = declining phase from the peak under Inverse Polynomial functions.
Initprd=Initial week average daily production
pwk= peak week
Mxprod= peak production/day at peak week
Tprod=total production/lactation

APPENDIX D

Table 65: Least Squares Analysis of variance of the lactation curve parameters for Gamma function for Combined data

Source of Variations	d.f	MEANS SQUARES								
		a	b	c	R^2	s	Initprd	pwk	Mxprod*10^3	Tprod
Breed	2	9.36***	3.116***	0.029***	0.043	11.541***	100576.40***	204.698***	372.522***	350.21
Parity	4	3.060***	0.114	0.007***	0.452***	2.684***	24084.47***	103.535***	39.014***	2.952
Lactation Length	3	0.346	0.379***	0.078***	0.024	18.132***	4441.81	112.501***	7.320***	165.800
Season of Calving	3	0.283	0.057	0.002	0.101**	1.747**	5580.94	5.652	19.262***	6.729
Period of Calving	4	1.819*	0.168*	0.010***	0.364***	4.411***	18964.44***	12.594	3.404	9.546
Residual	[A]	0.182 [567]	0.062 [507]	0.001 [563]	0.030 [567]	0.353 [563]	2198.17 [565]	7.718 [498]	7.195 [511]	2.014 [565]

Residual d.f are given in [ ] for each parameter.
Note the significance of parameters
* P<0.05
** P<0.01
*** P<0.001

Note

a=general level of production under Gamma funtions.
b=rate of rise to the peak under Gamma functions.
c=rate of decline from the peak under Gamma functions.
s= persistency.
Initprd=Initial week average daily production
pwk= peak week
Mxprod= peak production/day at peak week
Tprod=total production/lactation

Table 67: Least Squares Analysis of variance of the lactation curve parameters for Modified Gamma function for Combined data

Source of Variations	d.f	MEANS				SQUARES				
		a	b	c	R^2	s	Initprd	pwk	Mxprod*10^3	Tprod.*10^6
Breed	2	8.562**	2.377***	0.124***	0.030	3.134***	86685.16***	151.420***	272.774***	360.996***
Parity	4	2.648***	0.064	0.002	0.385***	5.927***	19621.33***	106.762***	24.371***	5.927***
Lactation Length	3	1.522	0.300***	0.093***	0.032	17.538***	4059.86	96.707***	10.208	160.375***
Season of Calving	3	0.839	0.036	0.024	0.136**	0.626*	4344.65	7.072	25.806***	6.120*
Period of Calving	4	1.384	0.110	0.012	0.227***	2.811***	11125.21**	10.784	21.430	11.831**
Residual	[A]	0.208 [562]	0.058 [521]	0.017 [561]	0.029 [562]	0.234 [575]	2414.49 [559]	8.038 [490]	4.899 [505]	1.985 [561]

Residual d.f are given in [ ] for each parameter.

* P<0.05
** P<0.01
*** P<0.001

Note

a=general level of production under Gamma funtions.
b=rate of rise to the peak under Gamma functions.
c=rate of decline from the peak under Gamma functions.
s= persistency
Initprd=Initial week average daily production
pwk= peak week
Mxprod= peak production/day at peak week
Tprod=total production/lactation

Table 69: Least Squares Analysis of variance of the lactation curve parameters for Inverse Polynomial function for Combined data

Source of Variations	d.f	MEANS			SQUARES			
		b_0*10^{-3}	b_1*10^{-3}	b_2*10^{-3}	R^2*10^{-3}	Initprd	pwk	Tprod*10^4
Breed	2	573.09***	145.03***	0.137***	213.28**	68626.36***	152.581***	620.096***
Parity	4	80.25**	42.49**	0.168***	268.34***	5172.93*	26.365***	30.941**
Lactation Length	3	60.59*	10.23	0.672***	30.99	2364.46	58.781***	234.072***
Season of Calving	3	5.50	4.51	0.021	168.02**	5040.25*	1.629	20.789*
Period of Calving	4	65.75*	50.29***	0.332***	149.60**	16695.73***	11.436*	1.484
Residual	[A]	23.31	5.85	0.030	41.72	1874.97	3.567	7.195

Residual d.f are given in [ ] for each parameter.
[A] Varied with parameter analysed
Residual d.f. b_0 = 533, b_1 = 563, b_2 = 561, R^2 = 562, Peak week = 532 Total Produc=547

* P<0.05
* P<0.01
* P<0.001

b_0= rising phase under Inverse Polynomial function
b_1= average slope under the Inverse Polynomial function
b_2= declining phase from the peak under Inverse Polynomial functions.
itprd=Initial week average daily production
k= peak week
rod= peak production/day at peak week
od=total production/lactation