ASSET Series A (2008) 8 (2): 169-179

ASSET
An International Journal

MODELING THE PATTERN OF UDDER GROWTH DURING PREGNANCY AND LACTATION IN THREE NIGERIAN GOAT BREEDS

[1]I. J. JAMES, [1]O. A. OSINOWO, [2]M. O. OZOJE AND [3]O. A. FANIMO

[1]Department of Animal Physiology,
[2]Department of Animal Breeding and Genetics,
[3]Department of Animal Production and Health
University of Agriculture, Abeokuta, Nigeria

ABSTRACT

Linear, quadratic and exponential regression equations were used to model the pattern of udder growth during pregnancy while Wood's, modified Wood's, inverse polynomial regression and polynomial regression equations were adopted during lactation using descriptors such as udder length (UL), udder width (UW) and udder circumference (UC) in West African Dwarf (WAD), Red Sokoto (RS) and Sahel breeds of goats in Nigeria. UC and UW were found to be the best descriptors of udder growth during pregnancy and lactation respectively in the three breeds. The quadratic and polynomial regression equations best fitted data from the three breeds of goats during pregnancy and lactation respectively. The equations during pregnancy were: $UC = 22.0 – 0.0384X + 0.0005X^2$, $R^2 = 0.97$ (for WAD); $UC = 26.5 – 0.0402X + 0.0006X^2$, $R^2 = 0.96$ (for RS); $UC = 33.1– 0.0286X + 0.0004X^2$, $R^2 = 0.98$ (for Sahel), while the equations during lactation were: $UW = 1.2 + 9.5X – 0.2X^2 – 3.5\log X – 11.6 (\log X)^2$, $R^2 = 0.90$ (for WAD); $UW = 4.2 + 7.6X – 0.2X^2 – 4.4\log X – 8.6(\log X)^2$, $R^2 = 0.97$ (for RS) and $UW = 4.6 + 8.5X – 0.2X^2 – 5.0\log X – 9.2(\log X)^2$, $R^2 = 0.95$ (for Sahel). During pregnancy, data from Red Sokoto does were best fitted by the linear, quadratic and exponential equations ($R^2 = 0.82$), the R^2 value being 1% higher than that of WAD and Sahel does. During lactation, data from Sahel does were best fitted by the Wood's, modified Wood's, inverse polynomial regression and polynomial regression equations ($R^2 = 0.92$) with 13% and 1% higher R^2 values than WAD and RS respectively. In essence, UC and UW could preferably describe the pattern of udder growth during pregnancy and lactation respectively, while quadratic and polynomial regression equations could be used preferably to model the pattern of udder growth during pregnancy and lactation respectively.

Key words: Model, udder growth, pregnancy, lactation, goats

INTRODUCTION

Udder growth is a complex process, which is characterized by mammary cell hyperplasia during gestation and early lactation; cell hypertrophy during late lactation and cell death during declining lactation (Knight and Wilde, 1993). Udder growth, which results from increase in udder dimensions in goats, has been described by several indices (Anderson, 1974). Most researchers adjudged deoxyribonucleic acid (DNA) to be the best parameter for assessing udder growth, though other measurements including untrimmed and trimmed wet weights of udder, dried fat-free tissue weights, ribonucleic acid contents by

Anderson *et al.* (1981) and udder dimensions by James and Osinowo (2004a) have been determined. Early studies on the pattern of udder growth in goats relied greatly on empirical approach involving multiple comparisons of means rather than using regression models that contain linear, quadratic, cubic, exponential and logarithm terms (Anderson and Wahab, 1990). However, in recent times, attention has shifted to the use of regression analyses, which give better physiological meaning to, and interpretation of parameters generated. In this study, udder dimensions consisting of udder length (UL), udder width (UW) and udder circumference (UC) were assessed as descriptors of the pattern of udder growth in goats, involving testing of linear, quadratic and exponential regression equations (during pregnancy) and Wood's, modified Wood's, inverse polynomial and polynomial regression equations (during lactation). The objective of this research was to determine the udder measurement which best describes the pattern of udder growth, the regression equation which best fits the data and the breed of goat whose data is best fitted by the equations during pregnancy and lactation.

