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Growth Model Adjustment of Local Goat Population under Pastoral Conditions in Tunisian Arid Zone

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Abstract: Kids weights recorded from eight indigenous goatherds raised under arid pastoral conditions were used to characterise kid's growth curve. Among twelve tested non-linear models, Gompertz function permitted the best kids growth curve fitting by its convergence rapidity and estimation accuracy. Models iterative behaviour were tested by the iterations number, the Coefficient of Determination (CD) and the Residuals Means Squares (RMS). Convergence was reached after 9 iterations at a CD equal to 67%. Indigenous kids weighed 2.41 kg at birth and reached 16.18 kg in 8 months of age with a wide individual variation. Kid's growth showed stagnation at the summer beginning, due to climate stress and forage scarcity. During the first 4 months of age, the daily weight gain reached 102 g/day as a maximum average and then, decreased to less than 25 g/day. About 80% of asymptotic weight was reached since the 4 months of kid's age. Kid's early separation from pastoral herds was recommended to reduce land degradation and to allow better reproduction performances. The indigenous kid's growth process illustrates the adaptation of the population with the arid environment under natural harsh conditions. Small body size and low weights mean fewer requirements and may permit to reach rapidly the physiological maturity needed to start the reproduction process despite of the constraining arid conditions.

Key words: Arid environment, growth curve, indigenous population, kid weight, Tunisia

INTRODUCTION

Traditionally, local goat population valorizes the arid Tunisian region scarce resources under the harsh climate of arid zone. The lactated kid's meat is the main product for this breeding mode and contributes with about 75% of the regional meat production (Najari, 2003, 2005).

The productive behaviour of indigenous population illustrates its adaptation towards the specific natural and technical production factors (Ademosum *et al*., 1985; Steinbach, 1989). Especially the productive trait, must synthesize all animal group capacities needed either to profit from resources and also, to prevent negative impacts of production constraints and stress (Ba Diao *et al*., 1994). So, the growth model assessment is of particular importance due to its practical implications in genetic evaluation and organizing herd management (Gipson and Wildeus, 1994; Leclercq and Beaumont, 2000; Schinckel and De Lange, 1996). Uunderstanding growth curve of the indigenous population kid's permits to characterize the animal group and to reduce production cost through optimizing resources use (De Lange *et al*., 1998; Schinckel and Craig, 2001). For our special breeding system, the kid's growth exploration contributes to avoid excessive land degradation under arid conditions regarding the decertification risks.

During animal lifetime, the essential weight gaining is obtained before the maturity stage (Gille, 1989; Gipson *et al*., 1996). It's well known that animals achieve the target mature size in a well-defined manner known as sigmoid or S-shaped curve (Laird *et al*., 1965). This has led to use typical curves to describe animal growth due to the general predictable pattern followed by the growth process (Barbato, 1991; Bathaei and Leroy, 1996; De Lange *et al*., 1998; Sparre and Siebren, 1998).

The present study aims at characterizing the growth curve of local population kids raised under arid rangeland conditions of southern Tunisia. Such characterization may lead to optimize herd's management and to prevent therefore excessive land degradation.

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MATERIALS AND METHODS

Study zone: Data were collected from the arid region of Tunisia as ecologically defined by Floret and Pontanier (1982). The climate is arid Mediterranean, very hard and precarious. With a mean annual varying from 100 to 200 mm, precipitation presents a large spatial and seasonal variation. The climate is also characterized by its large temperature amplitude. Most important of rangelands of the country and mainly used for extensive camel and small ruminants grazing (Nasr *et al.*, 2000; Novikoff and Skouri, 1981), are located is this area.

Animal material: The indigenous goat population constitutes an animal group adapted to the arid rangelands harsh conditions. The indigenous goat population shows a large variability both in morphology and performances (Najari *et al.*, 2005). Characteristics of the population include the ability to walk long distances, water deprivation resistance and good kidding ability. Native goat is hairy and basically black coat colored with spots on the head horned and have bread and dewlap on the neck. Fertility rate is about 87% and prolificacy rate varies between 110 and 130% (Najari *et al.*, 2004). Kidding begins in October and continues till February with a concentration in November and December when 69.2% of kids are born.

