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Description of growth curve by non-linear function and prediction of weaning weight from milk production and composition in Turkish Awassi sheep

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Abstract
The aim of study to prediction for growth lambs after birth from milk production and composition by multiple formats for description of growth curve after birth non-linear regression in Turkish Awassi sheep for production season 2022-2023. The study was carried out the ruminant research station of the General Commit for Agricultural Research / Ministry of Agriculture (20 km west of Baghdad). The results showed a significant regression ($p \leq 0.05$) of the weaning weight of the lambs on the daily milk yield rate (kg) of 19.537 + 1.502, with a coefficient of determination of 0.21. Weight at weaning decreased significantly ($p \leq 0.05$) on the percentage of fat and non-fat solids (%) 0.466 and 0.794, and the value of (R2) was 0.13 and 0.16. The regression coefficient for the weight gain between birth and weaning of the lambs on daily milk production was significant, as its coefficient reached 0.981 kg, and the regression of the weight gain between birth and weaning on the percentage of lactose, protein, and non-fatty solids was significant, as its coefficients reached 0.285, 0.253, 0.703, respectively. Not significant on the percentage of fat. The regression coefficient of weight gain between birth and weaning of lambs on their dams daily milk production was significant ($p \leq 0.05$), as its coefficient reached 0.981 kg. The regression of weaning weight on birth weight was positive and significant, reaching 0.282 kg, with a coefficient of determination of 0.26. While the regression of the rate of weight gain from birth to weaning on birth weight was positive and highly significant, as its coefficient reached 0.307 and the coefficient of determination (R2) was 0.39, while the regression of weight at weaning (WWT) on the dams weight at birth (DWT) was not significant. The coefficient of determination (R2) for weight at weaning and weight gain from birth to weaning was 0.62 and 0.71, respectively.

Keywords: Growth curve function and prediction milk production Turkish Awassi sheep

Introduction
Animal production generally depends on raising livestock (cows, sheep, goats, camels) and also raising, improving and producing poultry and fish to provide basic materials for human nutrition (red and white meat, milk and its derivatives, and table eggs) in addition to secondary products such as wool, leather, etc. (Haenlein, 2007) [6]. Awassi sheep are also characterized by high-quality red meat and milk production rates, their ability to adapt to environmental conditions and lack of pastures, and their high ability to respond to genetic improvement programs (Elia, 2018) [2]. Milk production in ewes is considered one of the most important factors in the growth of lambs from birth to weaning, because they depend on it at this critical stage, and their growth and survival are important in the first three weeks of their lives. (Daltro. *et al*. 2021) [3] The appearan of differences between the weights of lambs begins in the first two weeks after birth. (Supakorn *et al*. 2014) [12] indicated that milk production and its components are affected by the most important genetic factors (breed) and some non-genetic factors (year of production, month of birth, environmental factor (temperature, health and nutritional status, age of the mother ewe, her health condition, type of birth, sex of her offspring, management and care systems followed, as well as the genetic makeup (Generated from mothers and fathers selected on the basis of their high milk production) has an important influence on the growth of lambs and their early arrival at the production stage, Lupi *et al*. (2015) [9]. indicated that Describing growth curves is necessary to determine the expected weight or rate of weight gain from birth to maturity.

The study of growth curves is necessary when developing plans and methods of breeding and management in small ruminant farms, as they demonstrate a specific behavior of the studied genotypes in increasing live weight as the animal ages to ensure the best production. Growth curves stand out as one of the important expressions of the relationships existing between different stages of life. Animals, by using specific statistical forms to explain underlying biological phenomena to varying degrees and developing an educational and administrative work map to improve animal productivity and improve local breeds. The Brody model is one of the most widely used statistical standards in interpreting the shape of the growth curve, through which the value of the coefficient of determination (R^2) is adopted. At high levels, we obtain an equation that enables us to predict the weight of newborns in advanced stages of life, since this model is the easiest to interpret data, and then we can plan and select animals by describing their growth curve and help determine the best date for marketing males. A number of researchers have used different models to estimate the weight of body (Kopuzlu *et al*., 2014) [8]. The regression coefficient is defined as the amount of change for any dependent variable when the independent variable changes by one unit. Thus, it is used to determine the true relationship between two variables with the aim of putting this relationship in the form of an equation with different functions (simple or multiple - linear or non-linear) while monitoring the values of the coefficient of determination (R2). For the purpose of prediction and application in selection programs and appropriate decision-making, the application of non-linear functions is carried out according to several models, the most important of which are Brody, von Bertalanffy.