MATERIALS AND METHODS

Location of study, animal management and experimental procedure

The study was carried out at the goat unit of the livestock farms of the University of Agriculture, Abeokuta, Southwestern Nigeria. The climate is humid with a mean annual rainfall of 1037 mm. The annual mean temperature and humidity were 34.7^0C and 82%, respectively. Sixteen does comprising ten West African Dwarf (WAD), three Red Sokoto (RS) and three Sahel goats weighing 13.4 – 24.1 kg were used for the study. They were managed semi-intensively. The udder dimensions; udder length (UL), udder width (UW) and udder circumference (UC) were measured with a flexible canvas tape-rule as described by James and Osinowo (2004b) prior to conception (3 months) and during pregnancy. During lactation udder dimensions were measured weekly for 12 weeks commencing from 4 days *post partum* before suckling by kids. The frequency of data collection was monthly prior to conception and during pregnancy.

Data analysis

The monthly data generated prior to conception and during pregnancy were plotted in a graph and values read-off for day of conception (day 0), 50, 100 and 150 days of gestation. A gestation length of 150 days was assumed, enabling the retroactive determination of conception day given the day of parturition. In order to obtain the least squares means, the data was analysed by methods of least-squares (SYSTAT, 1992) using the model:

$Y_{ijk} = m + B_i + D_j + B*D_{ij} + \varepsilon_{ijk}$

where,

Y_{ijk} = The value of udder growth descriptor
m = The overall mean of udder growth descriptor
B_i = The fixed effect of i^{th} breed (i = 1-3)
D_j = The fixed effect of j^{th} day of gestation; week of lactation (j = 1-4; 1-12)
$B*D_{ij}$ = The interaction between breed and day of gestation; week of lactation
ε_{ijk} = Random error associated with each record

Modeling the pattern of udder growth

The UL, UW, and UC were modeled using regression equations thus enabling description of the pattern of udder growth of Nigerian breeds of goats during pregnancy and lactation. The regression equations are presented in Table 1. The regression analyses were carried out by imputation of the regression equations into linear and non-linear regression modules of SYSTAT (1992) for the generation of parameters needed for evaluating their fitness on the data. The module was set at 100 iterations and simplex method was adopted which calculated the loss function at different points until the minimum is reached before generating the parameters.

RESULTS AND DISCUSSION

Linear, quadratic and exponential equations modeling the pattern of udder growth of WAD, RS and Sahel goats during pregnancy are presented in Table 2. Generally udder circumference (UC) proved to be the best descriptor of udder growth during pregnancy and this was evidenced by its higher R^2 values (Table 2). This is so because the general increase in UC is as a result of increase in UW and also since both udder dimensions were positively correlated (James, 2000). Table 2 shows that the quadratic equations best fitted data from all udder growth descriptors measured in the three Nigerian goat breeds during pregnancy. This shows that the pattern of udder growth during pregnancy is non-linear. This is because growth rates of udder during pregnancy differ significantly with stage of gestation. Slight and exponential increases in udder dimensions during the first and last trimesters of pregnancy have been reported by James and Osinowo (2004a). Hurley (2006) reported that the rate of mammary growth during peripartum was higher than the rate during early and mid pregnancy. He attributed it to extensive lobuloalveolar development leading to rapid increase in the size of udder. Table 3 shows that the polynomial regression equations best fitted data from all udder growth descriptors measured in the three Nigerian goat breeds during lactation as observed during pregnancy. This shows that the pattern of udder growth is non-linear during lactation as well. This is because growth rates of udder during lactation differ significantly with stage of lactation. James (2000) reported positive increases in udder dimensions (positive growth) and decreases in udder dimensions (negative growth) during early and mid-late stage of lactation, respectively. Similar trend was observed during lactation by Knight and Peaker (1984). The observation could be attributed to continual increase in secretory cell number and activity in early lactation resulting to increased mass of mammary tissue for lactogenesis and galactopoiesis and winding down of activity resulting from reduced number of mammary cells in mid and late lactation (Hurley, 2006). The superiority of both non-linear equations to linear equation used in this study is expected because most data on growth in animal sciences follow allometry pattern of growth which is non-linear. The observation that the quadratic and polynomial regression equations best fitted data from all udder growth descriptors measured in the three breeds during pregnancy and lactation, respectively, differs from the reports of Anderson *et al.* (1981) in goats during pregnancy. The disparity could be as a result of different breeds of goats used in the studies, with different mammary growth rates. While in this study, tropical