Animal control and data collection: The experiment has been carried out since 1999. From birth to early summer, kids of eight herds were subject to periodical weight controls.

After editing the original data, 4767 kids' weights have been retained for this study.

The kid's weighing period was reduced to the first year when the essential growing period is observed for small ruminants. In the south of Tunisia, kids are consumed at a young age, especially in summer due to its low fat percentage as compared to that of lamb (Najari, 2003).

Tested growth models and evaluation criteria: Due to the identical basic aspects of the physiologic growth process, several functions are largely used to describe the general growth curves. Regarding the data structure and the resources specificities, each growth model will allow the better adjustment only for some cases due to the models' differences in hypothesis and numeric approach of resolution (De Lange *et al.*, 1998). The applied models in our study are listed in Table 1, these mathematical functions are solved by iterative procedures (Mignon-Grasteau *et al.*, 2000; Schinckel and Craig, 2001).

Table 1: Convergence performances of tested growth models

Curve model	Weight equation	Iterations No.	CD	RMS
Brody Phase I	$A.e^{(b.(age))}$	15	0.51	11.17
Brody Phase II	$A.(1-b.e^{(-c.age)})$	219	0.51	11.08
Logistic	$A/(1+b.e^{(-c.age)})$	66	0.38	13.37
Logistic 4 p	$D+(A-d)/(1+b.e^{(-c.age)})$	180	0.62	8.60
Gompertz	$A.e^{(-c(-b.(age-c)))}$	9	0.67	7.41
Janoschek	$A-(A-b).e^{(-c.(aged))}$	197	0.65	7.90
Weibull	$A-((A-b)/(1+(c.(age)^{d})))$	178	0.65	7.80
Richards[1]	$A.(1+(b-1).e^{(-c.(age3))})$	12	0.67	7.42
Von Bertalanaffy	$A.(1-b.e^{(-c.(age3))})$	173	0.51	11.19
Polynomial	$A+ b.age + c.age^2 + d.age^3$	11	0.66	7.48
Polynomial 4d	$A +b.age + c.age^2 + d.age^3 + f.age^4$	9	0.66	7.48
Monomolecular[1]	$A.(1-e^{(-b.(age-c))})$	13	0.62	7.52

A, b, c, d and f : Models parameters. CD: The determination coefficient. RMS: Residuals means scares. [1] Divergence with null starting values, convergence with initial value for A equal to 1

Evaluation criteria used to compare studied models were computing difficulty and fitting goodness. Computing difficulty was defined as the number of iterations needed to converge (Najari, 1991). Starting values of parameters are null for all models to allow the same convergence conditions. Goodness of fit was defined as the magnitude of the Residual Mean Squares at convergence (RMS), which provides a measure of the precision of estimation (Mignon-Grasteau and Beaumont, 2000). The accuracy is also evaluated by the nonlinear Coefficient of Determination (CD).

RESULTS

Weight distribution: Figure 1 shows the projection of the collected weights with respect to kid's age. This typical data variation represents the expression of kid's genotypes under variable and limiting conditions (Najari *et al.*, 2002; Steinbach, 1987). A high variability of observations within the collected data and a poorly fitted curve are often a reflection of extensive management system (De Lange *et al.*, 1998). The dispersion of weights is so wide and does not show a clear concentration around a trend, especially after three months age. This

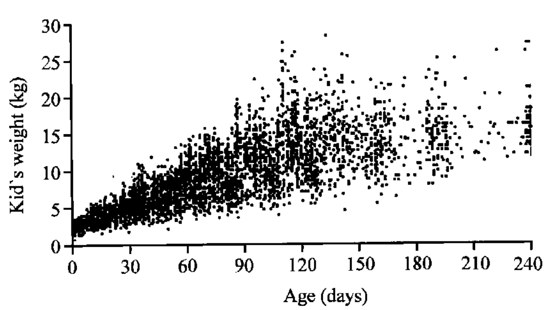

Fig. 1: Distribution of the observed weights (kg) in relation to indigenous kid's age (days)

situation represents a constraint towards the convergence procedure (Schinckel and De Lange, 1996) and puts in rough test the capacity of convergence of used models.