The aim of study predict the growth of lambs after birth through milk production and composition, and to use multiple formulas to describe the postpartum growth curve with non-linear functions in Turkish sheep.

Materials and Methods

The study was conducted at the Ruminant Research Station of the Agricultural Research Department/Ministry of Agriculture located in Abu Ghraib (20 km west of Baghdad), for the 2022-2023 production season, and a sample of 50 Turkish Awassi lambs anddam.

Sheep are raised in semi-open pens (35% covered and 65% open) designated for their shelter. The area of the pen is (75 m²) Giving birth goats are placed in special birth pens with an area of (75 m²) The first after birth, and the newborn continues to be breastfed until weaning (120 days).The herd is managed according to a program that includes nutrition, preparation for the season, preparations for the pregnancy and birth stages, as well as health and veterinary care. Goats are fed depending on their productive condition, depending on the seasons, and according to the availability of fodder. Green fodder or coarse fodder, represented by alfaalfa, is also provided. As for feeding newborns, they are left with their mothers until weaning (120 days), and after weaning, they are given free range of concentrated feed and coarse feed.

The daily milk yield of each certified ewe was measured using a graduated cylinder, twice a month for the first three months of the productive season, as the newborns were isolated from the mothers in the evening and then milked early in the morning.

Analysis of milk components

Analysis of milk components was conducted twice for each ewe during the three months. A sample of the milk was taken after weighing the milk and mixing it well in clean plastic containers of 50 ml capacity with tight lids. They were closed after taking the sample and transported cooled to a laboratory for the purpose of examining the milk components analysis by device called Julie-Z7. the components that were measured included the percentage of protein, fat, lactose and non-fatty solids.

Statistical analysis

The data were analyzed statistically using the program Statistical Analysis System -SAS (2018) to study the regression of each growth characteristic and the calculated evidence on milk production and its components, extract prediction equations, and apply exponential equations to characterize the growth curve, as the growth curves were described according to exponential equations. The following - Nonlinear regression models (Gautam *et al*., 2019) [4].

The first equation (Brody Equation)

$$Wt = A * (1 - B * (-K * t)$$

The second logistical equation

$$Wt = A/(1 + B * e(-K * t)$$

Wt: live weight at a certain age.
A: Age at maturity weight prediction.
B: Turning point with growth as a value at time zero (t=0).
e: natural logarithm of weight at primary age.
K: Growth rate between starting weight and age-specific weight at prediction.
t: the time or age when the weight for age is recorded when forecasting

And expressing the relationships between weights with curves according to Linear, Quadratic, and Cubic formulas.

As well as applying the following exponential equations according to simple non-linear regression analysis, while calculating and recording the coefficient of determination (R2)

Regression of weaning weight (WWT) on birth weight (BWT)

WWT^ =a +bBW

Regression of weaning weight (WWT) on dam birth weight (DWT).

WWT6^ =a +bDW

Results and Discussion

The results of Table 1 indicate that there is a significant regression ($p \leq 0.05$) of the weight at weaning of the lambs on the daily milk production rate (kg) of the ewes, as its coefficient reached 1.502 kg. This is evidence that the weaning weight increases by a rate of 1.502 kg with an increase in the daily milk production rate of 1 kg per day. The Coefficient of Determination (R2) was 0.21, which means the milk production of the ewes gives 0.21 of the weaning weight of the lambs. The results of Sultan and Mohammed (2019) [11] indicated that ewes with higher weights and more milk production have higher weaning weights for their lambs. It was similar to the results of Al-Dabbagh (2019) [1], and the results of Table 1 showed that the weight at weaning decreased significantly ($p \leq 0.05$) on the percentage of fat and non-fat solids (%) 0.466 and 0.794, and the value of (R2) was 0.13 and 0.16, while the regression of weaning weight on the percentages of lactose and protein are non-significant.