non-dairy goats were used, Anderson *et al.* (1981) made use of major temperate dairy breeds. The nature and type of udder growth descriptor used could also be implicated on this. In this study, measurement of udder dimensions (udder growth descriptors) were employed whereas trimmed wet weight of udder, dried fat-free tissue weight of udder, total DNA and RNA content of udder were used by the latter authors. It is expected that there will be some variations in the result generated since growth rates of different cells; tissues and organs differ (Anderson *et al.*, 1981; Dijkstra *et al.*, 1997). The observation corroborates the findings of James and Osinowo (2004b) who selected UC as the best measure of udder size during pregnancy in goats. Although, UW was superior to UC in describing the pattern of udder growth in the three breeds of goats during lactation (Table 3), they do not differ significantly ($P>0.05$) from each other, and more so, both parameters exhibited high positive correlation (James, 2000). The pattern of udder growth during pregnancy and lactation was better described in RS goats using linear, quadratic and exponential regression equations but during lactation, it was best described by Sahel goats using Wood's, modified Wood's, inverse polynomial regression and polynomial regression equations (Tables 2 and 3; Figure 1-6). This is expected since different goat breeds exhibit different udder growth rates (Anderson *et al.*, 1981; Dijkstra *et al.*, 1997) and different rates of increase in udder dimensions (Amao, 1999; James, 2000; James and Osinowo, 2004a).

CONCLUSION

The parameters, UC and UW were the best descriptors of the pattern of udder growth in WAD, RS and Sahel goats during pregnancy and lactation, respectively.

The quadratic and polynomial regression equations best fitted data from the three breeds of goats during pregnancy and lactation, respectively.

The pattern of udder growth during pregnancy was better described in RS goats but during lactation, it was best described in Sahel goats using quadratic and polynomial regression equations, respectively, considering the pattern of growth in animal growth studies.

Table1. Regression equations for modeling pattern of increases in udder dimensions during pregnancy and lactation in West African Dwarf, Red Sokoto and Sahel goats

FUNCTION	MODEL	MODEL DEFINITION	REFERENCE
Pregnancy			Anderson et al.(1981)
Linear	$Y = a + bX$	Y = Udder growth descriptor of interest a,b = Constants (parameters) X = Day of gestation	
Quadratic	$Y = a + bX + cX^2$	Y = Udder growth decriptor of interest a,b,c = Constants(parameters) X = Day of gestation	Anderson et al.(1981)
Exponential	$Y = AebX$	Y = Udder growth descriptor of interest A,b = Constants(parameters) e = Base of natural logarithm X = Day of gestation	Anderson et al.(1981)
Lactation			
Wood's	$Y = Axbe\text{-}cx$	Y = Udder growth descriptor of interest A,b,c = Constants(parameters) e = Base of natural logarithm X = Week of lactation	Wood (1967)
Modified Wood's	$Y = Axbe\text{-}x(c + dx)$	Y = Udder growth descriptor of interest A,b,c,d = Constants(parameters) e = Base of natural logarithm X = Week of lactation	Gipson and Grossman (1990)
Inverse polynomial	$Y = X/a + bX + cX^2$	Y = Udder growth descriptor of interest A,b,c, = Constants(parameters) X = Week of lactation	Nelder (1966)
Polynomial regression	$Y = a + bX + cX^2 + d\log X + e\,(\log X)^2$	Y = Udder growth descriptor of interest a,b,c,d,e = Constants(parameters) X = Week of lactation	Ali and Schaeffer (1987)

ISSN 1595—9694 © UNAAB 2003

Table 2. Linear, quadratic and exponential regression equations modeling pattern of udder growth in West African Dwarf, Red Sokoto and Sahel goats during pregnancy and their R^2 values.