Growth curve model fitting: Table 1 presents the results of the convergence procedure of the parameters estimation. For each tested model, the iteration number, the Coefficient of Determination (CD) as well as the Residuals Means Squares (RMS) were considered. The convergence criterion was 10^{-8}. All tested models converged after an iteration number varying between 9 and 219. Among all functions, only Richards and Monomolecular models do not need null starting value of their equation parameters to converge. This can be considered as a constraint to the use of these two models, because the choice of the starting values can inhibit the convergence when the estimation is not adequate (Najari, 1991).

The most rapid convergence is obtained with the Gompertz and polynomial functions, which needed only 9 iterations to generate the best possible estimation of the growth curve parameters. Further than rapidity, the Gompertz function seems to be the most accurate; the CD value, estimating the fitting goodness, was 67%. The obtained CDS which decreased to 0.67, are insufficient to retain the parameters estimation (Gille, 1998). Considering the data dispersion (Fig. 1) and the nature of the arid and variable environment during the experimental period of four years, better curve fitting performances could not be expected (Najari, 2005). The Residual Mean Square (RMS) values ranged from 7.41 to 13.37. Logistic, Brody's and Von Bertalanffy models generated the major and the worst value. Polynomial regression models provided a good fit for kid's growth; however, the correspondent parameters (a, b, c, d...) have no meaningful biological interpretation (Ben Hamouda, 1985).

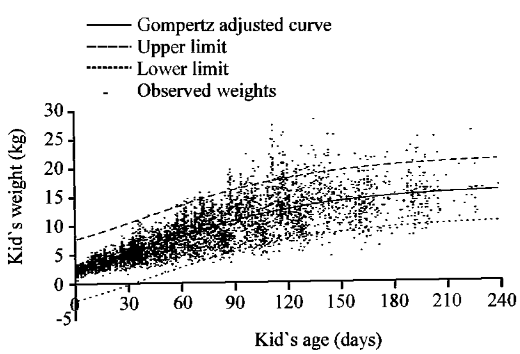

Fig. 2: Kid's growth curve adjusted by Gompertz model with upper and lower limits of the estimated kid's weights, projected on initial control data (kg)

Indigenous kid's growth curve and growth rate: The indigenous kid's growth parameters issued from the curve assessment by the Gompertz functions are presented in Table 2 with respective variation limits. The kid's growth curve adjusted by the Gompertz function is presented in Fig. 2, including lower and upper limits of weights estimation.

Having the curve parameters values A, b and c, the growth curve equation is:

$$P = 16.18e^{e(-0.0172(t-38.15))} \quad (1)$$

Where Pc is the kid's weight (kg) and t is the kid age (days).

The first derivative of the equation (1), or the growth rate (g/day), is defined as:

$$DAG = 16.18e^{e(-0.656-0.0172t)}\ 0.0172e^{(0.656-0.0172t)} \quad (2)$$

Where DAG is the daily average gain (g/day) and t is the kid age (days).

The inflexion point is located at 38.15 days, at a weight of 5.95kg.

The growth rate curve evolution, estimated by the Gompertz Eq. 2, is presented in Fig. 3.

Kid's growth performances: Estimated by the Gompertz growth model, some kids' performances are listed in Table 3. The average kid's weight is 2.41 kg at birth and reaches about 16 kg at 8 month age. The average daily gain during the first month age was 111 g/day. The daily gain increased until 39 days age, corresponding to the inflexion point of the growth curve and the pick of the

Table 2: Kid's growth curve parameters estimated by Gompertz model

Parameter	Estimated value	Asymptotic SE	95% confidence interval Lower	Upper
A	16.18	0.2107	15.76	16.60
B	0.172	0.0005	0.016	0.018
C	38.15	0.9847	36.22	40.07

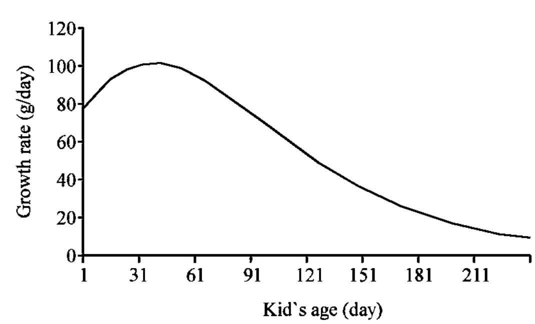

Fig. 3: Kid's growth rate curve estimated by Gompertz model

Table 3: Indigenous Tunisian goat population growing performances estimated by Gompertz model