Table 1: Prediction of weaning weight (kg) in lambs based on daily milk production and milk components

Traits of Dam	Regression(b)	(Prediction equation)	Significant	Squared (R^2)
daily milk (Kg)	1.502	Y^= 19.537 +1.502X	*	0.21
Fat (%)	466.0-	Y^= 18.944-0.466X	*	0.13
Lactose (%)	0.207-	Y^= 18.817 -0.207X	NS	0.04
Protein (%)	0.374	Y^= 20.155 -0.329X	NS	0.11
non-fat solids(%)	0.794	Y^= 19.81 +0.794	*	0.16
(*$p \leq 0.05$, NS)				

We also note from Table 2 that the regression coefficient of weight gain between birth and weaning of lambs on their mothers' daily milk production was significant ($p \leq 0.05$), as its coefficient reached 0.981 kg/kg, as early weight gain reflects the health, vitality and activity of the lambs, especially during their receipt of sufficient quantities. of milk, thus achieving important weights later. These results were similar to the findings of Haile *et al* (2020) [7]. The regression of weight gain between birth and weaning on the percentage of lactose, protein, and non-fat solids was significant, as their coefficients reached 0.285, 0.253, and 0.703, respectively, and the regression was not significant on the percentage of fat.

Table 2: Prediction of weight gain for birth at weaning (kg) in lambs during daily milk production and milk composition

Traits of Dam	Regression(b)	(Prediction equation)	Significant	squared (R^2)
Daily milk(Kg)	0.981	Y^= 14.95 +0.981X	*	0.12
Fat (%)	0.077	Y^= 15.78 +0.077X	NS	0.04
Lactose (%)	0.285	Y^= 14.63 +0.285X	*	0.15
Protein(%)	0.253	Y^= 14.02 +0.253X	*	0.12
Non-fat solids (%)	0.703	Y^= 15.87 +0.703X	*	0.12
*($p \leq 0.05$), NS.				

The results of Table 3 indicated that some exponential equations were applied according to a simple non-linear regression analysis with the calculation and recording of the coefficient of determination (R2) for growth in Awassi lambs. It was found that the regression of weaning weight on birth weight according to the formula WWT^ =a +bBW is positive and significant, reaching 0.282 kg with a coefficient of determination of 0.26. While the regression of the rate of weight gain from birth to weaning on birth weight was positive and significant, as its coefficient reached 0.307 and the coefficient of determination (R2) was 0.39, while the regression of weight at weaning (WWT) on the mother's weight at birth (DWT) was not significant according to the formula WWT6^ =a +bDW significantly. Thus, evaluating and predicting weaning weight is appropriate, especially at six months of birth weight, as this age is considered appropriate for marketing lambs.

Table 3: Characterization of the growth curves of lambs using exponential equations

Regression Traits (|Kg)	Regression(b)	(Prediction equation)	Significant	Squared (R^2)
Weaning weight/Birth weight	0.282	$Y^\wedge= 19.77 + 0.282\ BWT^2$	*	0.26
Weight gain for birth to Weaning /Birth weight	0.307	$Y^\wedge= 13.96 + 0.307\ BWT^2$	*	0.39
Weight at weaning/Dam weight at birth	0.114	$Y^\wedge=18.03 + 0.114\ WWT^2$	NS	0.10
* ($p \leq 0.05$).Ns. Non significant				

Table 4 shows that the expected weights of the lambs at weaning (weaning weight was predicted from the mother's weight at birth) and at weaning and at the age of six months, which are close to the total real weights of Awassi sheep through the application of the Brody Equation and Logistic Equation functions, and this result reflects the validity of the function. Brody Equation in the first place and the Logistic Equation function in the second degree to predict the weights of lambs at weaning or at six months of age, with the possibility of applying it to yearling age and perhaps beyond that. The coefficient of determination (R2) for weight at weaning and weight gain from birth to weaning reached 0.62 and 0.71, respectively, when applying the Brody Equation, while the coefficient reached 0.54 and 0.66 for the two traits when applying the Logistic Equation to symmetry. Studying nonlinear models in characterizing the growth curve is very important for the purpose of selection for growth and effective use of local genetic resources.

Table 4: Real mean and expected weights from birth to 6 months of age for lambs

Traits	S.E ± Real mean	SE ± Mean expected	
		Brody Equation	Logistic Equation
Weaning weight	0.51±19.37	0.44±19.02	0.47±20.27
Squared (R^2)	-	0.62	0.54
weight gain during lactation	0.35±14.63	0.31±13.91	0.48±14.83
Squared (R^2)	-	0.71	0.66

Conclusion

It can be concluded from the results that ewes with high weights and high daily and total milk yield, and by constantly breastfeeding their lambs, have high birth and weaning weights and weight gain by predicting exponential equations according to simple non-linear regression analysis with the calculation and recording of the coefficient of determination (R2). Studying nonlinear models to characterize the growth curve is very important for the purpose of selection for growth and effective use of local genetic resources, thus achieving an important genetic and economic return.

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