FUNCTION	BREEDS OF GOATS						
	WEST AFRICAN DWARF	R^2	RED SOKOTO	R^2	SAHEL	R^2	Overall Means
LINEAR	UL = 6.6 + 0.023X	0.69	UL = 12.0 + 0.018X	0.77	UL = 13.6+ 0.018X	0.69	
	UW = 6.2 + 0.022X	0.71	UW = 6.2 + 0.022X	0.72	UW = 8.0 + 0.023X	0.72	
	UC = 20.7 + 0.043X	0.73	UC = 25.1 + 0.047X	0.73	UC = 32.0 + 0.034X	0.75	
Means		0.71		0.74		0.72	0.72
QUADRATIC	UL = 12.5 – 0.0240X + 0.0003X^2	0.95	UL = 12.5 – 0.010X + 0.0002X^2	0.96	UL = 14.3 – 0.0200X + 0.0003X^2	0.96	
	UW = 6.9 – 0.0211X + 0.0028X^2	0.95	UW = 8.2 – 0.0191X + 0.0026X^2	0.95	UW = 8.8 – 0.0225X + 0.0030X^2	0.97	
	UC = 22.0 – 0.0384X + 0.0005X^2	0.97	UC = 26.5 – 0.0402X + 0.0006X^2	0.96	UC = 33.1– 0.0286X + 0.0004X^2	0.98	
Means		0.96		0.96		0.97	0.96
EXPONENTIAL	UL = 6.5e0.0029X	0.74	UL = 12.0e0.0014X	0.79	UL = 13.6e0.0012X	0.71	
	UW = 6.1e0.0029X	0.76	UW = 7.5e0.0024X	0.76	UW = 8.0e0.0025X	0.76	
	UC = 20.6e0.0018X	0.77	UC = 25.0e0.0018X	0.76	UC = 32.0e0.0010X	0.77	
Means		0.76		0.77		0.75	0.76
Overall means		0.81		0.82		0.81	

ISSN 1595—9694 © UNAAB 2003

Table 3. Wood's, modified Wood's, inverse polynomial regression and polynomial regression equations modeling pattern of udder growth in West African Dwarf, Red Sokoto and Sahel goats during lactation and their R^2 values.