Performance	Average	Maximum	Minimum
Adult weight (kg)	16.18	16.60	15.76
Inflexion age (days)	39.00	43.00	35.00
Inflexion weight (kg)	5.93	5.80	6.11
Birth weight (kg)	2.41	2.63	2.23
Weight (kg) at:			
1 month	5.06 (31%)*	5.56	4.59
2 months	8.05 (50%)	8.77	7.35
3 months	10.64 (68%)	11.45	9.83
4 months	12.58 (78%)	13.37	11.77
6 months	14.77	15.42	14.09
8 months	15.65	16.19	15.10
DAG (g/day)			
Birth to 1 month	88.33	111.33	65.33
Birth to 4 months	84.75	92.92	76.17
Birth to 8 months	55.21	58.21	51.96
1 to 2 months	99.68	139.33	59.33
4 to 6 months	25.65	36.83	14.42
6 to 8 months	14.71	34.83	-5.33

growth rate curve (Fig. 3). The age of the maximum growth rate ranged between 35 and 45 days when the mean daily growth was 102 g/day. After this age, the growth rate decreased progressively and becomes lower than 30 g/day after 5 month age. Alexandre *et al.* (1997 a-c) confirms the variable and reduced kid's growth rates, their rapid decrease and their important individual variation between 25 and 250 g/day for the Creole breed.

DISCUSSION

Growth model assessment: Among the tested models, the Gompertz equation seems to be the most appropriate to adjust the growth curve of the indigenous kids raised under extensive production system. According to Laird *et al.* (1965), this model is ideally suited for describing growth curve, since domestic animal meat generally comes from animals that did not achieve mature or asymptotic weight. This model takes into account the exponential decay of the specific growth rate of the animal based upon initial body weight and inflection point parameters. The Gompertz model confirms here, that it can be considered a typical representation of the S-shaped growth curve as proposed by De Lange *et al.* (1998). Indeed, this model has been shown to be valid for a wide range of mammalian species and Aves (Barbato, 1991; Mignon-Grasteau and Beaumont, 2000). Other models, such as Von Bertalanffy and Brody, were more appropriate for other studied cases and data sets (Gipson, 1997; Lopez de Torre *et al.*, 1992). In our case, Von Bertalanffy and Brody functions illustrated the worst performances, requiring a major iteration number with the lowest CDS and the greatest RMS values. Richards's model also had a difficulty with convergence in other similar cases (Gipson, 1997).

Gompertz parameters and growth exploration: The curve asymptote is usually used to estimate the adult weight when the Gompertz model is used to adjust the growth (Ben Hamouda, 1985; Najari *et al.*, 2005). As shown by Eq. 1, the A value is about 16.18 and seems to be less than the real indigenous goat adult weight which is estimated, by our data base, at 24.9 kg (Najari, 2005). It's well known that Gompertz model can underestimate the A constant especially when relative belated age is used to estimate the curve parameters (Mignon-Grasteau and Beaumont, 2000). When the kid's weighing age is limited to four months, the A constant was estimated to 22.7 kg; relatively enough to represent the indigenous goat adult weight.

It seems that kids grow during the first year and tend to stabilize their weight around a value estimated by A, the asymptote, at early summer due to nutrition restrictions and climatic stress. Kids keep weight quasi invariable during the summer season and they restart growing next favorable period to converge to the real adult weight.

Except the adult weight estimation, the kid's weight calculated by the equation (1), seemed to be comparable to those directly recorded at similar ages. In fact, differences between observed and estimated weights at similar ages did not exceed 160 g.

The most important period of growth seems to be the first four months of age (Fig. 3), when the relative important growth rate allowed kids to get the main weight gain in its life. With respect to the curve asymptote (A), the kid's weight represents 78% around four month age. After that, the kid's growth potential was seriously reduced (Fig. 2 and 3). Forage resources and suckled milk could not meet kid's requirements to continue growing. Hence, keeping kids after four or five months of age in the herd do not provide any important additional meat production; however, it can induce major costs and land degradation because this period coincides with the starting of the hot dry summer season.