FUNCTION	BREEDS OF GOATS						
	WEST AFRICAN DWARF	R^2	RED SOKOTO	R^2	SAHEL	R^2	Overall Means
WOOD'S	UL = 12.3X-0.13e-0.007X	0.75	UL = 15.9X-0.13e-0.006X	0.87	UL = 18.9X0.01e0.021X	0.94	
	UW = 11.4X-0.12e-0.012X	0.73	UW = 12.2X-0.14e-0.009X	0.90	UW = 13.4X-0.12e-0.006X	0.88	
	UC = 30.4X-0.05e-0.005X	0.76	UC = 36.9X-0.08e-0.012X	0.91	UC = 41.2X-0.12e-0.004X	0.90	
Means		0.75		0.89		0.91	0.85
MODIFIED WOOD'S	UL = 13.6X0.73e-X(0.363 - 0.015X)	0.77	UL = 17.0X0.02e-X(0.072 - 0.004X)	0.91	UL = 19.4X0.08e-X(0.055 - 0.002X)	0.99	
	UW = 12.6X-0.02e-X(0.063 - 0.003X)	0.76	UW = 53.1X0.065e-X(0.123 - 0.006X)	0.92	UW = 10.5X-0.04e-X(-0.507 + 0.003X)	0.60	
	UC = 25.5X1.63e-X(0.52 + 0.002X)	0.66	UC = 39.6X0.09e-X(0.104 –0.004X)	0.94	UC = 45.2X0.12e-X(0.125 - 0.006X)	0.95	
Means		0.73		0.92		0.88	0.84
INVERSE POLYNOMIAL	UL = $X/(-0.006 + 0.087X + 0.003X^2)$	0.73	UL = $X/(-0.009 + 0.072X + 0.001X^2)$	0.83	UL = $X/(-0.002 + 0.051X + 0.001X^2)$	0.94	
	UW = $X/(-0.003 + 0.091X + 0.004X^2)$	0.72	UW = $X/(-0.010 + 0.091X + 0.004X^2)$	0.88	UW = $X/(-0.009 + 0.083X + 0.002X^2)$	0.86	
	UC = $X/(-0.001 + 0.034X + 0.004X^2)$	0.75	UC = $X/(-0.001 + 0.029X + 0.001X^2)$	0.90	UC = $X/(-0.002 + 0.026X + 0.001X^2)$	0.87	
Means		0.73		0.87		0.89	0.83
POLYNOMIAL REGRESSION	UL = 2.7 – 8.9X – 0.1X2 – 3.3LogX – $10.9(LogX)^2$	0.91	UL = 7.3 + 8.5X – 0.2X2 – 5.1LogX – $9.3(LogX)^2$	0.96	UL = 15.5 + 2.8X – $0.1X^2$ – 0.5LogX – 3.8 $(LogX)^2$	1.00	
		0.90		0.97		0.95	
	UW = 1.2 + 9.5X – 0.2X2 – 3.5LogX – $11.6(LogX)^2$	0.86	UW = 4.2 + 7.6X – 0.2X2 – 4.4LogX – $8.6(LogX)^2$	0.98	UW = 4.6 + 8.5X – $0.2X^2$ – 5.0LogX – 9.2 $(LogX)^2$	0.98	
	UC = 21.0 + 8.9X – 0.2X2 – 3.8LogX –$10.5(LogX)^2$		UC = 15.4 + 0.2X – 0.5X2 – 0.1LogX – $23.0(LogX)^2$		UC = 24.7 + 0.2X – $0.3X^2$ – 7.3LogX – 19.1 $(LogX)^2$		
Means		0.89		0.97		0.98	0.95
OVERALL MEANS		0.78		0.91		0.92	

ISSN 1595—9694 © UNAAB 2003

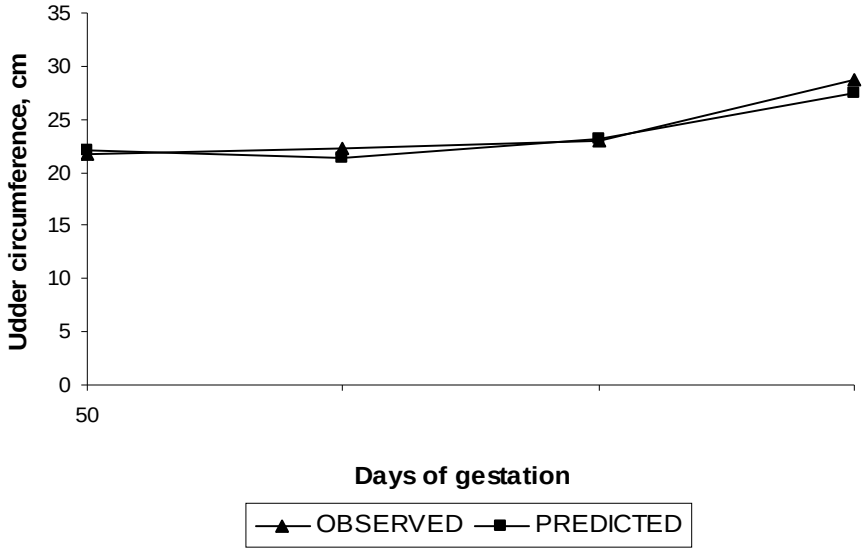

Fig. 1. Observed and predicted values of udder growth descriptor (udder circumference) in West African Dwarf goats during pregnancy.

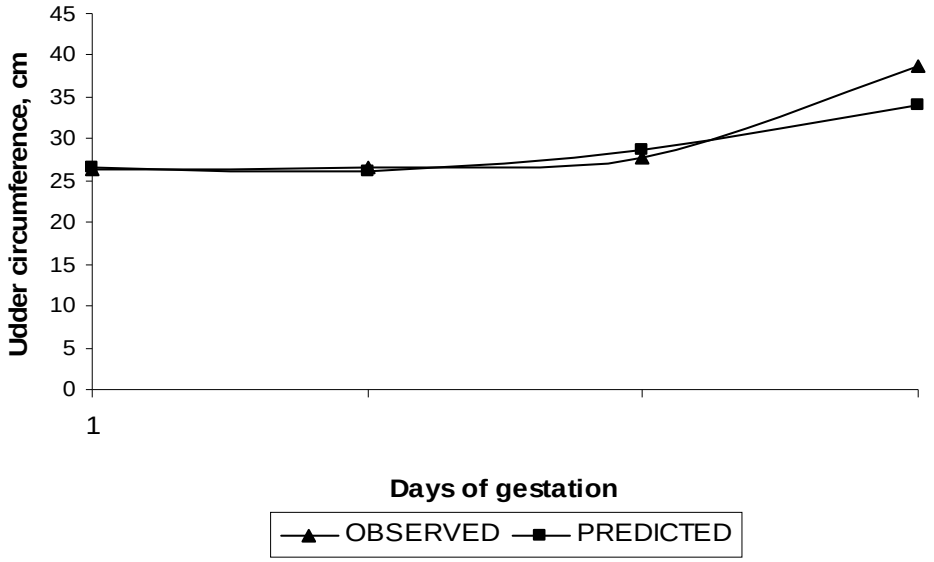

Fig. 2. Observed and predicted values of udder growth descriptor (udder circumference) in Red Sokoto goats during pregnancy.

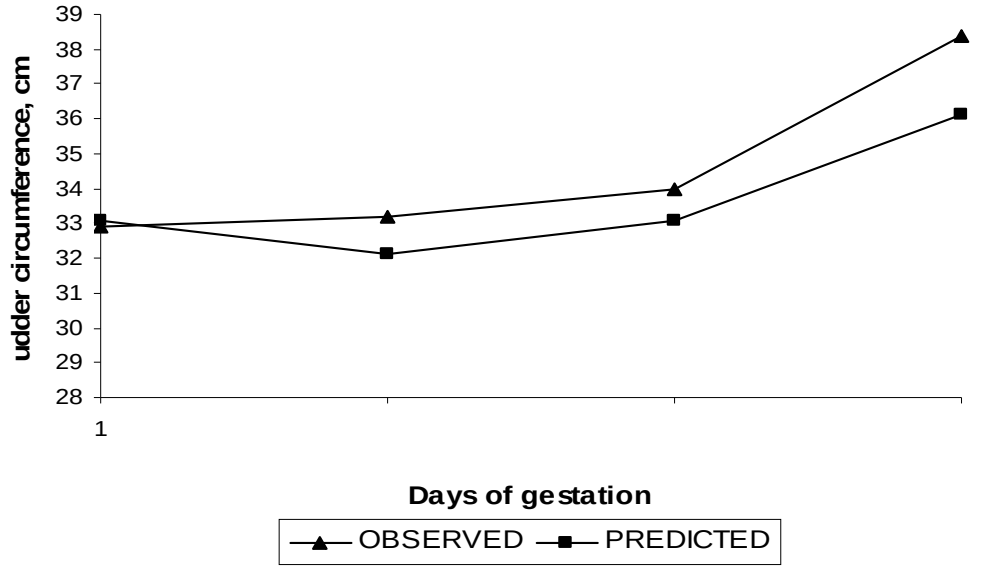

Fig. 3. Observed and predicted values of udder growth descriptor (udder circumference) in Sahel goats during pregnancy.