Thus, it is recommended to separate kids from herds at an age about 4 to 5 months. This early kid's separation avoids major production costs after the kid's growth stagnation. Also, the herd size alleviation resulting reduces the animal pressure on rangelands and prevents excessive land degradation during the driest season. Regarding herd reproduction performances, stopping goat lactation in the summer reproductive season permits a better numeric production; weaned goat mothers have a minor endocrine inhibition and better corporal conditions to success the fecundation period (Atti, 2000).

The weaned young kids can be directly consumed or fattened in specialized farms, in an intensive management to allow higher meat production.

The indigenous goat growth performances can be considered very low as compared to those of some caprine breeds raised under favorable conditions (Bembridge and Tapson, 1993; Sharma *et al.*, 1998; Van Niekerk and Casey, 1988), or in oasian breeding mode in Tunisian arid region (Najari *et al.*, 2000) where the local kids weigh in average about 2.92 and 14.85 kg, respectively at birth and at 4 months age. The weak performances of the indigenous goats are mainly attributed to, rather than the population genetic potential, the effects of the harsh conditions of the arid environment. Technical and natural resources reduce seriously performances even for the highest individual genetic potential, which doesn't find the needed nutritional conditions to express their real genetic capacity (Alexandre *et al.*, 1997a-c; Najari *et al.*, 2002).

The kid's weight evolution seems to be favourable to a rapid physiologic maturity, which characterises several indigenous populations. It is well known that mammalian female maturity and puberty are related to their body conditions (Chemineau *et al.*, 1996). Females have to reach a critical physiologic weight to start its reproductive life (Alexandre *et al.*, 1997a; Bocquier *et al.*, 1998; Mavrogenis *et al.*, 1984). Thus, a rapid and early growth allows females to reproduce at the first year age due to the relatively small adult weight. During favourable years, it is common that indigenous female kids can be covered in summer without major problem. The small body size allows local populations to success the reproduction process (Oltenacu, 1999) and by which, to guarantee the survival and the genetic continuity of the population even under drastic conditions. This can be considered as an adaptation criterion to the harsh environment. Also, the low requirements can be covered with the scarce vegetation without any excessive land degradation.

Indigenous goat population meat production seems to be adapted with natural and technical resources. It guaranties a sensible herd cash flow with respect to decertification risks and forage scarcity. Three main aspects characterize the indigenous kids' growth. Firstly, the capacity to profit from the possible favourable conditions, under a variable climate, to produce rapidly a weight gains. Secondly, by assuring the physiological weights required for the reproduction process starting since the first year age. Thirdly, by minimizing the nutritive requirements for maintenance and growth, which can be covered with the scarce and sparse range vegetation. Such genetic profile illustrates the priority allowed by the natural selection process, under arid conditions and for numerous generations, to guaranty genetic continuity of the animal group and to avoid excessive land degradation assuring at the same time a low meat production.

CONCLUSIONS

The Gompertz model was found the most appropriate, in term of rapidity and accuracy, to adjust kid's growth curves even when the weighing protocol changes. However, some parameters have to be handled and interpreted with care to understand the weight evolution kinetic till early summer.

Indigenous kids grow rapidly and profit from any favorable conditions to get the possible weight gaining during the first 5 month. The realized weight seems to ensure the physiological maturity needed to the reproduction beginning. Since this age is usually reached at early summer, kid's separation from herds is recommended to reduce production costs and to improve herd productivity. This allows reducing herd sizes and avoiding excessive land degradation. At the same time, weaning kids by separation allows suckling goats to improve body conditions and to reproduce efficiently through the reduction of the endocrine reproduction inhibition.

The small body size added to a rapid growth, characterizing local goats, can be considered as an essential adaptation criterion to natural difficult conditions of the extensive animal production in arid lands. The reduced adult weight means reduced feed requirements under difficult conditions and poor rangelands.

Considered as the main product, indigenous kid's meat production respects the environment fragility and decertification risks and it contributes to guaranty the animal group continuity through a fast regeneration rhythm.

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