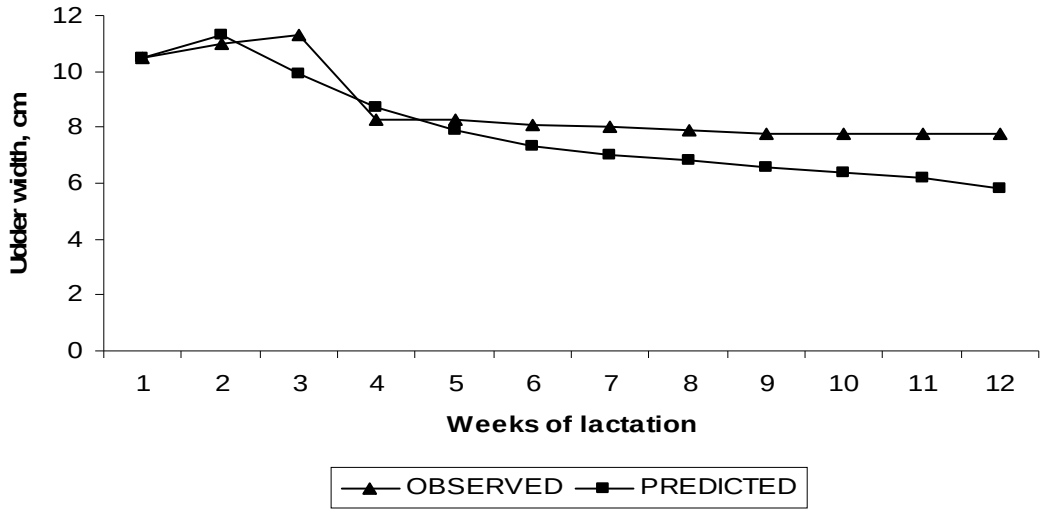

Fig. **4. Observed and predicted values of udder growth descriptor (udder width) in West African Dwarf goats during lactation**.

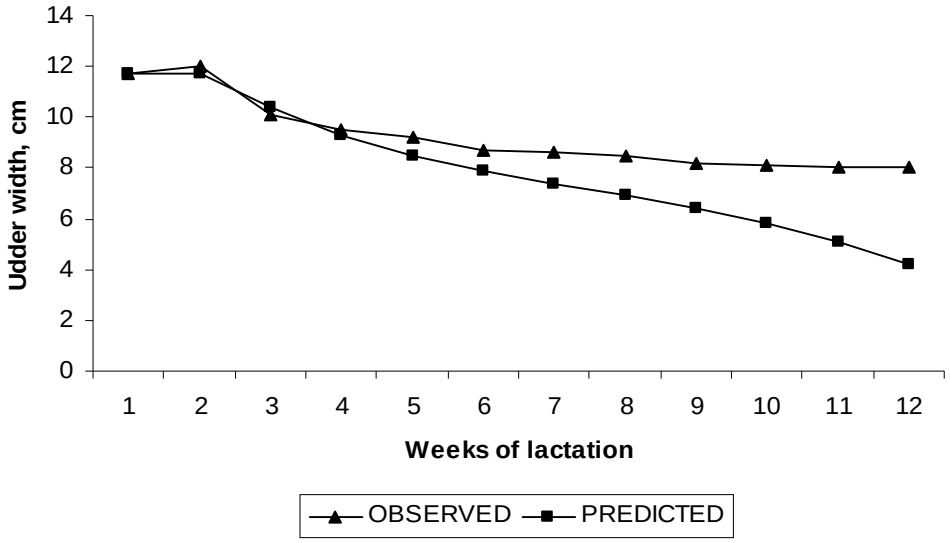

Fig. 5. Observed and predicted values of udder growth descriptor (udder width) in Red Sokoto goats during lactation.

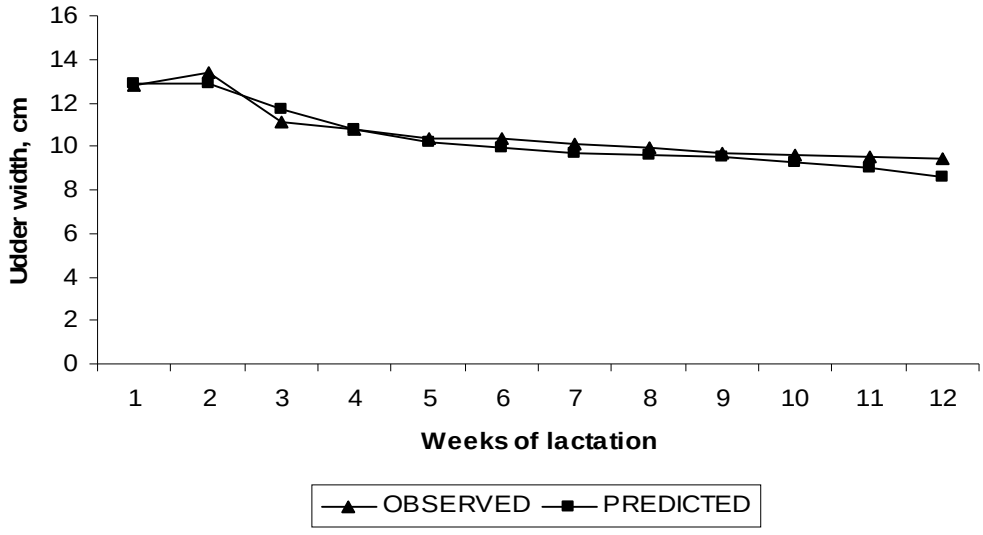

Fig. 6. Observed and predicted values of udder growth descriptor (udder width) in Sahel goats during lactation.

REFERENCES

Ali, Y. E.; Schaeffer, L. R. 1987. Accounting for covariances among test-day milk yields in dairy cows. *Can. J. Anim. Sci.,* 67: 637-644.

Amao, O.A. 1999. Evaluation of udder traits in West African Dwarf and Red Sokoto goats. *M. Agric. Dissertation.* Department of Animal Production and Health, University of Agriculture, Abeokuta, Nigeria.

Anderson, R.R. 1974. *Endocrinal control.* Page 97 in lactation: A comprehensive treatise. Vol. 1. Larson, B. and Smith, V., ed. Academic Press Inc., New York, NY.

Anderson, R.R., Harness, J.R., Snead, A.F.; Salah, M.S. 1981. Mammary growth pattern in goats during pregnancy and lactation. *J. Dairy Sci.* 64: 427 - 432.

Anderson, R.R., Wahab, I.M. 1990. Changes in parenchyma and stroma of goatudders during pregnancy, lactation and involution. *Small Ruminant Res.* 3: 605.

Dijkstra, J., France, J., Dhanoe, M.S., Maas, J.A., Hanigan, M.D., Rook, A.J.; Beever, D.E. 1997. A model to describe growth patterns of the mammary gland during pregnancy and lactation. *J. Dairy Sci.* 80: 2340 - 2354.

Gipson, T.A.; Grossman, M. 1990. Lactation curves in dairy goats: a review. *Small Rumin.* Res.3: 383 - 396.

Hurley, W.L. 2006. Mammary gland growth and development. http// classes.aces.uiuc.edu/AnSci308/lactation/ mammary gland growth and development.

James, I.J. 2000. Changes in udder traits of West African Dwarf, Red Sokoto and Sahel goats during pregnancy and lactation and their effects on partial daily milk yield. *M. Agric. Dissertation.* Department of Animal Production and Health, University of Agriculture, Abeokuta, Nigeria.

James, I. J., Osinowo, O.A. 2004a. Changes in udder size and liveweight of West African Dwarf, Red Sokoto and Sahel goats during lactation and their phenotypic relationship with partial daily milk yield. *Nig. J. Anim. Prod.,* 31(1): 119-129.

James, I. J., Osinowo, O.A. 2004b. Relationship between udder measurements during pregnancy and partial daily milk yield in goats. *Nig. J. Anim. Prod.,* 31(2): 252-262.

Knight, C.H., Peaker, M. 1984. Mammary development and regression during lactation in goats in relation to milk secretion. *Q. J. Exp. Physiol.* 69: 331.

Knight, C.H. Wilde, C.J. 1993. Mammary cell changes during pregnancy and lactation. *Livestock Prod. Sci.* 35: 3 - 19.]

Nelder, J.A. 1966. Inverse polynomials, a useful group of multi-factor response functions. *Biometrics.* 22: 128 - 141.

SYSTAT, 1992. Systat Computer Package, version 5.02. Systat, Inc. 1800 Sherman Ave., Evanston, IL USA, 6021, 708.864.5670.

Wood, P.D.P. 1967. Algebraic model of the lactation curve in cattle. *Nature* 216:164-165.